March 2018 CGRFA/WG-AqGR-2/18/Inf2 E

联合国粮食及农业组织
Food and Agriculture Organization of the United Nations
Organisation des Nations Unies pour l'alimentation et l'agriculture
Продовольственная и сельскохозяйственная организация Объединенных Наций
Organización de las Naciones Unidas para la Alimentación y la Agricultura
منظمة الأغذية والزراعة للأمم المتحدة

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

AD HOC INTERGOVERNMENTAL TECHNICAL WORKING GROUP ON AQUATIC GENETIC RESOURCES FOR FOOD AND AGRICULTURE
Second Session
Rome, 23–25 April 2018
REVISED DRAFT REPORT ON *THE STATE OF THE WORLD'S AQUATIC GENETIC RESOURCES FOR FOOD AND AGRICULTURE*

Food and Agriculture
Organization of the
United Nations

DRAFT
NOT FOR CITATION

REVISED DRAFT REPORT ON
THE STATE
OF THE WORLD's

AQUATIC GENETIC RESOURCES
FOR FOOD AND AGRICULTURE

CONTENTS

BOXES

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AGRDEU	Aquatic Genetic Resources Deutschland
AqGR	Aquatic Genetic Resources
ASFIS	Aquatic Sciences and Fisheries Information System
BAC	bacterial artificial chromosome
BMEL	Federal Ministry of Food and Agriculture of Germany
CBD	Convention on Biological Diversity
CCRF	Code of Conduct for Responsible Fisheries
CGRFA	Commission on Genetic Resources for Food and Agriculture
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COFI	FAO Committee on Fisheries
COFI AWG AqGR/T	COFI Advisory Working Group on Aquatic Genetic Resources and Technologies
CRISPR	Clustered regulatory interspaced short palindromic repeats
CRISPR/Cas	clustered regularly interspaced short palindromic repeats-CRISPR associated
CSO	Civil Society Organization
CyHV-3	cyprinid herpesvirus 3
ddRADseq	DNA sequencing
DIAS	Database on Introductions of Aquatic Species
DNA	deoxyribonucleic acid
DRB	Danube River Basin
DSTF	Danube Sturgeon Task Force
EAF	Ecosystem Approach to Fisheries
EST	Expressed sequence tags
EU	European Union
EUSDR	Danube Region
FAM	Freshwater Aquatic Macrophytes
FAO	Food and Agriculture Organization
FAO/FI	FAO Fisheries and Aquaculture Department
FPA	Freshwater protected areas
GEF	Global Environment Facility
GIFT	Genetically Improved Farmed Tilapia
GMAD	Global Marine Aquarium Database
GMO	genetically modified organism
GSI	genetic stock identification
ICES	International Council for the Exploration of the Sea
ICPR	International Commission for the Protection of the Rhine
IGO	Intergovernmental organizations or international governmental organizations
IMARPE	The Peruvian Institute of the Sea
IPM	Integrated pest management
ISSCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
ITWG AqGR	Intergovernmental Technical Working Group on AqGR
IUCN	World Conservation Union
LVFO	Victoria Fisheries Organization
MAS	Marker-assisted selection
MDB	Murray Darling River
MPA	Marine protected areas
MRC	Mekong River Commission
NACA	Network of Aquaculture Centres in Asia-Pacific

NGO	non-Governmental Organization
NFPA	National framework for priority action
mtDNA	mitochondrial DNA
OIE	World Organization for Animal Health
PCR	Polymerase Chain Reaction
QTL	Quantitative Trait Loci
R&D	research and development
RAPD	random amplified polymorphic DNA
RFLP	restriction fragment length polymorphism
RNA	RiboNucleic Acid
RNA-Seq	ribonucleic acid sequencing
SADC	Southern African Development Community
SMS	single molecule sequences
SNP	single nucleotide polymorphisms
SOFIA	State of World Fisheries and Aquaculture
SoW AqGR	State of the World's Aquatic Genetic Resources for Food and Agriculture
SPC	Pacific Community
TALEN	transcription activator-like effector nucleases
TBS	thematic background study
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Service
UV	ultraviolet
WA	Western Australia
WFC	Worldfish Centre
WSCS	World Sturgeon Conservation Society
XX	female sex chromosome
YY	male sex chromosome
ZFN	Zinc finger nuclease

INTRODUCTION

Background

Aquatic Genetic Resources for Food and Agriculture (AqGR) are a core function of the work of FAO, and the FAO Fisheries and Aquaculture Department (FAO/FI) has been requested by Member Countries, through the FAO Commission on Genetic Resources for Food and Agriculture (Commission), to lead the process towards the production of a report on *The State of the World's Aquatic Genetic Resources for Food and Agriculture* (SoW AqGR). Therefore, in 2007 the Commission called upon its Members to initiate steps to determine the current state of their aquatic genetic resources for food and agriculture (AqGR). Since then, this work has been supported by FAO/FI and by the Commission itself.

The SoW AqGR will be the first global assessment on AqGR for food and agriculture based on national reporting.

Process

In 2012, following the process established by the Commission, FAO invited countries to nominate National Focal Points and to prepare and submit National Reports, which would be the main source of information for the preparation of the SoW AqGR. FAO/FI provided guidelines in the form of a questionnaire for the preparation of these National Reports to all National Focal Points[1] in 2012, including a recommended structure and methodology for National Reports.[2]

The development of the National Reports should be seen as an opportunity to conduct a national strategic exercise to assess the status of AqGR at national level, and to reflect on needs and priorities for their conservation and sustainable use. In order to develop the capacity of National Focal Points and other national representatives on the preparation of the National Reports, FAO/FI has been organizing a series of regional workshops on the status of AqGR, in collaboration with partners in the aquaculture sector.

The first SoW AqGR has been prepared as a country driven process, and the steps that have been followed were:

1. Commission members submitted their National Reports on the status of AqGR to FAO;
2. the FAO/FI reviewed these National Reports and incorporated the information into a database;
3. data were analyzed and incorporated into the SoW AqGR document;
4. FAO/FI compared, where appropriate, the data provided by countries in their National Reports to official statistical data received from Members, in order to identify information gaps, possible inconsistencies and limitations on the number of species reported as farmed within the aquaculture sector in each country;
5. FAO/FI led the preparation of five Thematic Background Studies (Table A), which are intended to complement National Reports in thematic areas where scientific and official data and information are missing, outdated or there are significant knowledge gaps; and
6. FAO/FI incorporated reports on the status of AqGR for food and agriculture from relevant international, regional and sub-regional organizations.

[1] ftp://ftp.fao.org/FI/DOCUMENT/aquaculture/AqGR/List_of_NFPs.pdf
[2] www.fao.org/fishery/AquaticGeneticResources/en

Table A
Selected thematic background studies

Subject	Rationale
Incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives	Production and value statistics for farmed aquatic species and their wild relatives are highly aggregated to species or community levels, with many not even identifying the species used. Management of fish stocks, traceability of fish and fish products, and oversight and development of responsible aquaculture requires management of genetic diversity, linked to production. Increasingly, resource managers and the development communities are asked to identify indicators of the status of AqGR. Once better production data are available, indicators can be developed for monitoring and assessment.
Biotechnology and genomics in aquaculture	Aquaculture is making increasing use of biotechnology and application of genomic research for domestication, increased production, improved management and better traceability of fish and fish products in the supply chain. With advances often outpacing the development of policy and regulatory frameworks and consumer awareness the key is to harness biotechnology for beneficial ends, with biosecurity ensured through precaution and sound management of risks, and through understanding consumers' attitudes.
Genetic resources for farmed seaweeds	The farming of seaweeds to produce material for the food and other industries, as well as products for direct consumption as human food, is one of the world's largest aquaculture operation. Due to their increasing relevance as genetic resources for food security, they require coverage in a State of the World Report as they have often been omitted from other reports.
Genetic resources for farmed freshwater macrophytes (FAMs)	The cultivation and consumption of FAMs and their impact on food security has long been unrecognized and under-recorded despite their significant contribution to food production and nutrient recycling. This study is focused on the main FAMs cultivated for provision of human food and other uses as the treatment of wastewater or the production of supplementary feed in a number of farming systems.
Genetic resources of microorganisms of current and potential use in aquaculture	Bacteria, cyanobacteria, microalgae and fungi are cultured extensively as feed sources in aquaculture. Some bacteria are used as probiotics to enhance fish growth and health. Many species and strains of microalgae are kept as *ex situ* culture collections. The genetics resources of these important microorganisms for food and agriculture require coverage in a State of the World's Report.

National Reports submitted for the State of the World's Aquatic Genetic Resources for Food and Aquaculture

A total of 57 national reports had been received as of May 2016; 47 of which were reviewed and analyzed in the First Draft SoW AqGR (The First Draft Report). During the first session of the Intergovernmental Technical Working Group on AqGR (ITWG AqGR) held in Rome in June 2016, the First Draft Report was discussed and reviewed. The recommendations from the First ITWG AqGR were as follows:

- identify individual countries in the analysis in addition to the summaries by region or sub-region, as appropriate;
- include specific country examples and case studies to illustrate issues, where relevant;
- provide an analysis by developing versus developed countries, as appropriate;
- include some examples of new species and farmed types identified from National Reports that have not been previously been reported to FAO;
- revise the references to all countries to ensure they accurately reflect the information provided in national reports, in particular in the last part of sub-chapter 7.2 of chapter 7;
- revise the conclusions of sub-chapter 7.4 of chapter 7 that cannot be inferred from the information contained in the report, in particular on access and benefit sharing regimes;
- streamline the quotation in the last paragraph of sub-chapter 6.5 of chapter 6;

- use additional information (e.g. from the scientific literature, international, regional and national organizations and networks, and advanced scientific institutions) to complement National Reports and contribute to a more comprehensive assessment;
- harmonize definitions throughout the Report and provide a full glossary of key terms;
- clearly identify all sources of information, including in tables and figures;
- provide an in-depth analysis of findings, including inter alia on climate change, habitat change and invasive species as drivers impacting AqGR;
- distinguish between policies and strategies and include soft law instruments, such as codes of conduct and voluntary guidelines;
- clarify some of the concepts referred to in the chapters (e.g. *in situ* conservation and access and benefit sharing regimes);
- acknowledge the challenges of collaboration for the management of AqGR, especially for the transboundary conservation of migratory species;
- include some specific examples of successful AqGR *ex situ* and *in situ* conservation programmes and strategies, and stress the complementarity of the two conservation approaches;
- acknowledge the value of aquatic protected areas in conserving AqGR and there must be a balance between conservation and development taking into consideration conditions in different areas;
- demonstrate the close linkages between aquaculture and capture fisheries systems that depend on wild AqGR;
- ensure that information provided complement the information contained in The State of World Fisheries and Aquaculture (SOFIA);
- include an analysis of how effective the various networks contribute to the sustainable use and conservation of AqGR and
- highlight key findings and gaps that will require a policy response to improve the sustainable use and conservation of AqGR.

The reports of the COFI Advisory Working Group on Aquatic Genetic Resources and Technologies (COFI AWG AqGR/T) and the CGRFA ITWG AqGR were presented to the 16th Session of the Commission on Genetic Resources for Food and Agriculture (CGRFA). During this Session, the Commission invited countries that had not yet done so to submit their reports by 30 June 2017and invited countries that had already submitted a National Report to submit a revised version by the same date.

By end June 2017, 35 new National Reports had been submitted to the FAO Secretariat. In the Revised Draft SoW AqGR Report, all the 92 submitted National Reports have been reviewed and considered (Table B). Recommendations from COFI subsidiary bodies, the TBSs, and reports from international organizations were taken into account in the preparation of this Revised Draft Report.

In this Revised Draft Report, the analysis by region has been adjusted to be consistent with FAO's analyses of fisheries and aquaculture statistics. The relative response per region is an indication of how representative the National Reports are per region. Countries in all the 6 regions responded, with greatest levels of response from North America (100 percent of countries) and Asia (64 percent) (Table C).

Table B

National Reports received from FAO Members as of July 2017 by region (number of countries in region)

Africa (27)	Asia (21)	Latin America and the Caribbean (18)	North America (2)	Europe (17)	Oceania (7)
Algeria	Armenia	Argentina	Canada	Belgium	Australia
Benin	Bangladesh	Belize	United States of America	Bulgaria	Fiji
Burkina Faso	Bhutan	Brazil		Croatia	Kiribati
Burundi	Cambodia	Chile		Czechia	Palau
Cabo Verde	China	Colombia		Denmark	Samoa
Cameroon	Cyprus	Costa Rica		Estonia	Tonga
Chad	Georgia	Cuba		Finland	Vanuatu
Democratic Republic of the Congo	India	Dominican Republic		Germany	
Djibouti	Indonesia	Ecuador		Hungary	
Egypt	Iran (Islamic Republic of)	El Salvador		Latvia	
Ghana	Iraq	Guatemala		Netherlands	
Kenya	Japan	Honduras		Norway	
Madagascar	Kazakhstan	Mexico		Poland	
Malawi	Lao People's Democratic Republic	Nicaragua		Romania	
Morocco	Malaysia	Panama		Slovenia	
Mozambique	Philippines	Paraguay		Sweden	
Niger	Republic of Korea	Peru		Ukraine	
Nigeria	Sri Lanka	Venezuela (Bolivarian Republic of)			
Senegal	Thailand				
Sierra Leone	Turkey				
South Africa	Viet Nam				
Sudan					
United Republic of Tanzania					
Togo					
Tunisia					
Uganda					
Zambia					

Table C

Number and percentage of countries per region that have submitted National Reports

Region	Total number of Countries	Number of Countries responded	Percentage
Africa	54	27	50
Asia	33	21	64
Latin America and the Caribbean	47	18	38
North America	2	2	100
Europe	43	17	40
Oceania	17	7	41

The economic class's definition in this report was recommended by FAO/FI and is consistent with FAO Economic Class category. Ninety-two (47 percent of the total countries in the world) Members responded, 48 percent of the 92 responses were from "Other developing countries" (44) and the fewest responses (23) were from "Least developed countries" (Table D).

Table D
Number of countries submitting National Reports in each economic class

Economic class	Number of countries	Number of respondents	Percentage
Developed countries or areas	58	25	43
Least developed countries	50	23	46
Other developing countries or areas	88	44	50

Analyses were also conducted according to a country's level of aquaculture production, as recommended by the COFI WG AqGR. Countries were grouped into:

I. major producing countries that produced more that one percent of global aquaculture production; and
II. minor producing countries that produced less than one percent.

Eleven countries were identified as major producers and include China, Indonesia, India, Viet Nam, the Philippines, Bangladesh, the Republic of Korea, Norway, Egypt, Japan and Chile. These countries produced 91 percent of global aquaculture production. One hundred percent of the major producers submitted their National Reports while 44 percent of the minor producers (81) responded (Table E).

Table E
Number and percentage of countries by level of aquaculture production that have submitted National Reports

Category	Total number of countries	Number of respondents	Percentage
Major producers	11	11	100
Minor producers	185	81	44

A word on the process of producing the Report

The questionnaire provided significant new and useful information on the state of the world's AqGR. Although further data have yet to be analyzed, it is clear that some of the inter-country variability in responses is a result of the composition of the country teams completing the questionnaires, how much they know about the different stakeholder groups and, indeed, how they have defined them, as well as their understanding of the different AqGR of interest. The only guidance provided in addition to the regional capacity building workshops was for country focal points to consult with or involve stakeholders in completing questionnaires. Yet it seems likely that a country team, say, composed of 50 percent fish farmers, would have answered questions differently from a team dominated by country resource managers.

As well as inter-country differences in team composition, influencing collective country team knowledge of AqGR conservation, management and use, there are undoubted differences in interpretations of the questionnaire and there was some ambiguity around the meaning of some AqGR terms.

Taken together, then, all of the above factors introduce an unquantifiable but nonetheless probably substantive degree of variability, which means the results from this first revised draft report must be viewed as indicative and often in need of further clarification and investigation.

Thus, it is hoped that the process of analysing the National Reports and the database created from them, along with continued interaction among FAO, the national focal points, the Commission and other experts on AqGR will continue.

CHAPTER 1
THE STATE OF WORLD AQUACULTURE AND FISHERIES

NOTE: THIS CHAPTER WILL BE UPDATED WITH THE MOST RECENT INFORMATION FROM THE UPCOMING *STATE OF WORLD FISHERIES AND AQUACULTURE 2018*

PURPOSE: Present a summary overview of production of species and general trends in aquaculture. The systems that are used and the type of species that are cultured. The species types have implications for the intensity of the productions system, how it is fed (or not), the environment they are grown in, their value, the source of seed/broodstock and the extent to which the system has domesticated its stock or relies on wild relatives.

The FAO reports every two years on the State of World Fisheries and Aquaculture (SOFIA).[3] This publication covers issues of *inter alia* production, trade, consumption and sustainability, as well as special topics of importance to fisheries and aquaculture and a summary of recent highlights of the Fisheries and Aquaculture Department.

The processes to create *The State of World Fisheries and Aquaculture* and *The State of the World's Aquatic Genetic Resources for Food and Agriculture* are complementary and will help facilitate the responsible use of fishery and aquaculture resources.

1.1 Global trend in fisheries and aquaculture production

Global aquaculture production of aquatic living genetic resources reached a total of 101 million tonnes in 2014, including 27 million tonnes of aquatic algae, 48 000 tonnes of non-food production and 73.8 million tonnes of food fish[4] with an estimated first sale value of US$166 billion. This production is derived from aquaculture operations conducted in freshwater, brackishwater and marine waters. Farmed food production comprised 49.8 million tonnes of finfish (US$99.2 billion), 16.1 million tonnes of molluscs (US$19 billion), 6.9 million tonnes of crustaceans (US$36.2 billion) and 7.3 million tonnes (US$3.7 billion) of other aquatic animals including amphibians (FAO, 2016a).

Production from capture fisheries have plateaued while aquaculture has experienced growth of about six percent/year over the last several decades (Figure 1) and is the world's fastest growing food production sector (FAO, 2014a). More aquatic species are being farmed now than ever before. The general consensus is that marine capture fisheries have reached a point whereby they will no longer provide more fish than they do at present, indicates that the substantial increase in demand for fish will need to be met by fish culture systems (World Bank, 2013, FAO, 2014a; FAO, 2016a).

Production estimates from inland capture fisheries are not well known (Bartley *et al.*, 2015), but inland fisheries are threatened by loss of habitat and competition for freshwater from sectors outside the fishery sector (FAO 2012; FAO, 2014a). The majority of catch from inland fisheries is not identified to species when reported to FAO (Bartley *et al.*, 2015). This lack of knowledge on what and how much is being harvested from the world's freshwater ecosystems is all the more problematic in conservation efforts as freshwater fish are the most threatened group of vertebrates used by humans (Ricciardi and Rasmussen, 1999; IUCN, 2010).

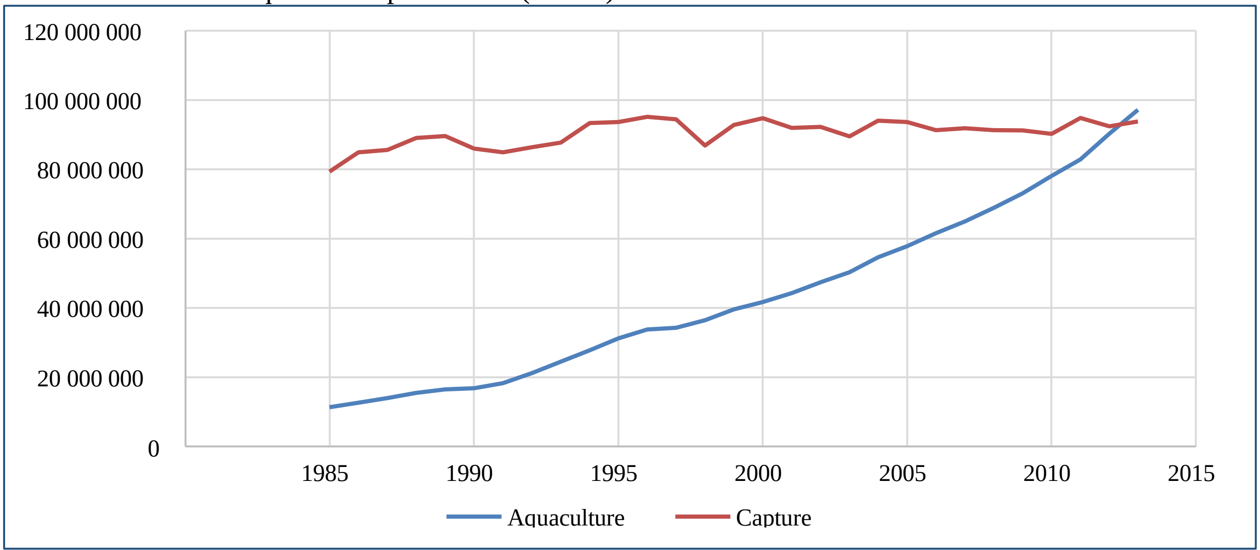
At the same time that the expectation is placed on the expansion of aquaculture production to meet increased demands for seafood, existing aquaculture production systems are facing challenges in terms

[3] www.fao.org/fishery/sofia/en

[4] The term "food fish" includes fin fishes, crustaceans, molluscs and other aquatic animals like frogs and sea cucumbers for human food, excluding aquatic mammals and crocodiles.

of available space, competition for water and feed resources alongside health and genetic concerns. Despite these constraints, aquaculture continues to grow owing to the increasing demand for food fish among most producing countries.

Figure 1.1
Global fisheries and aquaculture production (tonnes)



1.2 Diversity of aquatic genetic resources used in aquaculture and fisheries

The world's fisheries harvest over 2000 species including fish, crustaceans, molluscs, echinoderms, coelenterates, and aquatic plants (FAO, 2014a). The number of farmed aquatic species is smaller, but still extremely diverse. By 2014, a total of about 580 species and/or species groups were farmed around the world and production reported to FAO (Table 1.1).

Table 1.1
Diversity of aquatic species

Taxon	Wild species	Number of farmed species	Number of families
Finfish	31 000	362	>90
Molluscs	85 000	104	27
Crustaceans	47 000	62	>13
Other aquatic animals	**	15	>8
Aquatic plants	13 000	~37	>22
Total	180 000	580	

**These include echinoderms, coelenterates and tunicates too numerous to list, many of which have no potential as food and are all marine species, as well as a few amphibian and reptiles.

Source: FAO, 2016a, FAO, 2016b & IUCN, 2010

According to the latest available fisheries and aquaculture statistics published by FAO Fisheries and Aquaculture Department, the total production in 2014 from capture fisheries and aquaculture was 195.8 million tonnes (Table 1.2).

Table 1.2
World capture fisheries and aquaculture production in 2014 (Unit: thousand tonnes, in live weight)

	Capture	Aquaculture	Total
Fin fishes	78 265	49 862	128 127
Molluscs (edible)	7 674	6 113	23 788
Molluscs (pearls and ornamental shells)	10	48	59
Crustaceans	6 870	6 915	13 785
Aquatic invertebrates (edible)	632	409	1 041
Aquatic invertebrates (inedible)	5	0	5
Frogs and turtles	3	485	488
Aquatic plants	1 185	27 307	28 491
Total	**94 645**	**101 139**	**195 784**

The species diversity of AqGR for food and agriculture is extensive including two kingdoms and several phyla. Aquatic genetic resources can be split into major components according to phyla and or taxa (Table 1.3).

Table 1.3
Aquatic genetic resources categorization according to phyla and or taxa

Kingdom	Phylum	Examples
Plantea	Aquatic plants	Algae (seaweeds and micro-algae) Vascular plants
Animalia	Phylum Chordata	Finfish Amphibians and reptiles
	Phylum Mollusca	Clams and mussels Gastropods snails, abalone, octopus and Squids
	Phylum Arthropoda	Crabs and shrimps Cladocerans, brine shrimp
	Phylum Cnideria	Jelly fish and corals
	Other invertebrates e.g. Phylum Echinodermata	Sea urchins and sea cucumbers

1.3 State of World Aquaculture

Aquaculture production is not geographically homogenous, with significant differences between regions. The Asian region is a predominant producer accounting for about 89 percent of world food fish aquaculture production over the past two decades. Africa and the Americas have slightly increased their respective shares in world total production in recent years, while both Europe and Oceania have experienced a slight decline.

Declining production in some industrialized countries that were previously major regional producers (most notably the United States of America, Spain, France, Italy, Japan and the Republic of Korea) (FAO, 2014a) is driven mainly by the availability of fish imported from other countries where production costs are relatively low and the ability to capture the opportunity of developed country export markets is seen as a major reason for such production falls. This has also encouraged expansion of production strongly focused on export-oriented species in those countries (e.g. Pangassius, Penaeid shrimp, tilapia, salmon, molluscs and seaweed) (FAO, 2014a).

The majority of aquaculture production is destined for direct human consumption, although some by-products may be used for non-food purposes and a few farmed types are expressly produced for processing for industrial purposes (e.g. aquatic plants use to produce phyco-colloids such as agar and carrageenan). These may or may not be subsequently used for food purposes.

1.3.1 Diversity and production of farmed species

The diversity of species farmed is one reason for the growing production in aquaculture and a breakdown of global aquaculture production by each of the major groups and the number of species and families represented is shown in Table 1.4. Finfish are the largest category of farmed aquatic species by volume in all regions (Table 1.5).

Table 1.4
Global aquaculture production by major components

	No. Families	No. Species	Fresh water (tonnes)	Brackishwater (tonnes)	Marine (tonnes)
Aquatic plants	19	37	82 307	978 446	25 917 558
Molluscs	24	104	283 387	93 631	15 137 259
Freshwater/diadromous finfish	54	to be inserted	40 461 874	1 731 314	2 593 909
Marine finfish	35	to be inserted	40 679	454 613	1 788 164
Crustaceans	13	62	2 578 112	3 633 863	499 702
Holothuria/echinoderms, others	7	9	-	-	-
Amphibians/reptiles	2	6	-	-	-
TOTAL			-	-	-

Source: FAO, 2013.

Table 1.5
Number of taxonomic units reported to FAO by continent and environment

Inland aquaculture	**Africa**	**Americas**	**Asia**	**Europe**	**Oceania**
Finfish	66	86	115	82	22
Molluscs	0	3	5	1	0
Crustacean	0	8	16	7	5
Other animals	0	4	5	3	0
Algae	3	4	4	2	0
Total inland aquaculture taxa	69	105	145	95	27
Marine & coastal aquaculture	**Africa**	**Americas**	**Asia**	**Europe**	**Oceania**
Finfish	26	41	106	59	15
Molluscs	16	40	27	35	21
Crustacean	9	13	27	15	12
Other animals	3	0	7	5	1
Algae	5	8	20	12	3
Total marine & coastal taxa	59	102	187	126	52
All aquaculture	**Africa**	**Americas**	**Asia**	**Europe**	**Oceania**
Finfish	81	119	194	122	30
Molluscs	16	41	31	35	21
Crustaceans	14	19	39	20	17
Other animals	3	4	11	7	1
Plants	8	11	23	14	3
Total – all aquaculture taxa	**122**	**194**	**298**	**198**	**72**

Asia farms the most species of aquatic organisms and has the longest history of aquaculture (Table 1.6) The relatively few species farmed in Africa (in relation to the size, habitat diversity of the continent and the potential number of species available for farming) demonstrates the potential for further use of AqGR in African aquaculture.

Table 1.6
Number of species in aquaculture production by region and environment

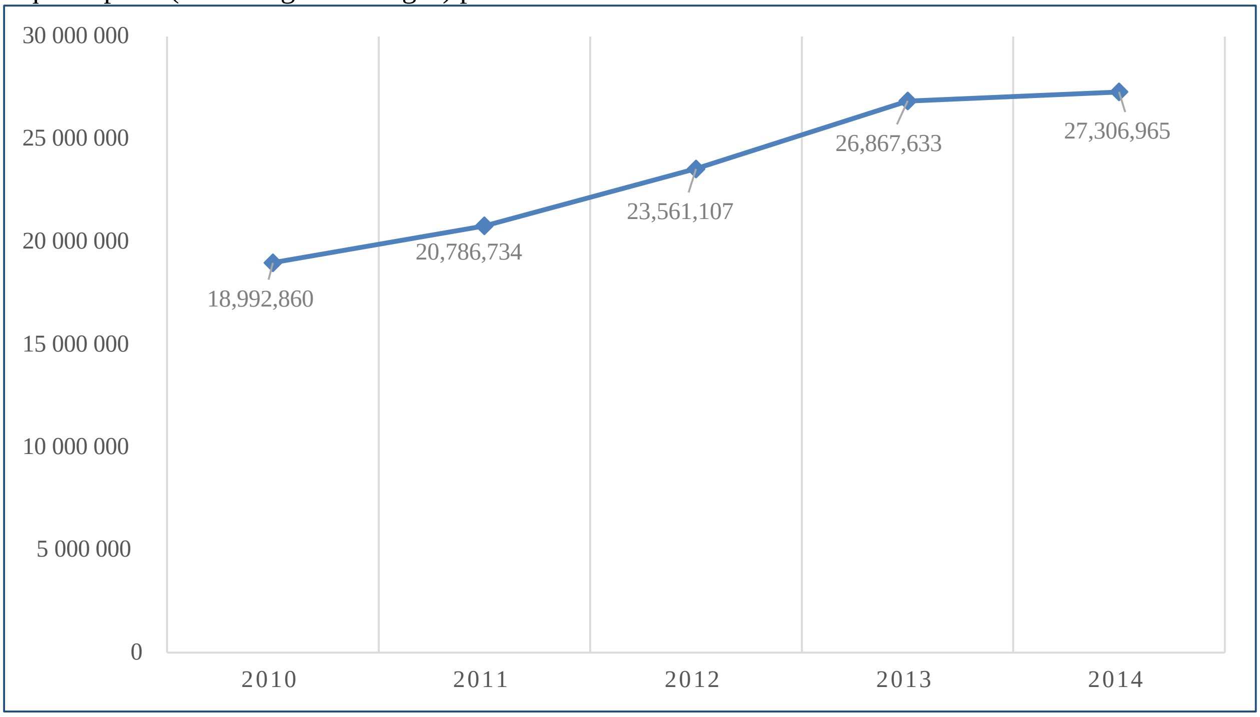
Environment/Region	Africa	Americas	Asia	Europe	Oceania	Total by environment
Marine & coastal	59	102	187	126	52	526
Inland aquaculture	69	105	145	95	27	441

*Totals do not sum as some species are farmed in marine & coastal and inland areas.

Aquatic plants are largely produced in marine and brackishwaters, but some microalgae are cultured in freshwaters. There are 27 species reported by FAO representing 19 families (Table 1.7). They are a mixture of food plants consumed directly and those produced for processing to extract phyco-colloids such as agar and carrageenans.

Aquatic plant aquaculture systems typically rely on natural productivity and are not typically fertilized, there are however managed culture systems. Farming of aquatic plants is undertaken in more than 50 countries and over the past decade has grown by eight percent per year (FAO, 2016a) (Figure 1.2).

Figure 1.2
Aquatic plant (excluding micro-algae) production from 2010 until 2014



Information on microalgae is not well reported in available aquaculture statistics despite being of increasing economic importance both as a food supplement (e.g. *Spirulina spp*.), as well as an important base for the hatchery production of many species (especially marine species). There are more than 17 genus of microalgae commonly cultivated for aquaculture purposes and there is a considerably great number of species use both commercially and within research collections.

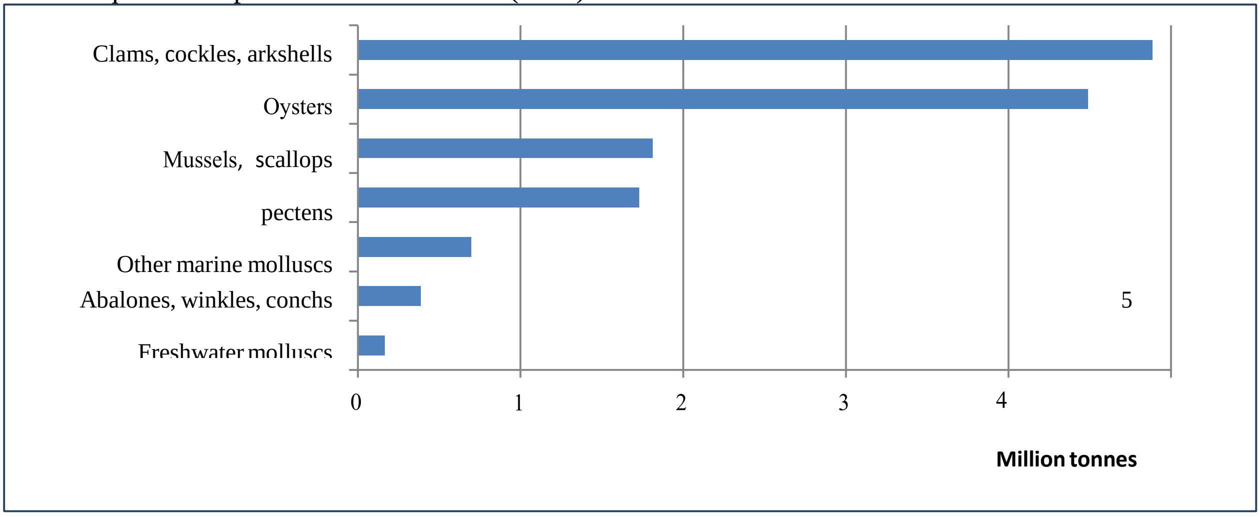
Table 1.7
World aquaculture production of aquatic plants in 2014 (unit: tonnes, in live weight)

Scientific name	FAO common name	2014
CHLOROPHYCEAE		
Monostroma nitidum	Green laver	6 055
Codium fragile	Fragile codium	5 550
Caulerpa spp	Caulerpa seaweeds	1 199
Enteromorpha clathrata	Bright green nori	1 000
Haematococcus pluvialis	(Haematococcus pluvialis)	226
Chlorophyceae	Green seaweeds	3
Chlorella vulgaris	Unicell. chlorella green alga	-
CYANOPHYCEAE		
Spirulina spp	Spirulina nei	85 705
Spirulina platensis	(Spirulina platensis)	100
Spirulina maxima	(Spirulina maxima)	...
PHAEOPHYCEAE		
Laminaria japonica	Japanese kelp	7 654 586
Undaria pinnatifida	Wakame	2 358 597
Sargassum fusiforme	Fusiform sargassum	175 430
Phaeophyceae	Brown seaweeds	19 149
Macrocystis pyrifera	Giant kelp	2
Laminaria saccharina	Sea belt	2
Undaria spp	Wakame nei	...
Alaria esculenta	Babberlocks	...
Laminaria digitata	Tangle	...
Macrocystis spp	Giant kelps nei	...
Nemacystus decipiens	Mozuku	...
RHODOPHYCEAE		
Eucheuma spp	Eucheuma seaweeds nei	9 053 044
Gracilaria spp	Gracilaria seaweeds	3 751 396
Kappaphycus alvarezii	Elkhorn sea moss	1 698 469
Porphyra spp	Nori nei	1 141 710
Porphyra tenera	Laver (Nori)	664 463
Eucheuma denticulatum	Spiny eucheuma	240 817
Gracilaria verrucosa	Warty gracilaria	936
Chondracanthus chamissoi	(Chondracanthus chamissoi)	2
Rhodophyceae	Red seaweeds	0
Gelidium amansii	Japanese isinglass	...
Gelidium spp	Gelidium seaweeds	...
Asparagopsis spp	Harpoon seaweeds	...
Palmaria palmata	Dulse	...
Porphyra columbina	(Porphyra columbina)	...
Miscellaneous aquatic plants		
Algae	Seaweeds nei	443 501
Plantae aquaticae	Aquatic plants nei	5 023
TOTAL		**27 306 965**

Source: FAOb, 2014

Farmed molluscs can be broadly split into bivalves and gastropods with 104 species in 24 families reported by FAO (FAO, 2016a). The overwhelming majority are cultured in marine systems. Bivalve mollusc are produced in systems using natural water fertility and therefore unfed. Some gastropod systems (abalone, conch, Babylonia) can be relatively intensive and utilize feeds. There is a very minor production of cephalopods (octopus) (Figure 1.3).

Figure 1.3
Global aquaculture production of molluscs (2010)

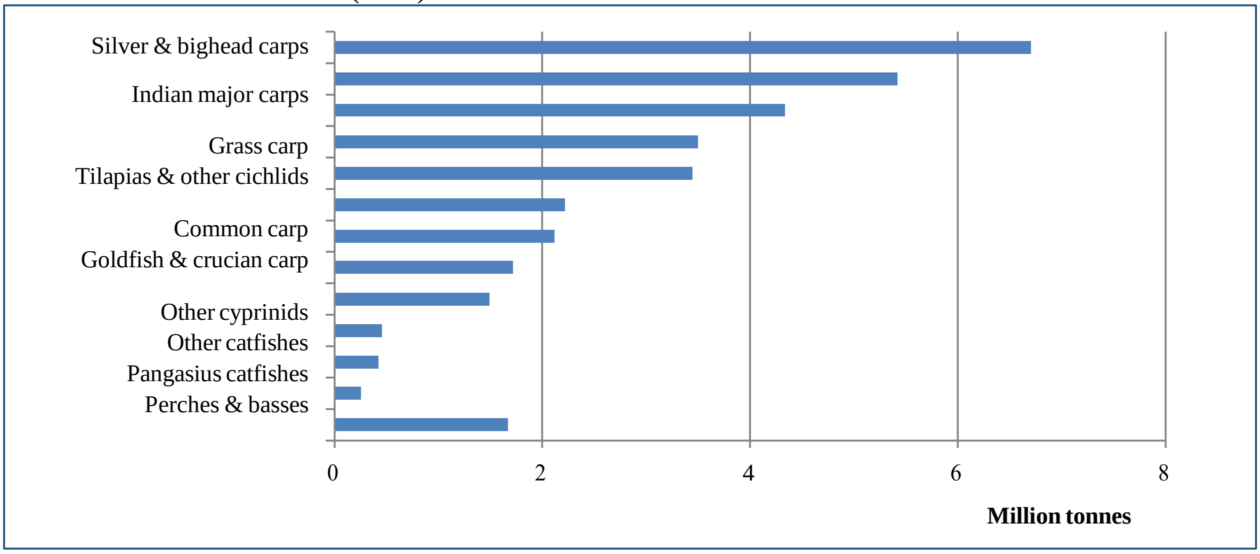


Source: FAO, 2010

Freshwater/diadromous finfish are the largest group in terms of families (54 families) cultured and is the largest in terms of total volume of all of the types of aquaculture production. Inland finfish aquaculture has been the most important driver for the global increase in annual output of farmed fish representing 65 percent of the annual fish production increase between 2005–2014 (FAO, 2016a).

This high level of production from freshwater emphasizes the importance of access to adequate quality and quantity of water for both farmed types and wild relatives as well as the vulnerability of these systems to external impacts on freshwater resources and land.

Figure 1.4
Production of freshwater fish (2010)



The farmed types used range from low trophic level species (carps, barbs, tilapia, pacu) to highly carnivorous species (salmon, eel, snakehead). The majority of production volume is based on the lower trophic level species. This underscores the contribution of these species to global food security and their relatively efficient production of high quality protein relative to other livestock systems. The salmonids are a carnivorous species and are highly significant in value terms; even though these production systems are now being developed to a point where they are becoming much more efficient users of feed resources. There is a wide range of ornamental freshwater species which are not included but do represent a significant value in terms of trade. (Figures 1.4 and 1.5).

Figure 1.5
Production of diadromous fish (2010)

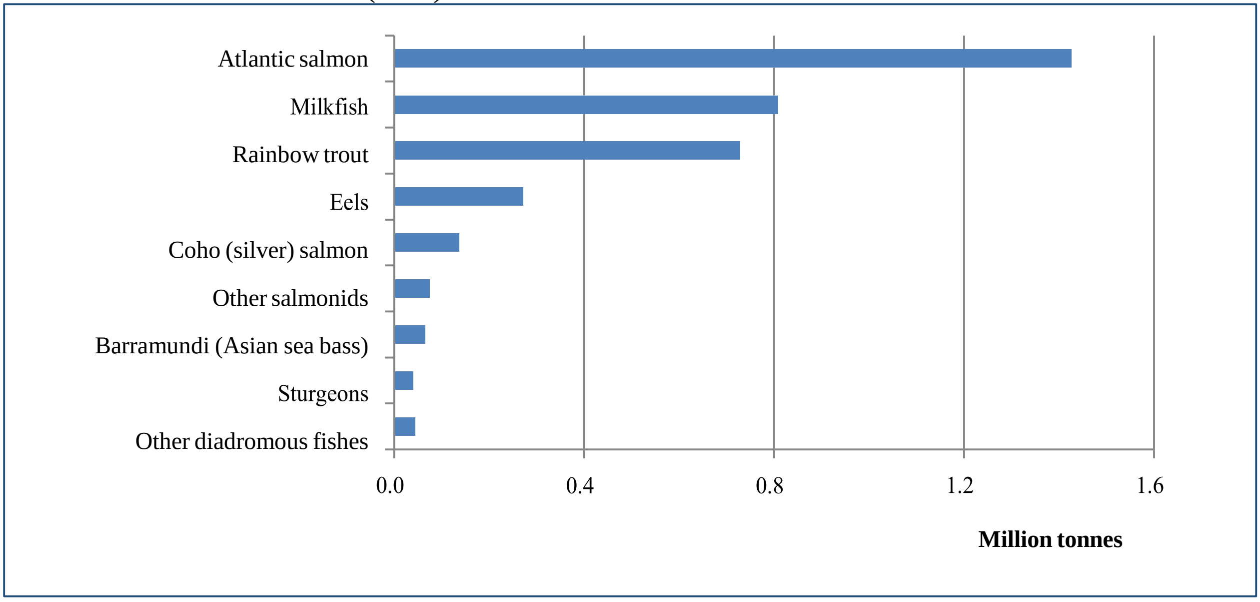
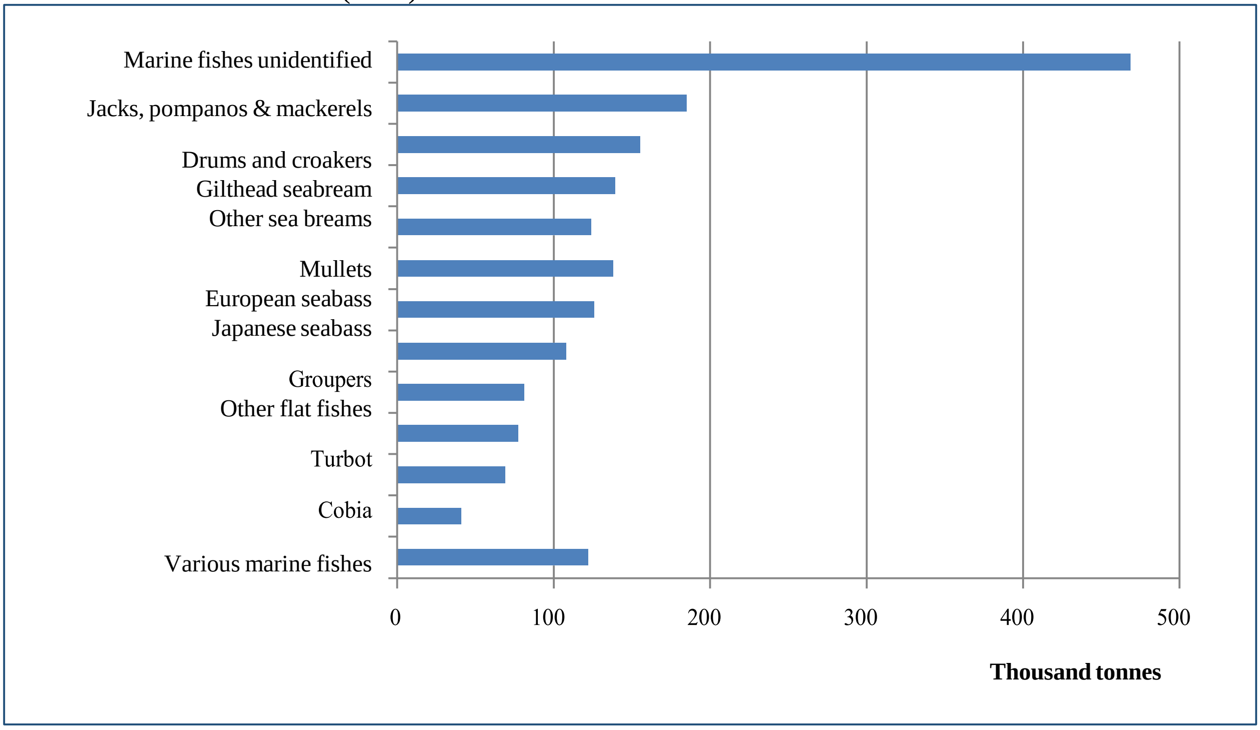


Figure 1.6
Production of marine finfish (2010)

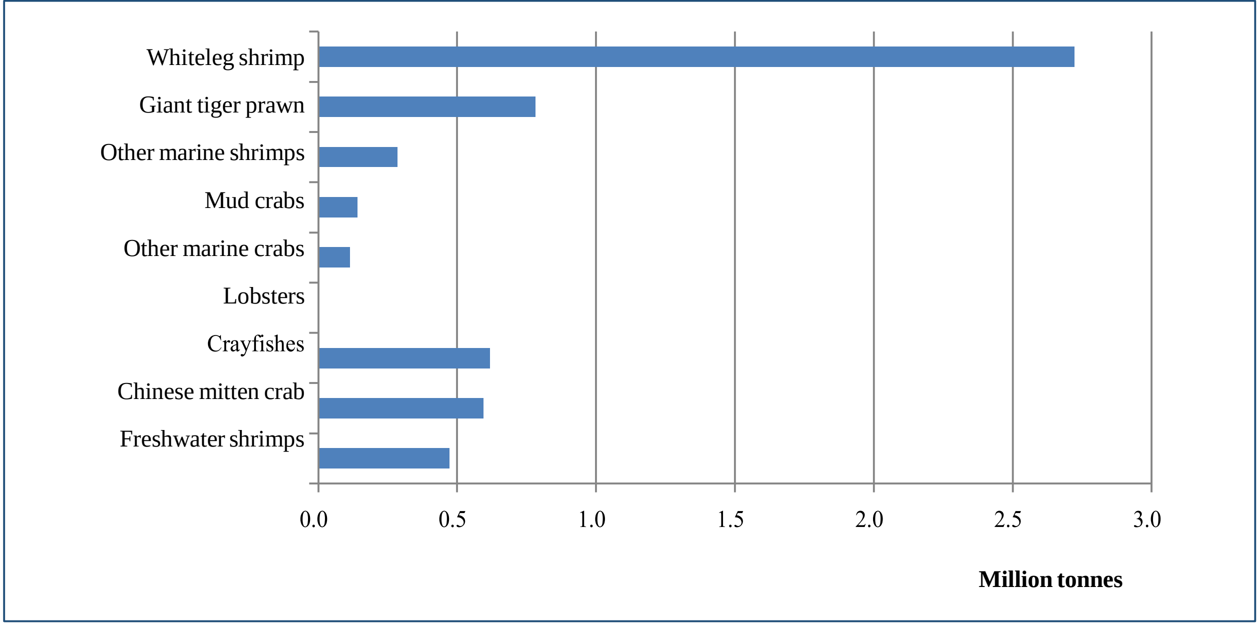


Marine finfish represent a much lower proportion of the total volume of finfish produce, but still represent 35 different families. The species tend to be carnivorous (snappers, groupers, pompano, tuna), but are also represented by a few species that are omnivorous or herbivorous (mullet, scats, rabbitfish) (Figure 1.6).

Crustaceans can be split between marine/brackish and freshwater production systems comprising 13 families and 62 reported species. Marine/brackishwater production is dominated by the penaeid

shrimp with minor contributions from other families such as lobsters and metapenaeids. Freshwater production is comprised of the Chinese mitten crab, different crayfish/crawfish species and freshwater prawns (*Macrobrachium* spp).
Some production of *L. vannamei* is also recorded as undertaken in freshwater inland areas, although this may not be strictly freshwater but extremely low salinity brackishwater. The majority of production is from warm water systems (Figure 1.7).

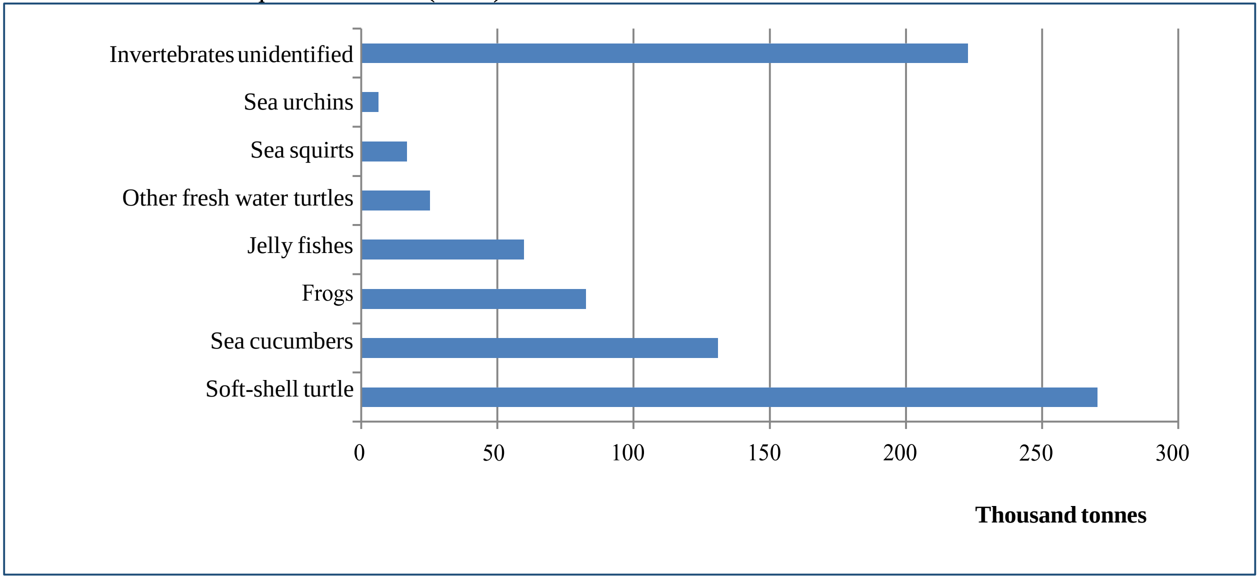
Figure 1.7
Production of the different crustacean groups (2010)



A range of niche species are also produced comprising seven families of sea cucumbers (Holothuria), sea urchins (Echinodermata) and other invertebrates, and two families of amphibians (2 species of frog) and reptiles (2 species or groups of freshwater turtle – note crocodile/alligator are not included). Ornamental Invertebrates are not included (e.g. corals, molluscs), as well as those produced for shells and jewelry (pearl, mother of pearl, Trochus).

Crocodile production is growing quickly in the Asian region with export of juvenile crocodiles to producing countries. China, Viet Nam, Cambodia, Thailand and Papua New Guinea all have crocodile farms, however this production is rarely or never reported in fishery or aquaculture statistics (Figure 1.8).

Figure 1.8
Production of other aquatic animals (2013)



Source: FAO, 2013.

1.3.1.1 Aquatic plants – farmed seaweeds

The genetic resources of farmed seaweeds are often omitted from regular reporting to FAO despite the significance of these seaweeds as sources of human food, natural colloids as food ingredients, cosmetics, biofuels, pharmaceuticals and neutraceuticals; and feed ingredients in aquaculture. Seaweeds are also being used as bioremediation or phyto-mitigation in integrated multi-trophic level aquaculture as a means to recycle aquaculture effluents by absorbing nutrients from other parts of the aquaculture system.

Global seaweed farming is predominantly in Asia both for the brown (*Saccharina* and *Undaria*) and red seaweed (*Euchuema*, *Gelidium*, *Gracilaria*, *Kappaphycus*, and *Pyropia*) compared to Europe which is still small in scale and can be found in countries such as Denmark, France, Spain, Portugal, Ireland and Norway.Previously, brown seaweeds (*Saccharina* and *Undaria*) dominates the farming of seaweed globally, until this was overtaken by the red seaweeds in 2010 which came mainly *Kappaphycus* and *Eucheuma*.

The brown seaweeds are farmed normally from sub-temperate to temperate countries such as China, Japan and the Republic of Korea, while red seaweeds such as *Kappaphycus* and *Eucheuma* are farmed from sub-tropical to tropical countries with productiondominated by Indonesia, the Philippines and Malaysia. At present, 20 species of red seaweed dominate commercial cultivation, followed by nine species of brown, and finally seven species of the green seaweeds.

There are other red seaweeds which are presently farmed either in the open seas, brackishwater ponds or land-based tanks. These are *Asparagopsis*, *Chondrus crispus*, *Gelidium*, *Gracilaria*, *Hydropuntia*, *Palmaria palmata* and *Pyropia.* Among the green seaweeds, *Caulerpa*, *Codium*, *Monostroma*, and *Ulva* are farmed for commercial purposes.

Traditional selection of strains based on growth performance and resistance to disease are still used in propagating farmed seaweeds. The breakthrough in the hybridization of *Laminaria japonica* in China paved the way for massive cultivation of this species globally. The development of plantlets from spores for outplanting purposes is still practiced to the present in some brown (*Laminaria*, *Saccharina*, *Undaria),* red *(Palmaria*, *Pyropia),* and green seaweeds *(Codium*, *Monostroma* and *Ulva).* Micropropagation through tissue and callus culture is becoming a popular method in generating new and improved strains in *Eucheuma* and *Kappaphycus*, though vegetative propagation is still widely used.

The main driver for the continued interest on seaweed cultivation has been the potential for the production of large volumes of a renewable biomass that is rich in carbohydrate and therefore attractive to 3rd generation biofuel production. Seaweed biomass has a wide range of applications as:

- bio-based and high-value compounds in edible food, food and feed ingredients, biopolymers, fine and bulk chemicals, agrichemicals, cosmetics, bio-actives, pharmaceuticals, nutraceuticals, botanicals;
- lower-value commodity bioenergy compounds in biofuels, biodiesels, biogases, bio-alcohols, and biomaterials; and
- global consumption of sea vegetables is rising as consumers become more aware of their health and nutritional benefits.

1.3.1.2 Aquatic plants – freshwater macrophytes

Freshwater macrophytes are relatively under-researched and under-documented. In fact, they have not been well covered in previous State of the World's Plant Genetic Resource reports. However, they play important roles in rural economic development, particularly in Asia, where they have both historical and cultural significance in providing healthy food and also employment while often recycling valuable nutrients in what are essentially low input systems, this benefitting millions of lower income primarily perurban stakeholders.

Box 1.1
Freshwater aquatic macrophytes for food and agriculture

The cultivation and consumption of edible cultivated freshwater macrophytes and their impact on food security has long been under-recognized and under-recorded in both scientific and grey literature. In a geographical context, they have largely been unrecognized outside South and Southeast Asia, where for centuries they have provided millions of often lower-income communities with a low-cost, nutritious foodstuff for both themselves and their associated livestock, including cultured fish. Freshwater macrophytes are often used to recycle "waste" nutrients, but they also provide significant employment and incomes. Freshwater aquatic macrophytes (FAMs) continually remain unrecorded in most government and (inter-) national agriculture and/or aquaculture statistics and planning documents despite their significant contribution to food production and nutrient recycling. In terms of the global aquaculture development community, the range and scale of edible cultivated aquatic plant production is little known or practiced outside South and Southeast Asia, and is rarely taught in curricula or addressed in the research agenda of the major academic aquaculture schools and agriculture and international non-governmental research organizations.

Aquatic plants form an ecological rather than taxonomic group and cannot be defined with any degree of precision. Though there are no standard definitions for freshwater macrophytes in the literature, they are generally considered plants that either require a fairly continuous supply of freshwater or are present in soils that are covered in freshwater for a significant proportion of their growing cycle. They are distinguished as macrophytes by their size compared with phytoplankton, but can also include filamentous algae, which sometimes grow into larger floating mats and which can then be harvested. FAMs can be categorized broadly into three groups, or categories, by their methods of growth within the water column, although some species at different stages in their life cycle can move between the different categories. The three categories are: (i) emergent species; (ii) submersed species; and (iii) floating species.

It is estimated that there are more than 40 species of edible FAMs, of which around 25 percent either are already being cultivated for food at a scalable level or have the potential to be developed into commercially viable cultivation species. In terms of their genetic improvement and species selection for improvements in growth performance, productivity, phytoremediation of wastewater and even disease resistance despite the significant translocation of germplasm between countries or regions over the last 600 years, there is relatively little information either in the research literature or at the grassroots production level to indicate selective breeding programmes and/or selection or genetic modification towards improved strains occurring. However, owing to their scale and their importance, particularly in Southeast Asia, FAMs can be considered a key tropical and subtropical cultivatable crop that can contribute to sustainable food production in developing countries in the future in a financially viable and environmentally responsible way.

There are many other roles that they do and can fulfil, which include being key components in multipurpose integrated production systems. The incorporation and use of FAMs in aquaculture and other wastewater treatment and remediation in continues to be developed. There is potential as aquaculture feed ingredients. There is often a close relationship of aquatic plant production between aquaculture and agriculture/horticulture, giving as an example the huge global market for ornamental aquatic plants, and therefore the need for clear differentiation and clarity in the future collection and presentation of global production statistics for different use categories of FAMs. This data collection is further complicated with particular species such as water morning glory (Ipomoea aquatica) being cultivated in different geographical locations for different purposes with different beneficial outcomes.

1.3.1.3 Microorganisms

Microorganisms, feed organisms and aquatic plants have not been comprehensively reported to FAO, yet they are a valuable component of AqGR. (Box 1.2).

Box 1.2

Microorganisms in fisheries and aquaculture

Aquaculture is the farming of aquatic organisms ranging from microbes to shellfish and finfish and in 2015. World food fish aquaculture production more than doubled from 2000 to 2012 and contributed 42 percent of total fish production in 2012. Aquatic microorganisms are indispensable resources for growth of shellfish and finfish in natural aquatic ecosystems and in aquaculture. This State of the World report provides information on the genetic resources of key microorganisms on which aquaculture depends.

These microorganisms fall into the microbial groups of (1) microalgae and fungal-like organisms, (2) bacteria, including cyanobacteria and (3) zooplankton. Many microalgal species are important in aquaculture, with different species being suitable as feed for shellfish and finfish larviculture, as components of “green water” widely used to enhance survival and growth of larval and adult fish, and as feeds to enhance the nutritional quality of *Artemia* and rotifers.

Microalgae are also grown in aquaculture to produce pigments and fatty acids of importance in fish aquaculture and as human nutraceuticals. Bacteria that are used in aquaculture include cyanobacteria such as *Spirulina* used for human diet supplements and a rapidly-growing suite of probiotic bacteria. These probiotic bacteria include species that improve survival and growth of fish and shellfish larval and adult stages.

Probiotic bacteria are expected to become increasingly important for disease prevention in aquaculture as antibiotic use is further curtailed and species are grown in more intensive aquaculture systems. Bacteria also play an important role in filtration systems needed in recirculating aquaculture systems.

Zooplankton, specifically *Artemia* and rotifers, have a long history and very wide application as feed for the aquaculture industry. Several species of *Artemia* are used, with *Artemia franciscana* being the most important. Of more than 2 000 species of rotifers, *Brachionus plicatilis* and *Brachionus rotundiformis* are most commonly used. Other zooplankton used in aquaculture include copepods that are growing in importance and cladocerans such as *Daphnia* that are widely used in freshwater larviculture.

The future success and growth of aquaculture depends on continued availability and more efficient culture of these important microbes, as well as conservation and expansion of the biological diversity and genetic resources of microbes used in aquaculture. Important issues include the ability to achieve long-term storage of important organisms without them being subject to genetic drift, the role of commercial and public culture collections, and the need for increased use of genomics to characterize all key microbial species used in aquaculture.

1.3.2 Diversity of production systems

With the wide diversity of farmed types (>580 reported to FAO), global aquaculture production systems are equally diverse. They cover a range of systems, extensive to intensive, across all types of aquatic environment (fresh-, brackish- and marine waters) and in every inhabited continent of the world.

These systems also have different characteristics with respect to the diversity and use of aquatic genetic resources, ranging from the use of wild seed to domesticated breeding lines. The diversity of aquaculture systems, the typical species produced and the source of broodstock and seed, is summarized in Table 1.8.

Table 1.8
Summary table of the diversity of aquaculture systems and the typical species produced

System type	Typical species/species groups	Source of seed stock	Source of Broodstock
Industrial/high technology systems	Marine Finfish: Atlantic salmon, Pompano, Crustacean: Penaeus vannamei, Freshwater Finfish: Rainbow trout, Pangassius, GIFT Tilapia, other Tilapia strains, Jayanti Rohu, Common carp strains, sturgeon, channel catfish	Hatchery	Captive broodstock Selective breeding and other genetic improvement; Domestication programmes
Higher value species fattening systems	Marine: Bluefin tuna, groupers, lobster, mangrove crab, yellowtail Freshwater: European & Japanese eel, marbled sand goby	Wild captured from targeted fisheries	Wild relatives
Lower value species fattening systems	Marine/brackishwater: Mullet, milkfish Freshwater: giant snakehead; African catfish		
Medium technological level commercial finfish and crustacean fed-systems	Marine/brackishwater Fishfish: Turbot, sea bream, European sea bass, Asian Sea Bass milkfish, snappers, cobia Crustacean: Penaeus monodon Freshwater Finfish: intensive tilapia, Pangassius, Indian major carp, Chinese carp, Mandarin fish Crustacean: Macrobrachium spp., crayfish spp., Chinese mitten crab	Hatchery	Captive broodstock used from growout systems No/limited selective breeding Some genetic material used from wild relatives for broodstock
Higher value mollusc systems	Marine/brackishwater: Fed systems: Abalone, Babylonia, Lantern net systems: scallop	Hatchery produced Seed	Captive broodstock

	Lines: Green lipped mussel Racks/poles: Pacific & European oyster systems Open water: Giant clam		
Low technology/ artisanal and backyard systems	Marine: rabbitfish, milkfish, scats	Hatchery	Broodstock maintained on farm or held in hatchery. Quality of strain ranges between highly inbred on-farm strain, to genetically well-managed national broodstock systems
	Freshwater: Indian carp, common carp, Chinese carp, tilapia, catfish, snakehead, climbing perch, silver barb, snakeskin gourami, giant gourami, pacu		
Integrated or mixed systems	Marine/brackishwater: Mangrove/ aqua-silviculture (crab/shrimp/trap pond systems)	Trapped wild species ongrown Hatchery culture species introduced	Wild broodstock Hatchery maintained broodstock
	Freshwater: Rice-fish (common carp, barbs, tilapia, channel catfish): rice crayfish (Pacifastacus)		
	Freshwater-brackishwater: rice fish/rice-prawn rotation systems (tilapia; mixed brackishwater fish; penaeid shrimp; Macrobrachium spp.)		
	Freshwater: Wastewater improvement systems (aquatic plants and/or molluscs/ herbivorous fish	Mainly hatchery	Hatchery maintained broodstock
	Marine: Integrated, multi-trophic systems (Seaweeds; Invertebrates – scallops, mussels, sea cucumber, sea urchin; finfish cages)	Mostly hatchery raised or vegetative growth (seaweed)	Mainly on farm stock or hatchery maintained broodstock
Lower value mollusc systems	Extensive stake systems (oyster, mussels) Extensive bottom systems (blood cockle, manila clam)	Natural Spatfall Spat collectors	Wild broodstock on farm or wild relatives
Aquaculture Feed species	Invertebrates (e.g. polychaete worms)	Hatchery	Hatchery maintained strains or use of farm stock (in the case of worms
	Zooplankton (e.g. moina)		
	Phytoplankton (e.g. chaetoceros, chlorella, skeletonema, tetraselmis, isochrysis, etc.)		
	Zooplankton (artemia)	Wild Collection	Inoculation of open waters with maintained strains Wild relatives naturally recruited
Food supplements	Spirulina	Hatchery	Maintained strains
Seaweeds/aquatic plants	Marine: seaweeds (euchema, gracilaria, laminaria, porphyra etc.)	Hatchery, Vegetative reproduction	Maintained tock or Hatchery held strains
	Freshwater: aquatic plants e.g. Ipomea, water cress (including ornamental/aquarium plants)		

Aquarium fish and other species	Indicative number of species marine Indicative number of species freshwater Also significant use of exotic species outside of their natural range	Hatchery	Hatchery maintained broostock

1.3.3 Marine and freshwater ornamental fish in the aquarium trade

In 2000, the Global Marine Aquarium Database (GMAD) was created and by August 2003 the dataset contained trade records covering a total of 2 393 species of fish, corals and Invertebrates and spanning the years 1988 to 2003. Asia provided more than 50 percent of the global total ornamental fish supply (FAO, 2000).

- A total of 1 471 species of marine fish are traded worldwide but the ten 'most traded' species account for about 36 per cent of all fish traded for the years 1997 to 2002 (Wabnitz *et al.*, 2003).
- A total of 140 species of stony coral, nearly all scleractinians, are traded worldwide. Coral species are in seven genera (*Euphyllia*, *Goniopora, Acropora, Plerogyra, Catalaphyllia*) are the most popular, accounting for approximately 56 per cent of the live coral trade between 1988 and 2002. There were also 61 species of soft coral traded.
- More than 500 species of invertebrates (other than corals) are traded as marine ornamentals, though the lack of a standard taxonomy makes it difficult to arrive at a precise figure.

There is no equivalent database for the freshwater aquarium trade and the diversity of species being produced and traded is not readily available. However, various aquarium guides list 650 (Sakurai, *et al.*, 1993) to 850 (Baensch and Riehl, 1997) common freshwater aquarium species.

An important distinction that can be made between the freshwater and marine aquarium trades is the level of reliance on capture of animals rather than culture. It is roughly estimated that the freshwater aquarium trade relies on cultured animals for 98 percent and only two percent of the products are captured.

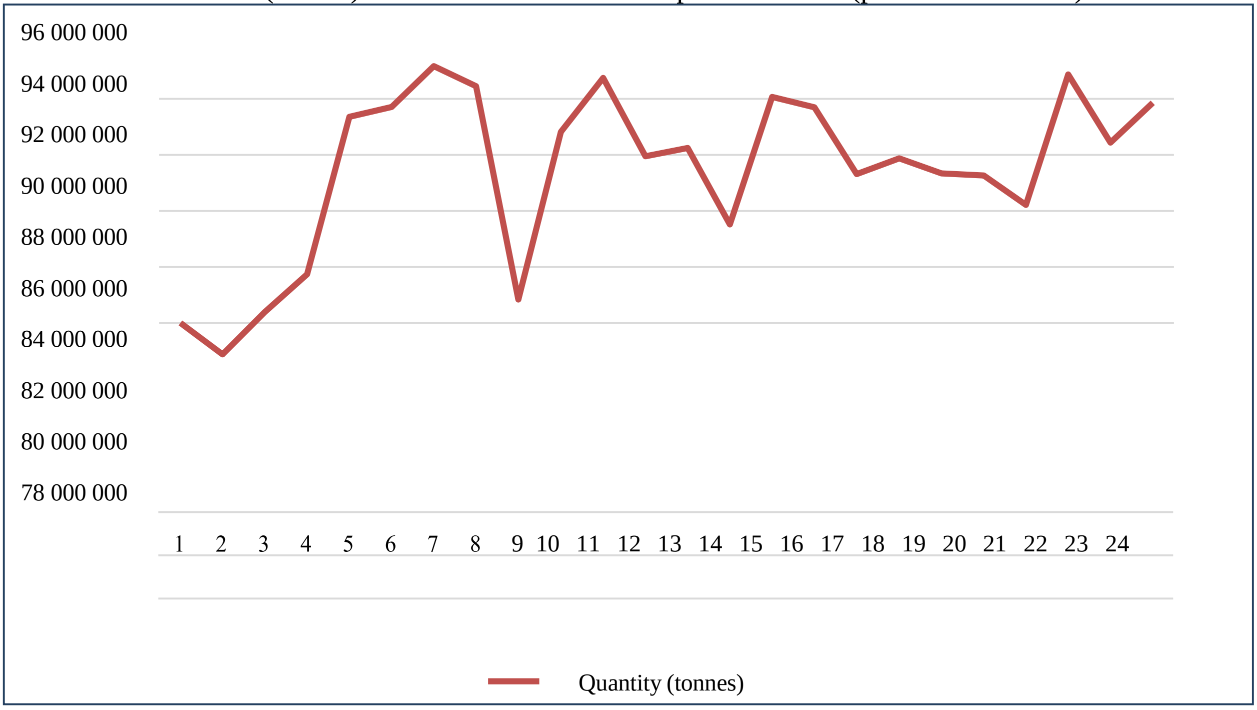
The marine aquarium trade relies on capture for 98 percent of its production versus two percent culture (Wabnitz *et al.*, 2003). There is a significant potential for increasing the contribution of aquaculture to the marine aquarium trade and the freshwater aquarium trade is also a significant contributor to the value of aquaculture production in some countries.

1.4 State of World Fisheries[5]

Harvest from marine capture fisheries and plateaued at approximately 94 tonnes (Figure 1.9).

[5] Analyses will be completed using most recent data following the release of the State of World Fisheries and Aquaculture 2016, in July 2016.

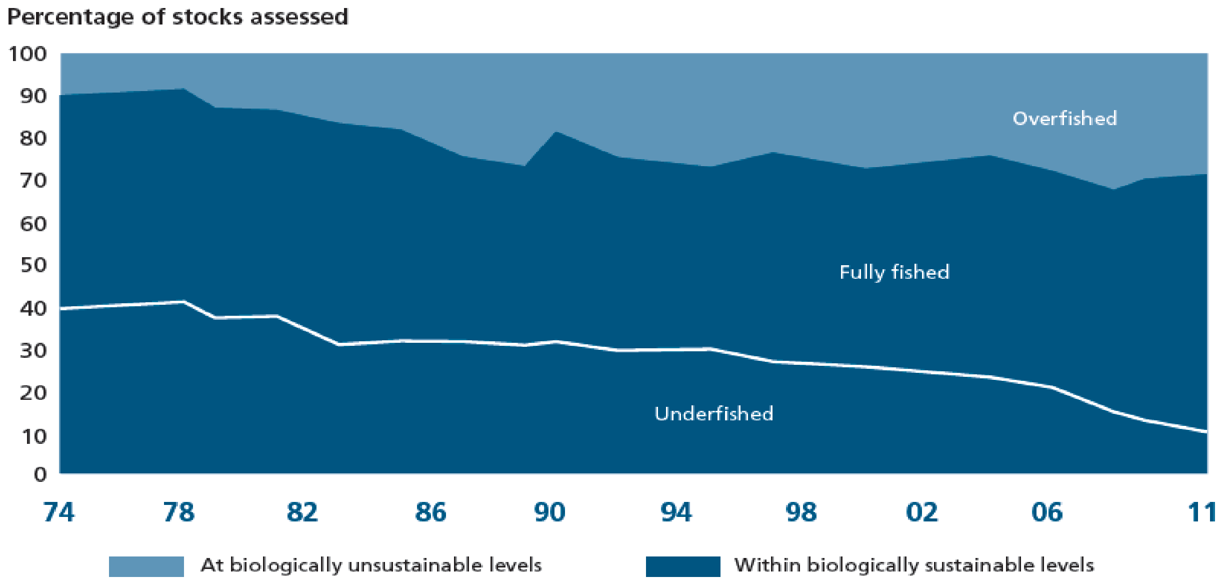
Figure 1.9
Production in volume (tonnes) from marine and inland capture fisheries (period 1990–2013)



1.4.1 Marine fisheries

The status of marine fisheries is based on an in-depth analysis of over 450 fish stocks (FAO, 2014a). The world's marine fisheries expanded continuously to a production peak of 86.4 million tonnes in 1996 but have since exhibited a general declining trend. The fraction of assessed stocks fished within biologically sustainable levels has exhibited a decreasing trend, declining from 90 percent in 1974 to 71.2 percent in 2011. In 2011, 28.8 percent of fish stocks were estimated as fished at a biologically unsustainable level and therefore overfished. Of the total number of stocks assessed in 2011, fully fished stocks accounted for 61.3 percent and under-fished stocks 9.9 percent. The majority of marine fisheries (61.3 percent) are harvested within sustainable limits (Figure 1.10).

Figure 1.10
The global trends in the state of world marine fish stocks, 1974–2011



Notes: Dark shading = within biologically sustainable levels; light shading = at biologically unsustainable levels. The light line divides the stocks within biologically sustainable levels into two subcategories: fully fished (above the line) and underfished (below the line).

Source: FAO, 2014a.

Asia harvests the majority of marine fish stocks, followed by Africa and Latin America (Table 1.9).

Table 1.9
Production of global marine capture fisheries by region in 2013, excluding aquatic plants

Geographical region	2013	Percentage of global total
Australia and New Zealand	595 184	1%
Melanesia	342 090	0%
Micronesia	213 052	0%
Polynesia	50 367	0%
South America	9 930 299	12%
North America	5 807 001	7%
Central America	1 878 751	2%
Caribbean	219 288	0%
Western Africa	1 763 872	2%
Northern Africa	1 647 189	2%
Southern Africa	895 018	1%
Eastern Africa	457 014	1%
Middle Africa	411 111	1%
Eastern Asia	20 880 008	26%
South-Eastern Asia	16 118 889	20%
Southern Asia	5 216 587	7%
Western Asia	968 789	1%
Central Asia	828	0%
Northern Europe	6 055 445	8%
Eastern Europe	4 092 538	5%
Southern Europe	1 541 822	2%
Western Europe	1 059 475	1%

Table 1.10
Main species harvested from marine fisheries and production in volume from 2008 until 2013

Species (ASFIS species)	2008	2009	2010	2011	2012	2013
Atlantic cod	770 503	868 049	951 933	1 051 545	1 114 401	1359 568
Atlantic herring	2 479 203	2 516 755	2 203 687	1 780 268	1 773 235	1816 987
Marine fishes nei	8 786 014	9 934 983	10 391 131	10 403 497	1 0879 822	1 0951 308
Pacific herring	283 915	306 104	330 802	397 440	451 457	510 015
Japanese flying squid	403 722	408 188	359 322	414 100	351 229	330 136
European pilchard(=Sardine)	1 065 295	1 244 588	1 245 956	1 037 161	1 018 940	1 001 126
Haddock	332 178	365 611	396 483	430 028	430 917	308 671
California pilchard	742 028	758 070	696 585	639 235	364 386	255 291
Japanese anchovy	1 270 331	1 072 589	1 204 106	1 325 758	1 296 383	1 326 077
American cupped oyster	90 947	96 141	115 925	121 165	137 884	173 514
Chub mackerel	1 937 613	1 641 344	1 641 508	1 715 551	1 581 180	1 654 545
Atlantic redfishes nei	39 933	59 456	46 603	50 005	56 255	53 961
Atlantic menhaden	187 742	182 210	228 966	227 141	224 404	167 590
Japanese pilchard	192 159	191 907	205 327	318 791	269 972	380 023
Pacific saury	622 119	475 727	432 372	458 954	460 961	402 386

Table 1.11
Principal taxonomic groups that make up the 98 percent of the global marine harvest

Taxonomic group	Production (tonnes)	% of total global marineCatch
Clupeiformes	15 670 089	23%
Scombroidei	13 555 855	20%
Pisces miscellanea	11 851 081	18%
Percoidei	10 052 462	15%
Gadiformes	8 652 069	13%
Salmoniformes	1 131 795	2%
Pleuronectiformes	1 040 586	2%
Beloniformes	758 946	1%
Mugiliformes	539 911	1%
Scorpaeniformes	508 976	1%
Stromateoidei, Anabantoidei	489 633	1%
Trachinoidei	455 527	1%
Anguilliformes	447 902	1%
Aulopiformes	402 831	1%
Siluriformes	367 685	1%

1.4.2 Inland fisheries

Global inland fishery harvests are in excess of 12 million tonnes, however there are credible reasons to believe that this production figure is under-estimated. Asia harvests the most from inland fisheries producing at least 65 percent of the global production. Africa produces 23 percent of the production.

Table 1.12

Global production from inland capture fisheries (freshwater and diadromous fish) by region

Geographical region	2013	Percentage of global total
Melanesia	11 732	0%
Australia and New Zealand	3 837	0%
Polynesia	51	0%
Eastern Africa	1 318 114	11%
Western Africa	733 920	6%
Middle Africa	515 225	4%
Northern Africa	243 902	2%
Southern Africa	4 181	0%
South America	354 754	3%
Central America	129 583	1%
Caribbean	3 177	0%
South-Eastern Asia	2 920 062	24%
Southern Asia	2 661 492	22%
Eastern Asia	1 962 203	16%
Western Asia	86 820	1%
Central Asia	54 070	0%
Eastern Europe	697 845	6%
North America	554 759	4%
Northern Europe	50 967	0%
Southern Europe	19 563	0%
Western Europe	19 021	0%
Totals - Quantity (tonnes)	**12 345 278**	**100%**

Source: Fao, 2013.

Figure 1.11

Inland capture fisheries production in volume

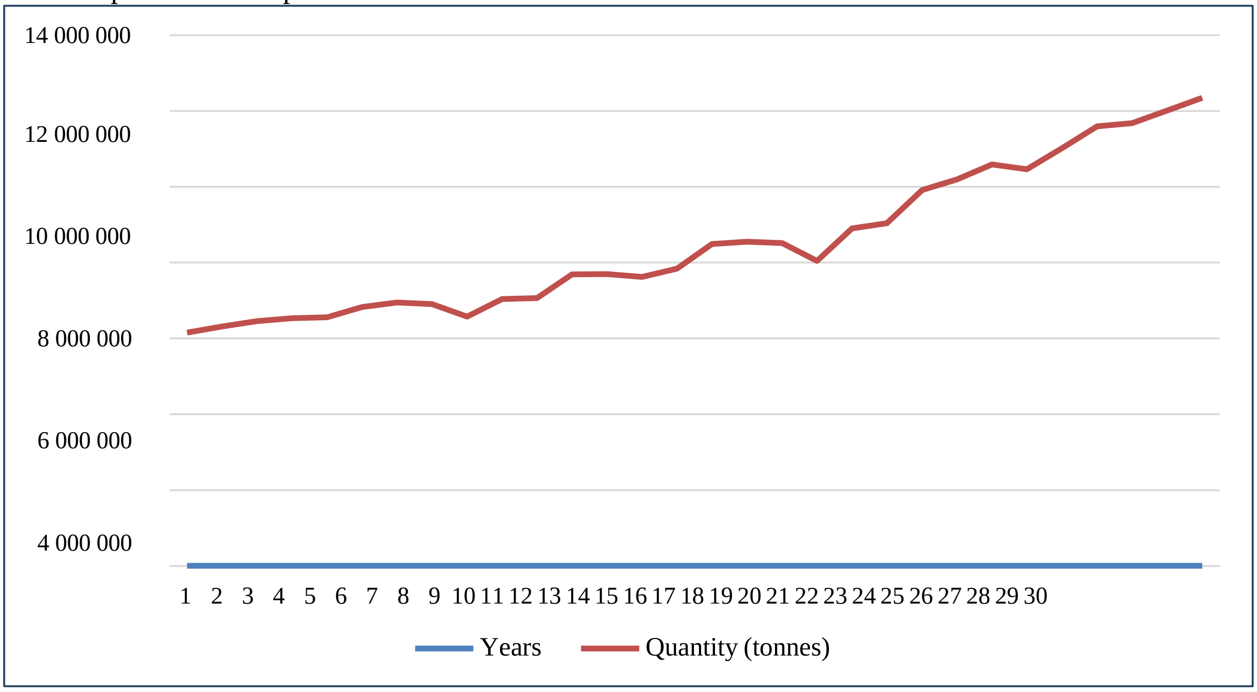


Table 1.13
Main species harvested from inland fisheries

Species	2013 (tonnes)
Freshwater fishes nei	6 456 211
Chum(=Keta=Dog) salmon	199 501
Black and Caspian Sea sprat	74 385
Freshwater bream	41 337
Pink(=Humpback) salmon	562 850
Roaches nei	20 570
Sockeye(=Red) salmon	136 597
Caspian shads	350
Pike-perch	18 098
Characins nei	66 864
Alewife	2 800
Common carp	89 715
Coho(=Silver) salmon	28 939
Northern pike	22 893
Whitefishes nei	3 581

The status of the world's inland fisheries is difficult to determine for most fisheries. Unlike marine fisheries were fishing pressure is a major determinant of the status, other factors external to the fishery sector has a major influence on status (FAO, 2012, FAO, 2014a). Habitat condition, water quality and connectivity of water bodies often influence inland fisheries more than fishing pressure. Complicating the determination of the status of inland fisheries is the fact that much of the harvest is unreported or not reported to species (Bartley *et al.*, 2015).

Table 1.14
Main species in inland capture fisheries and the percentage of total inland harvest

Species (ASFIS species)	% of Total global inland harvest
Freshwater fishes nei	52.3
Pink(=Humpback) salmon	4.6
Chum(=Keta=Dog) salmon	1.6
Sockeye(=Red) salmon	1.1
Common carp	0.7
Black and Caspian Sea sprat	0.6
Characins nei	0.5
Freshwater bream	0.3
Roaches nei	0.2
Coho(=Silver) salmon	0.2
Northern pike	0.2
Pike-perch	0.1
Caspian shads	0
Alewife	0

1.5 Key findings and conclusions

[To be completed]

1.6 References

Baensch, H.A. & Riehl, R. 1997. *Aquarium Atlas.* Vol 2, Freshwater. Aqua Medic Inc. 992 pp.
Bartley, D.M., De Graaf, G.J., Valbo-Jørgensen, J. & Marmulla, G. 2015. *Inland capture fisheries: Status and data issues*. Fisheries Management and Ecology, 2015, 22. pp 71–77.
FAO. 2000. *The State of World Fisheries and Aquaculture 2000*. FAO, Rome.
FAO. 2010. Fisheries and aquaculture software. FishStatJ – software for fishery statistical time series.

In: FAO Fisheries and Aquaculture Department [online]. Rome. [Cited 10 March 2018]. Available at: www.fao.org/fishery/statistics/software/fishstatj/en

FAO. 2012. The State of World Fisheries and Aquaculture 2012. Rome. 209 pp. Also available at: www.fao.org/3/a-i2727e.pdf

FAO. 2013. Fisheries and aquaculture software. FishStatJ – software for fishery statistical time series. In: FAO Fisheries and Aquaculture Department [online]. Rome. [Cited 10 March 2018]. Available at: www.fao.org/fishery/statistics/software/fishstatj/en

FAO. 2014a. *The State of World Fisheries and Aquaculture 2014*. FAO, Rome. 223 pp. Also available at: www.fao.org/3/a-i3720e.pdf

FAO. 2014b. Fisheries and aquaculture software. FishStatJ – software for fishery statistical time series. In: FAO Fisheries and Aquaculture Department [online]. Rome. [Cited 10 March 2018]. Available at: www.fao.org/fishery/statistics/software/fishstatj/en

FAO. 2016a. *The State of World Fisheries and Aquaculture 2016*. FAO, Rome. 204 pp. Also available at: www.fao.org/3/a-i5555e.pdf

FAO. 2016b. Fisheries and aquaculture software. FishStatJ – software for fishery statistical time series. In: FAO Fisheries and Aquaculture Department [online]. Rome. [Cited 10 March 2018]. Available at: www.fao.org/fishery/statistics/software/fishstatj/en

IUCN. 2010. *IUCN Redlist of threatened species*. Also available at: www.iucnredlist.org/

Ricciardi, A. & Rasmussen, J.B. 1999. *Extinction rates of North American freshwater fauna*. Conservation Biology 13. pp 1220–1222. Also available at: http://dx.doi.org/10.1046/j.1523-1739.1999.98380.x

Sakurai, A., Sakamoto, Y., Mori, F. & Loiselle, P.V. 1993. *Aquarium Fish of the World: The Comprehensive Guide to 650 Species*. Chronicle Books, San Francisco, CA. 296 pp.

Wabnitz, C.C.C., Green, E., Taylor, M.L. & Razak, T. 2003. *From Ocean to Aquarium: From Ocean to Aquarium: the global trade in marine ornamental species*. UNEP-WCMC Biodiversity Series 17. 65 pp.

World Bank. 2013. *Fish to 2030 Prospects for Fisheries and Aquaculture*. World Bank Report Number 83177-GLB. World Bank, Washington D.C.

CHAPTER 2
THE USE AND EXCHANGE OF AQUATIC GENETIC RESOURCES OF FARMED AQUATIC SPECIES AND THEIR WILD RELATIVES WITHIN NATIONAL JURISDICTION

PURPOSE: The purpose of this chapter is to provide annotated inventories on and the status of aquatic genetic resources of farmed aquatic species and their wild relatives.

KEY MESSAGES:

Major findings from an examination of Country Reports and other information sources are as follows:

- Aquatic genetic resources for food and agriculture include DNA, genes, chromosomes, tissues, gametes, embryos and other early life history stages, individuals, strains, stocks and communities of organisms. Unlike domesticated crops and livestock where many breeds, varieties and cultivars have been well established and recognized for centuries or millennia, aquatic species have a much smaller number of traditionally few recognized strains and stocks of a very few species.
- Naming of aquatic species and farmed types was reported to be generally accurate and up to date for most countries although there are also numerous cases where names of species and farmed types are not accurate.
- The use of genetic information in management depends on accurate information and baseline data. Although a global information system does not yet exist, potential elements of such a system have been developed.
- The information contained in the Country Reports could contribute to a new information system on AqGR.
- Countries reported farming of 694 species, or species items. Asia farms the most aquatic species and North America the fewest, although this is partially explained by more countries practicing aquaculture in Asia than in North America.
- Common carp was the species most often reported as being farmed, followed by Nile tilapia, rainbow trout, grass carp and North African catfish.
- Based on the Country Reports, the 11 major producing countries on average farmed a higher number of species (26 species/country) than the 79 other countries (seven species farmed/country).
- Introduced species (also known as non-native or alien species) can be very important in aquaculture with approximately 200 species, or species items reportedly farmed where they are non-native.
- Nine of the 10 most widely cultured species are farmed in more countries where they are non-native than in countries where they are native.
- Aquaculture is increasing in most areas and is expected to continue to increase for most species.
- The Country Reports identified over 250 species and species items that have not previously been reported with their production statistics to FAO.
- Many of the species not previously reported were ornamental fish (29 percent) and microalgae (25 percent), which are yet to be covered by the current FAO global data collection system.
- The top 10 listed species reported as candidates for domestication and use in aquaculture were *Mugil cephalus*; *Sander lucioperca*; *Perca fluviatilis*; *Lates niloticus*; *Chanos chanos*; *Heterotis niloticus*; *Rachycentron canadum*; *Clarias gariepinus*; *Solea solea* and *Psetta maxima*.
- Aquatic genetic resources are being managed in aquaculture in about 60 percent of the responses, which is significantly greater than the often-cited figure of only 10 percent.
- There is a large range of genetic technologies useful in improving production in aquaculture, including selective breeding, hybridization, polyploidization, chromosome set manipulation, mono-sex production, marker assisted selection, transgenesis and gyno/andro genesis. However, transgenesis was not reported by any country.
- Although the wild type was the most common farmed type used in aquaculture (in about 41 percent of responses) selective breeding was the technology most often used to improve certain desirable traits in aquatic species.

- Aquaculture depends on AqGR from the wild in the form of early life history stages or broodstock to at least some extent in almost 90 percent of the responses.
- Major producing countries (i.e. those countries that contribute more than 1 percent to global aquaculture production) reported a higher use of genetically improved organisms than more minor producing countries.
- Countries reported that in general genetic data were available and used in aquaculture, with major producers using the information more than the minor producers and least developed countries used information on AqGR to a lesser degree than other countries.
- Most of the programmes on selective breeding were funded by the public sector, but the private sector was the main funder of all of the other technologies although the differences between the numbers of responses for public and private funding were very slight.
- Public financing of genetic improvement programmes was much more prevalent in the major production countries than in the minor production countries.
- Wild relatives play a significant role in fisheries and aquaculture with rivers and coastal areas being the habitats from where most wild relatives were reported.
- For most wild relatives that are fished, a management plan exists, but over 200 cases of wild relatives were reported to be declining and almost 30 cases reported to be depleted.
- The main reason cited for the change in abundance of wild relatives was habitat loss and degradation followed by pollution.
- Habitat for most wild relatives was reported to be decreasing in the majority of Country Reports, however there were a number of reports where the trend in change of habitat was not known.
- As with farmed aquatic species, genetic data may exist for wild relatives, but are often not used in management.
- For the top 10 wild relatives for which catch was reported to be declining, only three are listed as having any conservation concerns in the IUCN Red List and for only two has IUCN identified a trend in numbers.
- Production from non-native species was reported to be increasing in fisheries for wild relatives and in aquaculture, especially in the minor producing countries.
- Over 200 aquatic species were reported to have been exchanged (import and export) with the Nile tilapia and North African catfish the most exchanged species globally and Latin America and the Caribbean reporting the most exchanges by region.
- Living specimens was the most often exchanged type of AqGR accounting for about 77 percent of the reported exchanges.

2.1 Background

The use and exchange of Aquatic Genetic Resources (AqGR) of farmed aquatic species and their wild relatives has been practiced for millennia. The earliest humans gathered fish, shellfish and aquatic plants from wetlands and coastal areas in Africa and continued this practice as early humans migrated out of Africa and prehistoric examples of fishing are found in middens around the world (Sahrhage and Lundbeck, 1992).

Early evidence of fish farming is found over two thousand years ago in China; the ancient Romans held marine species in special coastal enclosures not only for eventual consumption, but also as an indication of wealth and status. European monks farmed and transferred the common carp from its native range in Asia and the Danube River to many parts of Europe; the scientific name for common carp, *Cyprinus carpio*, is derived from the fact that the fish was introduced to Western Europe through Cyprus (Nash, 2011).

While an incredible amount of biodiversity is used in fisheries and aquaculture (Bartley and Halwart, 2017), most information on this biodiversity in terms of production and number of farmed organisms and their wild relatives is at the species level. Very little information is available on the genetic diversity of farmed organisms and their wild relatives.

2.2 Definitions and nomenclature

Aquatic Genetic Resources for food and agriculture include DNA, genes, chromosomes, tissues, gametes, embryos and other early life history stages, individuals, strains, stocks and communities of organisms. Unlike domesticated crops and livestock (FAO, 2007; FAO, 2015), where many breeds, varieties and cultivars have been well established and recognized for centuries or millennia, aquatic species have very few recognized strains and stocks (i.e. the equivalent to breeds in livestock or cultivars in crops). The operational definitions used in this report and proposed for standard usage in the description of Aquatic Genetic Resources are explained in Box 2.1.

Box 2.1.
Standardizing nomenclature in Aquatic Genetic Resources

In 2016 FAO held an Expert Workshop on Incorporating Genetic Diversity and Indicators into Statistics and Monitoring of Farmed Aquatic Species and their Wild Relatives (FAO, 2016). This workshop recognized that there was a lack of standardization of terms used to describe aquaculture genetic resources and recommended a number of operational descriptors as applicable to Aquatic Genetic Resources. In general the nomenclature follows the custom in naming plant cultivars and animal breeds. The following descriptors used throughout the State of the World report are based on these.

Term	Definition
Cultivar or variety	A plant or grouping of 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.
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.
Farmed type	Farmed aquatic organisms that could be a strain, hybrid, triploid, monosex group, other genetically altered form, cultivar or variety.
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.

Also unlike the terrestrial agriculture sector, all wild relatives of farmed aquatic species can still be found in nature although wild types of some species are becoming threatened through *inter alia* introgression with farmed types and non-native genotypes (see below). The term 'wild relative' signifies an organism found in nature that is the same species (conspecific) as one being farmed. This natural reserve of genetic diversity not only supports capture fisheries and helps the species adapt to anthropogenic and natural impacts, but it also provides a source of individuals and genes to be used in aquaculture.

2.3 Information on fisheries and aquaculture

Accurate and timely information lies at center of documenting the use and status of genetic resources of farmed species and their wild relatives. FAO serves as the global repository for national statistics on fisheries and aquaculture production.

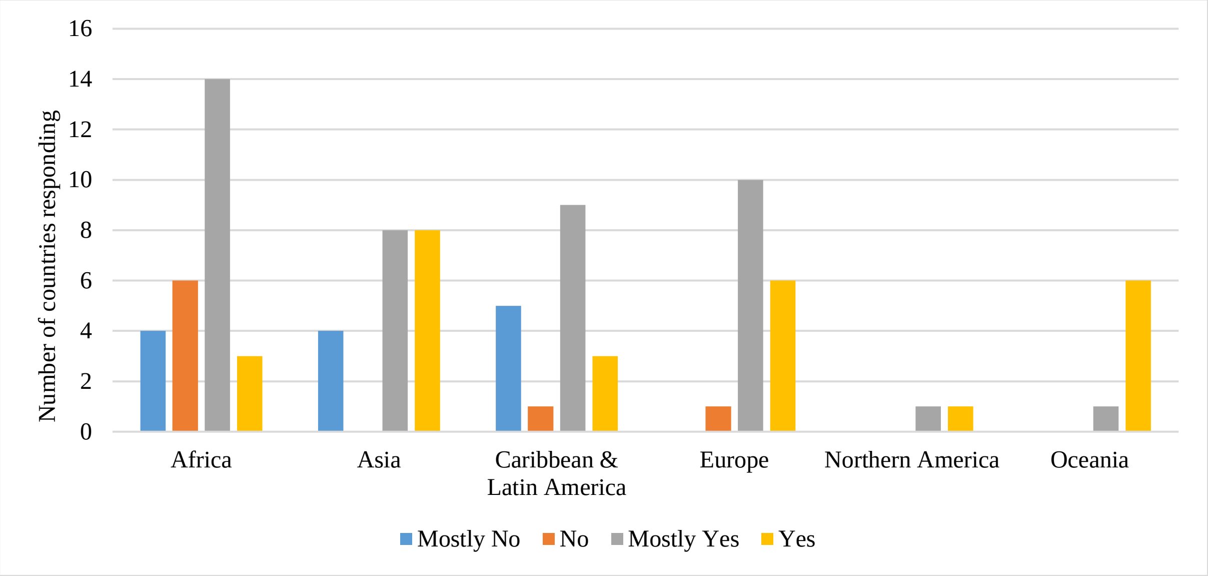
The international standard for collecting and reporting fisheries and aquaculture production includes the Aquatic Sciences and Fisheries Information System (ASFIS) list and the classification system of the International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP). Members of FAO are recommended to utilize and align to the ASFIS nomenclature for collecting national fisheries and aquaculture statistics for their own use and for reporting to FAO.

Country Reports indicated that the naming of species and farmed types was generally accurate and up to date (Figure 2.1). This trend was seen when countries were grouped by economic status (Figure 2.1 b) and by level of production (data not shown). However, it is unclear what taxonomic level the level of accuracy refers to in the Country Reports. Is it at the species level or below?

To date the ASFIS[6] list contains 12 700 species items[7]. The nomenclature includes only twelve taxa below the species level, i.e. interspecific hybrids but it is possible to include more if and when FAO members report production data of clearly identified and properly described hybrids. The list does not include any subspecies, stocks, strains or varieties of farmed species or their wild relatives. Information about Aquatic Genetic Resources below the species level can be extremely useful to resource managers, policy makers, private industry and the general public. Genetic diversity is the basic building block for selective breeding programmes and other genetic improvement technologies in aquaculture. Also it is key for natural populations to adapt to changing environments and evolve. Information on genetic diversity can be used *inter alia* to help meet production and consumer demands, to prevent and diagnose disease, to trace fish and fish products in the production chain, to monitor impacts of alien species on native species, to differentiate cryptic species, to manage broodstock and to design more effective conservation and species recovery programmes.

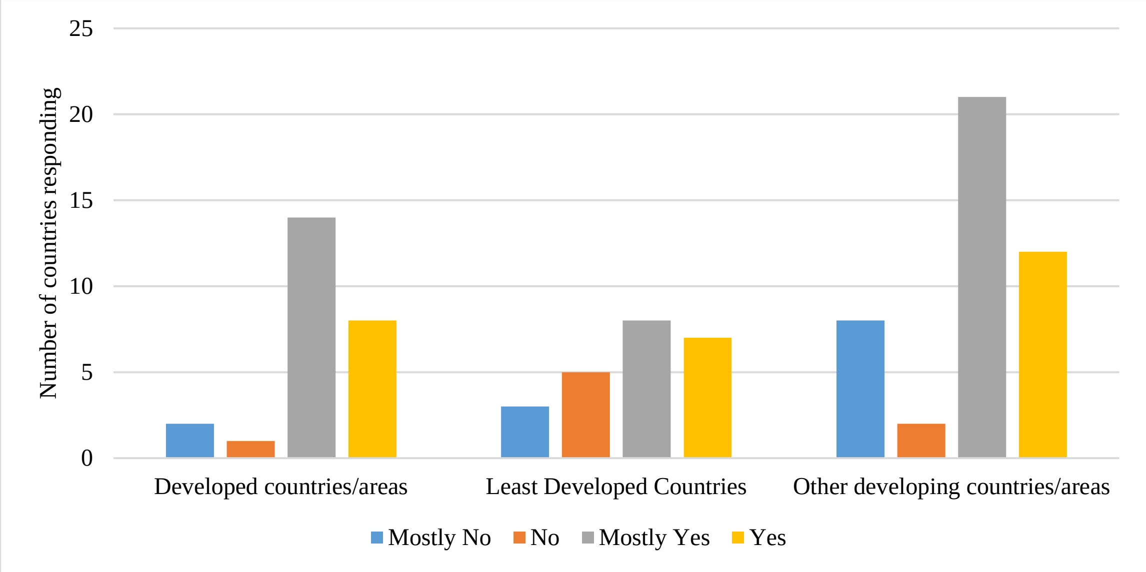
However, the majority of resource managers and those government officials that have routinely submitted information to FAO do not use or have sufficient access to information of aquatic genetic diversity of farmed species and their wild relatives below the level of the species, e.g. stocks and strains.[8]

Figure 2.1a. The naming of aquatic species and farmed types accurate and up to date by region



[6] www.fao.org/fishery/collection/asfis/en
[7] The AFSIS list and Country Reports contain entries that are not species, e.g. Oreochromis spp, hybrids, or higher level taxa such as cichlidae. Therefore in the analyses presented here 'species' also includes 'species items'
[8] The National Focal Points for AqGR have helped provide information below the species level for this report and are gratefully acknowledged.

Figure 2.1b. The naming of aquatic species and farmed types accurate and up to date by economic level



2.4 Incorporating genetic diversity and indicators into national statistics and monitoring of farmed aquatic species and their wild relatives

The FAO Commission on Genetic Resources for Food and Agriculture, realizing that substantial production from aquaculture and capture fisheries is based on groups below the level of the species and that genetic information has a variety of uses in fishery management, requested FAO to undertake a thematic study to explore means to incorporate genetic diversity and indicators into statistics and monitoring of Aquatic Genetic Resources (AqGR) of farmed aquatic species and their wild relatives.

Examples of incorporating genetic diversity into national and global reporting and monitoring do exist, but primarily in the terrestrial agriculture sector, where nomenclature for breeds and varieties has been standardized and used for centuries. In the aquaculture sector, the establishment of breeds of most species is a much more recent practice and thus the nomenclature and characterization of breeds is not standardized.

In capture fisheries genetic diversity is sometimes used in fishery management of high value species, but this is dependent on the establishment of baseline data and on regular sampling, monitoring and analyses of the fish stocks which are often beyond the financial and technical capacities for many species and areas. Stock identification in capture fisheries has traditionally been based on geographic location; production has been reported and monitored accordingly.

Some countries maintain registries of nationally important aquatic species, but production information is not routinely included unless the stock or species is considered threatened or endangered.

There are significant constraints to developing an information system below the species level for AqGR including:

- the lack of standardized genotypic and phenotypic description of a ‘strain’ or ‘stock’,
- the lack of complete baseline data that genetically characterize a strain or stock, and
- the private aquaculture industry’s view that genetic information on their products is proprietary (FAO, 2016).

Nonetheless, an information system was designed (FAO, 2016) (Table 2.1) that would complement FAO’s current work on fishery and aquaculture statistics.

Table 2.1. Data structure for an information system on Aquatic Genetic Resources of farmed types and their wild relatives

Information for farmed types	Information for wild relatives
Respondent – name of person providing information	Respondent – name of person providing information
Taxonomic status, genus, species and farmed type or strain	Taxonomic status, genus and species
Genetic characteristics of the farmed type	Genetic status and characteristic of the wild relative
Source of farmed type, from wild or aquaculture	Source of wild relative, native or introduced
Breeding history	Migratory pattern
Distinguishing characteristics and common name	Designation of stock name and distinguishing characters
Where farmed	Records of occurrence
Farming system(s)	Habitat(s), distribution, range
Time series of production	Exploitation or use
Status	Status, presence and abundance
Source of further information	Source of further information

Given the complexity and resources required, incentives would need to be developed to motivate governments, resource managers and private industry to participate and contribute to the information system. Incentives include, *inter alia*:

- Countries accessing funds to meet international commitments, e.g. from the CBD or Global Environment Facility (GEF);
- Private industry accessing markets through improved traceability and certification schemes;
- International organizations becoming centres of excellence in information on AgGR.

To address costs and complexities, options exist for incorporating genetic diversity into statistics and monitoring programmes. As a first step, an inventory of farmed types and strains of wild relatives could be created that would not involve monitoring and assessment.

This inventory would provide an accessible system documenting the aquatic genetic diversity in fisheries and aquaculture. For an information system that would permit monitoring, options also exist for the time interval between data input; thus, the cost of inputs to and maintenance of the information system would be lower with less frequent input.

The Country Reports are being incorporated into a database that would allow some monitoring on the status and trends of Aquatic Genetic Resources through the process of producing the State of the World reports. The rapid advances in genetic technologies and a growing need for sustainably produced seafood would suggest a need for monitoring at 2–3 year intervals to provide current information on change, opportunities and threats.

Reporting at this level would further promote capacity building and continuity, i.e. a body of experts, resource managers, industry representatives and other interested stakeholders that would provide, analyze and use the information.

International organization, private industry and national governments would need to commit to contributing to the information system. In light of the need to efficiently feed a growing human population, these stakeholders will be well served by incorporating genetic diversity information into national management, reporting and monitoring programmes and then reporting this information to the global community.

In light of the facts that a global information system on AqGR does not exist, and at national levels where they do exist they are not comprehensive and include information on only species that dominate production, a new information system with input from countries would need to be established. This will take human and financial resources as well as significant capacity building in many areas.

2.5 The use of Aquatic Genetic Resources in food production

2.5.1 Aquaculture

Aquaculture is the fastest growing food production sector and is expected to play a major role in providing seafood in the future as production from many capture fisheries has plateaued (SOFIA, 2014; Figure 1). Currently, about 50 percent of the seafood we eat comes from aquaculture (SOFIA, 2016). In order for aquaculture to fulfil its expected role in meeting future seafood demands, management of AqGR and the application of useful genetic technologies will be essential.

The wide use of Aquatic Genetic Resources in aquaculture is a relatively recent activity, for all but a very few species, such as the common carp (Balon, 1995). Unlike the plant and livestock sectors, where farmers have been domesticating and maintaining hundreds of useful breeds and varieties with distinct characteristics for millennia, domestication of aquatic species only became widespread during the last century (Nash, 2011).

2.5.1.1 Diversity of farmed aquatic species

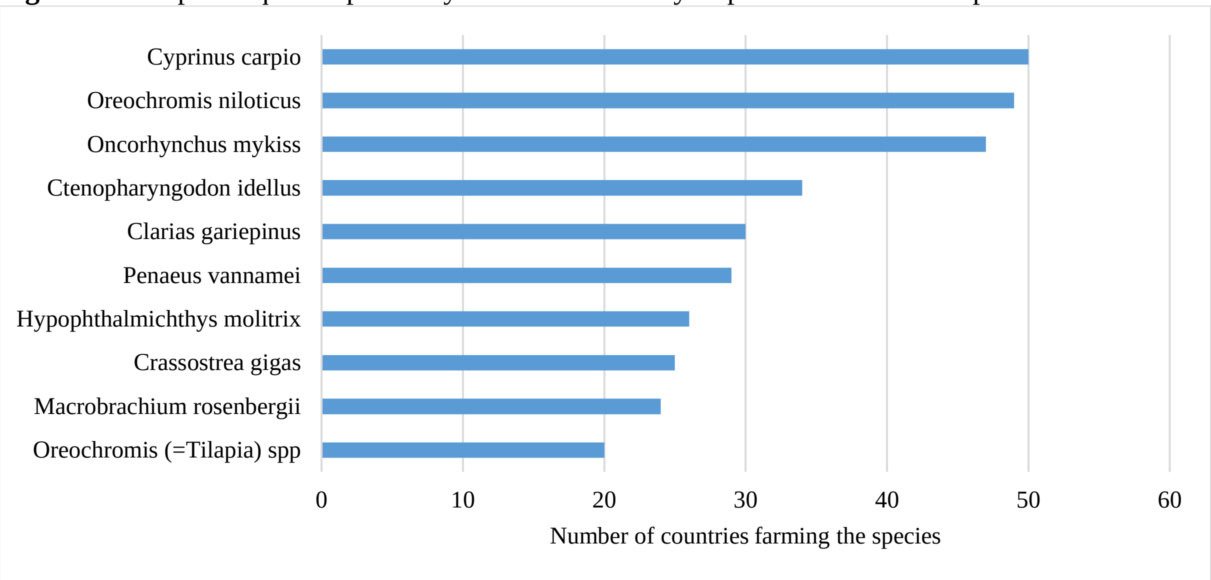
The current list of farmed aquatic species reported to FAO contains over well 500 species items from inland, marine and coastal waters. Farmed aquatic species are derived from an incredible taxonomic diversity that includes, two kingdoms and over four phyla (Chordata, Mollusca, Arthopoda and Echinodermata) (See Chapter 1, Table 5).

Aquatic species are farmed throughout the world with approximately 130 countries traditionally reporting to FAO through the annual submission of statistics by member countries.

Information from the Country Reports is a separate process from the traditional reporting and revealed that, of the species most commonly farmed (Figure 2.2), seven are from freshwater habitats with one alga, crustacean and mollusc from the marine environment.

The most commonly reported species being farmed was common carp, *Cyprinus carpio*, and it was introduced into 16 of the 20 countries where it is now farmed. In fact, many of the commonly farmed species are not native to many (most) of the countries that farm them (Table 2.2).

Figure 2.2. Top 10 aquatic species by number of Country Reports in which it is reported as farmed



Countries reported farming of 694 species, or species items. Asia farms the most species (Figure 2.3a), with North America farming the fewest. By economic classification, other developing countries reported farming the most species. These results are partially due to the differences in numbers of countries reporting from the different regions. However, the 11 major producing countries on average farmed a higher number of species than the 79 other countries that reported (Figure 2.3c). Thus, it appears that there is little correlation between level of economic development and number of species farmed, whereas there is an indication that there is a positive relationship between level of production and number of species farmed (Figure 2.3c). This is consistent with other information on the advantages of farming a diversity of aquatic species (Harvey *et al.*, 2017).

In the preparation of this report FAO requested feedback from international organizations working with AqGR in a development context. Input was received from six organizations[9] and included several species being prioritised in regional cooperation (Box 2.2).

Box 2.2

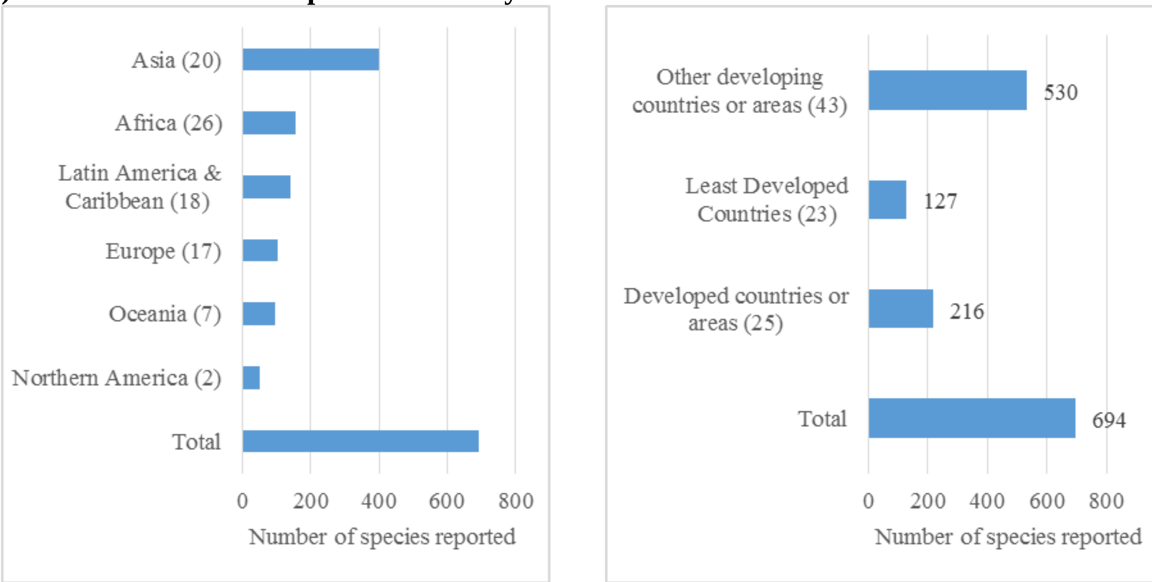
Key focal species for international cooperation

Tilapias	e.g. *Oreochromis niloticus*, *O. aureus*, *O. shiranus*, *O. tanganyikae*, *O. andersoni*, *O. esculentus*, *O. mossambicus*, *O. variablis* and hybrid farmed types
Catfishes	*Clarius gariepinus*, *Clarius macrocephalus*
Cyprinids/Carps	*Cyprinus carpio*, *Labeo rohu*, *Catla catla*, *Hypophthalmichthys molitrix*, *H. nobilis*, *Amblypharyngodon mola*, *Labeo vitorianus*
Salmonids	*Salmo trutta*
Freshwater Prawns	*Macrobrachium rosenbergii*
Brackish/Marine Crustaceans	*Penaeus monodon*, *Litopenaeus vannamei*, *L. stylirostris*, *Portunus pelagicus*, *Scylla* spp.
Molluscs	*Crassostrea gigas*, *Tridachna* spp., *Pinctada margaritifera*, *Abalone* sp.
Brackish/Marine finfish	*Lates calciferer*, *Chanos chanos*, *Epinephalus* spp., *Siganid* spp.

[9] Lake Victoria Fisheries Organization, Mekong River Commission, Network of Aquaculture Centres in Asia and the Pacific; South Pacific Community, Southeast Asian Fisheries Development Centre and WorldFish.

Figure 2.3. Number of species farmed by region (number of countries in group) Note that the total is the number of unique species, or species items, reported and not the sum of above groups as the same species could be farmed in different regions

a) Total number of species farmed by economic class



b) Average number of species farmed by countries' level of production

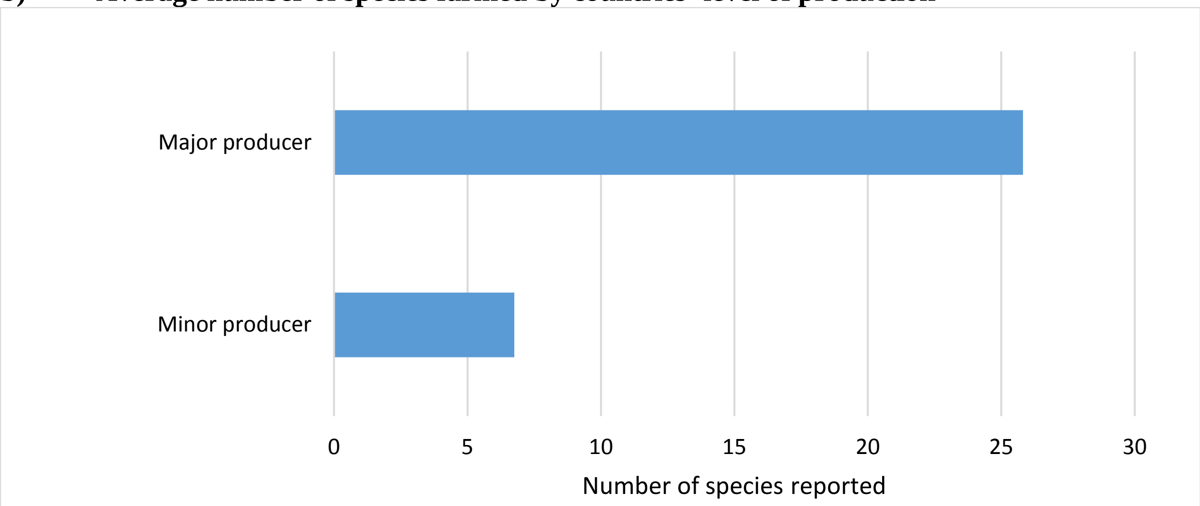


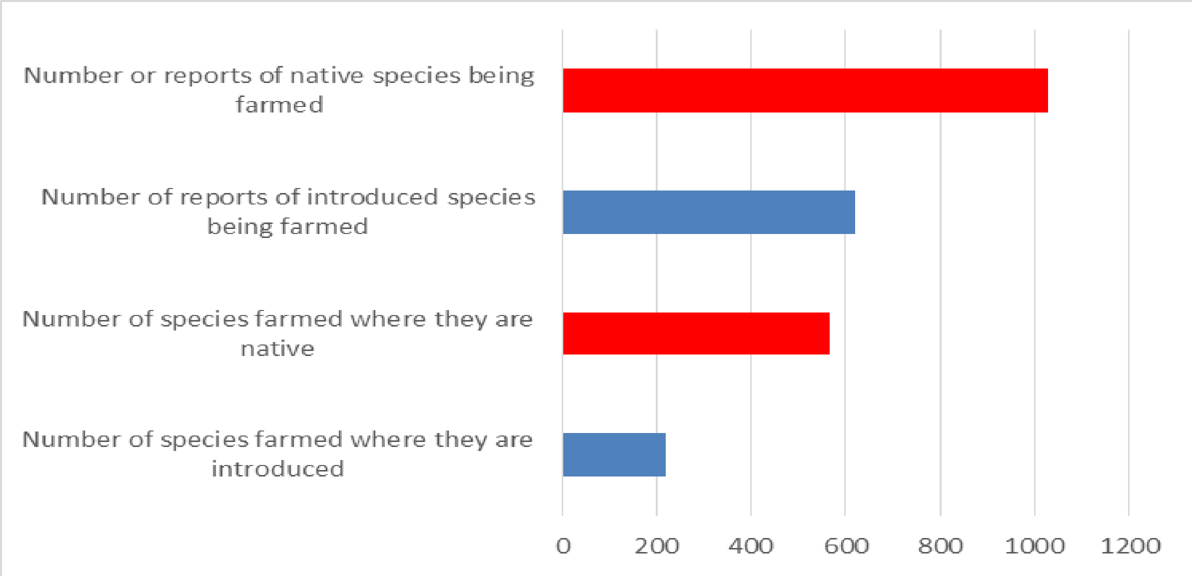
Table 2.2. For the most commonly farmed species reported, the number of countries where the farmed species is native and introduced

Species	Native	Introduced
Cyprinus carpio	11	37
Oreochromis niloticus	12	33
Oncorhynchus mykiss	5	40
Ctenopharyngodon idellus	3	30
Clarias gariepinus	14	12
Penaeus vannamei	9	19
Hypophthalmichthys molitrix	3	19
Crassostrea gigas	4	20
Macrobrachium rosenbergii	11	13
*Oreochromis (=Tilapia) spp.**	3	15

**Oreochromis spp. would probably also contain O. niloticus*

Introduced species play a significant role in aquaculture production (see also section 2.5.4 below). Approximately 200 species items were reported farmed in countries where they are introduced, i.e. non-native, and almost 600 species items reported farmed where they are native (Figure 2.4). There were over 1000 reports of farming native species or species items and over 600 reports of farming introduced species or species items (Figure 2.4). Although there were more reports of farming native species, nine of the 10 most productive species are mostly farmed in areas where they are non-native.

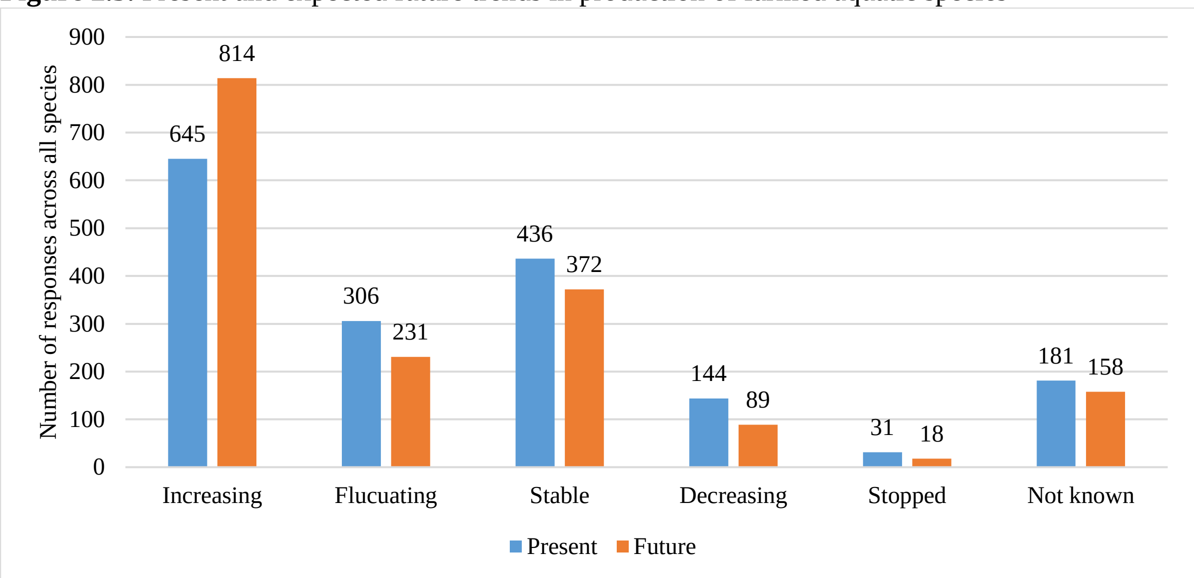
Figure 2.4. Numbers of native and introduced species reported in aquaculture



Aquaculture production is increasing and there is an expectation for this trend to continue (SOFIA, 2014). Production has been and is expected to continue increasing in the vast majority of species included in the Country Reports as well (Figure 2.5).

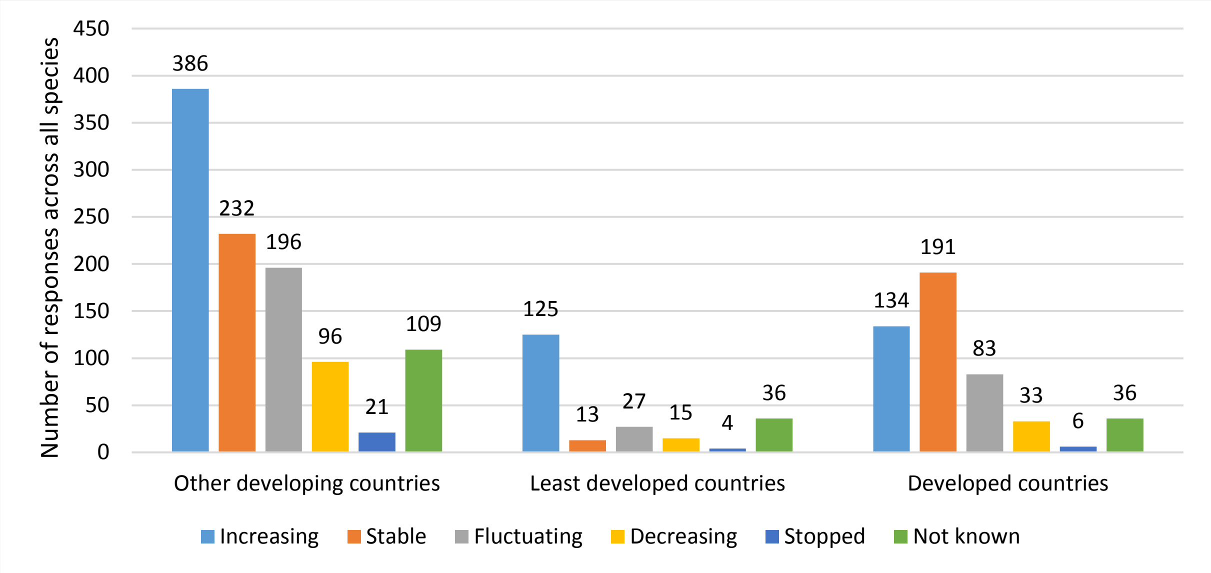
A few countries have discontinued farming of certain species, e.g. *Argopecten ventricosus, Cherax quadricarinatus, Rachycentron canadum, Crassostrea gigas, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Hypophthalmichthys nobilis, Isochrysis galbana, Metapenaeus affinis* and *Oreochromis aureus.* However the farming of these species was only reported as stopped in no more than one country.

Figure 2.5. Present and expected future trends in production of farmed aquatic species



Analysis of production trend by economic level of the countries indicated that aquaculture is mostly increasing in developing and least developed areas, but in developed areas production of most species is stable (Figure 2.6).

Figure 2.6. Production trend by economic classification of countries.



The Country Reports reflect the current national reporting and contain additional information not previously reported to FAO (Table 2.3). Numerous countries reported farming more species and 'species items' than they report through the regular FAO statistic survey and reported species items not currently listed in ASFIS (Table 2.4 and Figure 2.7) Q9.

Table 2.3. Summary of species and farmed type reports arising from the Country Reports on Aquatic Genetic Resources

Item	Count	Examples	Notes
Number of Country Reports recording more species cultured than recorded in FishstatJ	44	*See below*	*Based on species reported in Country Reports that have not been reported (in FishstatJ) as produced in that country since 2000.*
Number of Country Reports recording less species than recorded in FishstatJ	44	*See below*	*Based on FishstatJ reports going back to 2000*
Number of reports of cultured species that have never been previously reported as production to FAO (i.e. in FishstatJ)	253 (records) 207 (species)	***Fish*** *Clarias Jaensis (Cameroon – catfish)* *Claria magur (India – catfish)* ***Molluscs*** *Haliotus discus hannai (China/Republic of Korea – Abalone)* ***Crustaceans*** *Cherax canii (Australian – FW crayfish)* ***Plants*** *Cymodocea rotundata (Kenya – sea grass)*	*This represents the total number of species records across all reporting countries. Several newly reported species were duplicated in more than one country.*

		Cymodocean serrulata (Kenya – sea grass) *Eucheuma spinosum (Philippines – red algae)* ***Microalgae*** *Isochrysis galbana (Argentina, Belgium, Egypt, Kiribati, Morocco, Netherlands, Panama, Tonga)* ***Other*** *Heliocidaris erythrogramma (Australia – sea urchin)* *Xenia sp. (Madagascar – coral)*	
Number of farmed types[10] (i.e. with some type of genetic differentiation/intervention) reported as species	82	*e.g. Eight distinct selected tilapia strains in the Philippines, 60 new hybrids or crossbreds*	*Where countries have reported a farmed type as species (based on Question 9) and where specific hybrids or crossbreds have been reported (based on Question 8). These farmed types have not been previously reported as produced (i.e. not previously recorded in FishstatJ)*
Number of farmed types reported as significant	532	*see Box 2.3*	*Any genetic differentiation or intervention recorded for a species in a Country Report. Includes strains/ varieties, selected strains, hybrids, crossbreds, monosex and polyploid (based on Question 8)*
Number of farmed types reported in Total	1085	*See Box 2.3*	*Any genetic differentiation or intervention recorded for a species in a Country Report. Includes strain/ variety, selected, hybrid, crossbred, monosex (Based on Question 9)*

The largest group of species not previously reported were ornamental fish species (29 percent) and microalgae (25 percent). FishstatJ focuses reporting on species cultured for food and so would not normally list species that are only cultured as ornamental fish. There were nevertheless a significant proportion of edible finfish and crustacean species not previously reported as produced (12.6 and 6.3 percent respectively).

---

[10] A "Farmed type" is defined as a farmed aquatic organisms that could be a species, hybrid, triploid, monosex group, other genetically altered form, variety or strain. For the purposes of this table farmed type refers to those species in which some form of genetic differentiation (i.e. strain) or intervention (selection, polyploidy, monosex, hybrid) has been applied and thus excludes wild types. The number of wild types being farmed = 806, representing 43 percent of all types farmed.

Figure 2.7. Number of species reported that are not included in ASFIS list

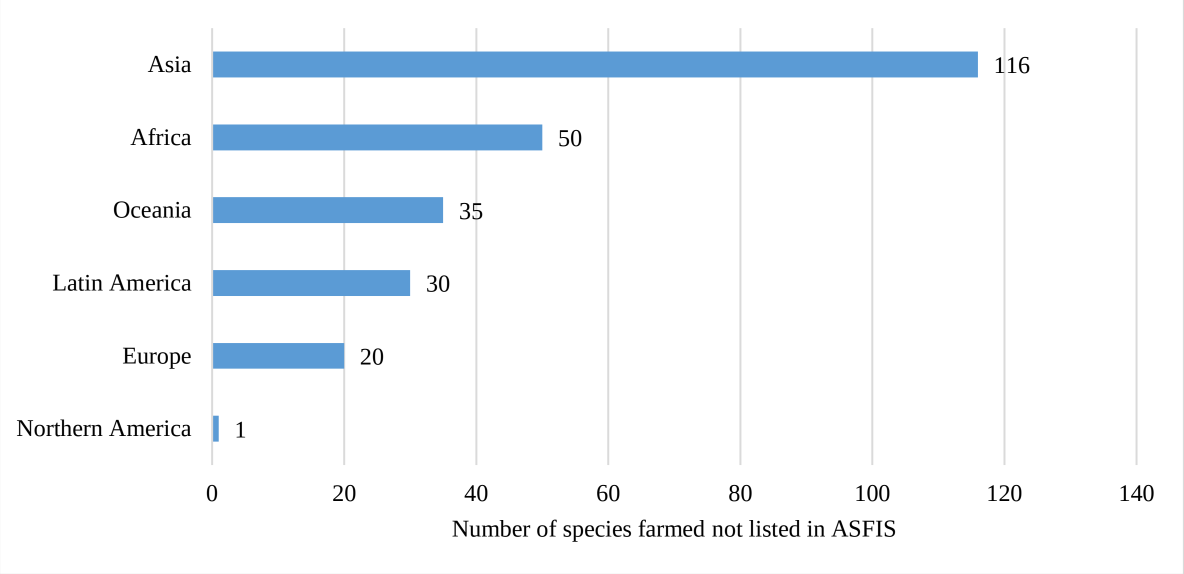


Figure 2.7a. Identification of the 253 species reported in Country Reports that have not previously been reported as produced (i.e. never previously reported in the FishstatJ database)

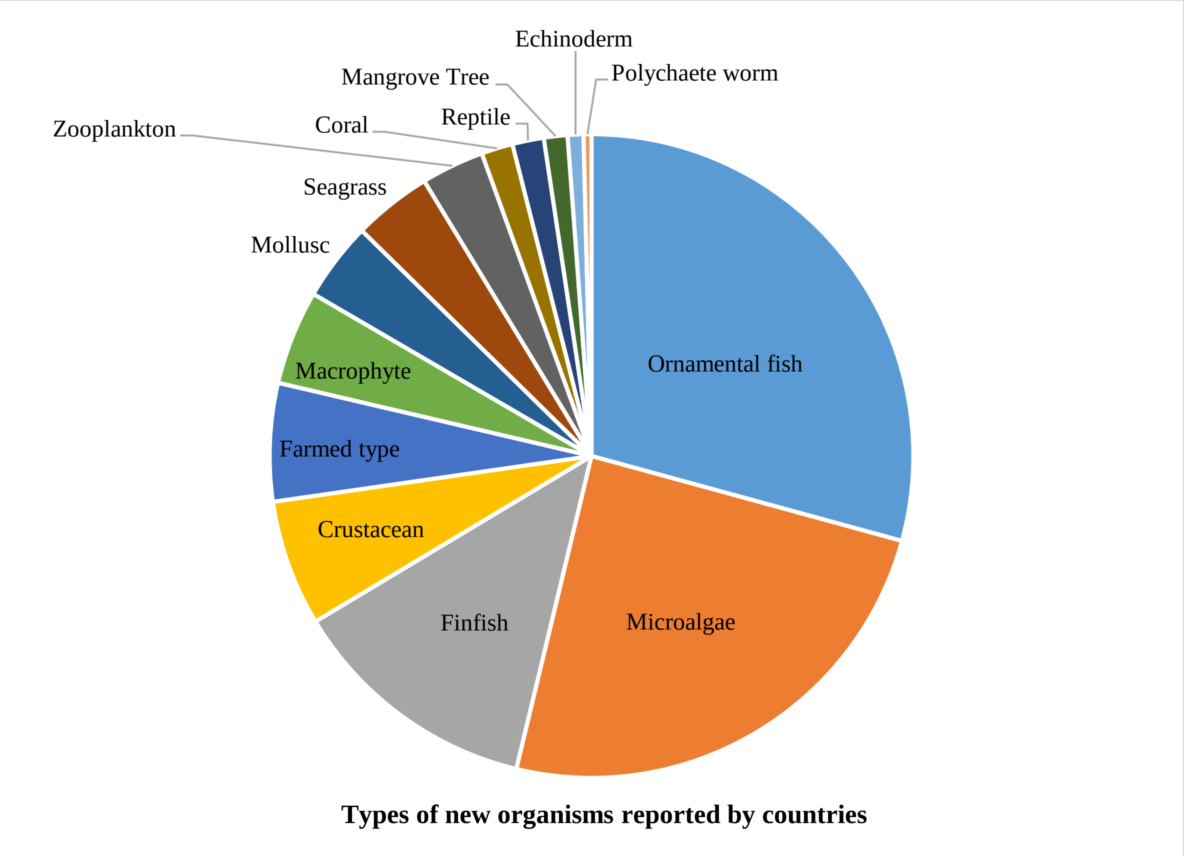


Table 2.4. The 10 countries reporting the most species items not included in ASFIS

Country	Number of species reported	Number of reported species in ASFIS	Number of reported species not in ASFIS
Panama	32	26	6
Guatemala	17	10	7
Indonesia	41	34	7
Japan	22	15	7
Madagascar	26	15	11
Viet Nam	67	55	12
Philippines	54	39	15
Sri Lanka	39	24	15
Kenya	33	14	19
Thailand	117	70	47

Country Reports included hybrid species items (Table 2.5). Currently the ASFIS contains 11 hybrids (Table 2.6), however countries do not always provide production information on the farming of these hybrids.

Table 2.5. Hybrids reported in Country Reports but not on the ASFIS list. The female parent listed first and reciprocal cross signifies mating of the same species with the other species as the female parent

Country	Scientific name
Brazil	*Pseudoplatystoma reticulatum x P. corruscans* and reciprocal cross
	P. reticulatum x P. hemeliopterus
Philippines	*Oreochromis mossambicus x O. niloticus*
Japan	*Onchorryncus mykiss x O. masou*
Viet Nam and Malaysia	*Epinephelus lanceolatus x E. coides* and reciprocal
	E. lanceolatus x E. fuscoguttatus
Thailand	*Barboniomus gonionotus x B. schwanefeld,;*
	Clarias batrachus x C. microcephalus
Lao People's Democratic Republic	*Channa micropeltes x C. striata*
Canada	*Patinopecten caurinus x P. yessoensis*

Species items reported for the SoWAqGR may not be on the ASFIS list or not have been reported previously because they may:

- have limited production;
- be primarily used in research;
- have very localized niche markets;
- be ornamental species;
- be microorganisms;
- have been misnamed or reported as strains or other type of non-standard nomenclature; and
- be new species being farmed.

Table 2.6. Hybrids in the ASFIS list and indication of whether the data were previously reported to FAO and included in FishStat

Scientific name	Family	Production data registered in FAO database	English name (FAO)	Names in other languages used by FAO
P. mesopotamicus x C. macropomum	Characidae	Yes	Tambacu, hybrid	Spanish: Pacotana, híbrido
C. macropomum x P. brachypomus	Characidae	Yes	Tambatinga, hybrid	
Clarias gariepinus x C. macrocephalus	Clariidae	Yes	Africa-bighead catfish, hybrid	French: Poisson-chat, hybride Spanish: Pez-gato, híbrido Chinese: 尖齿胡鲇与大头胡鲇杂交种
Morone chrysops x M. saxatilis	Moronidae	Yes	Striped bass, hybrid	French: Bar d'Amérique, hybride Spanish: Lubina estriada, híbrida Arabic: قاروس هجني أمريكي Chinese: (current name is wrong and needs to be corrected)
Oreochromis aureus x O. niloticus	Cichlidae	Yes	Blue-Nile tilapia, hybrid	Spanish: Tilapia azul-del Nilo, híbrido
P. mesopotamicus x P. brachypomus	Characidae	No	Patinga, hybrid	Spanish: Patinga, hibrido
Ictalurus punctatus x I. furcatus	Ictaluridae	No	Channel-blue catfish, hybrid	Chinese: 斑点-长鳍叉尾鮰杂交种
Pseudopl. corruscans x P. reticulatum	Pimelodidae	No		
Oreochromis andersonii x O. niloticus	Cichlidae	No		Chinese: 奥尼罗非鱼杂交种
Channa maculata x C. argus	Channidae	No		Chinese: 斑鳢-乌鳢杂交种
Leiarius marmoratus x P. reticulatum	Pimelodidae	No		

None-the-less, the Country Reports clearly demonstrated that more aquatic genetic diversity is being used than has been previously recognized. However, the differences in many countries' reports to FAO indicate that coordination of aquaculture statistics within a country is needed in some areas.

The ASFIS list does not include strains or varieties, however some Country Reports listed numerous infra-specific genetic diversity (Box 2.3. Strains).

Box 2.3

Strains in aquaculture

In terrestrial agriculture plants and animals have been domesticated into recognizable breeds and varieties, e.g. Angus beef, Bantu swine, Jasmine rice, and iceberg lettuce. The second Report on the State of the World's Animal Genetic Resources states there are over 7 000 breeds of animals (mammals and birds) (FAO, 2015).

For plant genetic resources there are even more. According to FAO (1997), 'Estimates of the number of distinct varieties of the rice species, *Oryza sativa*, range from tens of thousands to more than 100,000. At least seven different vegetables derive from the single wild cabbage species *Brassica oleracea* (kale, cauliflower, cabbage, Brussels sprouts, kohlrabi, broccoli calabrese, [and] savoy cabbage).'

Although there are examples of fish farmers using and even developing their own strains, in aquaculture there are very few standardized strains that are globally recognized. The common carp is a notable exception with the mirror carp, scaled carp, leather carp and wild-type widely recognized (Bakos and Gorda, 2001). The genetic basis for the different strains of carp is also known.

A strain in aquaculture should be distinct, stable and reproducible. That is, if a mirror carp breeds with a mirror carp you will get more mirror carps. Therefore mono-sex populations, hybrids and triploids would not be considered strains, even if they were distinct because they couldn't be bred and yield the same strain. The Country Reports listed numerous 'farmed types' that would not be designated 'strains' by our definition e.g. mono-sex tilapia, hybrid cold-tolerant tilapia, genetically male tilapia, all-female Atlantic salmon, and hybrid catfish.

Countries also reported on farmed types that could be considered as strains. Not unexpectedly common carp was often listed. Strains of common carp included "Feng Li" (Li means common carp in Chinese), "Heyuan Li", "Baiyuan Li", "Furong Li", "Yue Li", "Jin Li", "Huabai mirror carp", "Songpu mirror carp" and "Furui Li" from China. Indonesia reported seven strains of common carp for human consumption namely: Rajadanu, Jaya Sakti, Mantap, Marwana, Najawa, Majalaya and Sinyonya each strain with specific superior traits such as disease resistance, fast growth rate or high fecundity. Czechia reported that there are 20 registered strains of common carp in the country.

Nile tilapia was another species for which countries identified strains. The Philippines reported on the Genetically Improved Farmed Tilapia (GIFT) and other selected strains of Nile tilapia named FAST, GET ExCEL, BEST 200, the Genomar Supreme Tilapia and the SEAFDEC Supreme tilapia. These strains had superior growth rate or environmental tolerances compared to unimproved strains. The Philippines also reported using a Red tilapia strain, salt tolerant "Molobicus" and "iBEST" and a cold tolerant tilapia, derived from cross-breeding or hybridizing tilapia strains/species.

Czechia not only reported using strains of common carp, but also seven strains of tench (*Tinca tinca)* and a strain of albino catfish (*Silurus glanis*).

The State of the World Reports on plants and animals rely on standardized and recognized description of breeds and varieties for the assessment of genetic resources for food and agriculture. The aquatic sector lags far behind in establishing, recognizing and promoting strains of aquatic species. A system that recognizes strains with known characteristics would be an asset to help aquaculture grow in a sustainable and efficient manner. A registry of strains with their distinguishing characters has been proposed as a possible first step toward more accurate information on and increased production from AqGR (see section 2.4).

Although countries reported numerous farmed types, species and hybrids not currently listed in ASFIS, 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 listing, i.e. new hybrid or species, would be reported in a reliable and consistent manner by members of FAO. There is no mechanism within the structure of the ASFIS list to include strains, stocks or subspecies. An analysis of the Country Reports revealed that several new species and hybrids are being farmed than are currently on the ASFIS list. Several of these species items were reported by more than one country and will be added to the ASFIS list.

Some Country Reports listed subspecies as being farmed or as a wild relative. Current taxonomists have recommended the abolishment of this term (Nicolas Baily, FishBase coordinator, personal communication, 2016).

There were several species that countries identified as having aquaculture potential. Some of these are wild relatives of species that are farmed in other countries, but are not yet in a specific country; other species are currently being developed in research stations or by private industry in pilot programmes.

The most often reported species for future domestication and use in aquaculture was the grey mullet, *Mugil cephalus*. The 10 species most of often reported as candidates for domestication and use in aquaculture were (number of countries reporting), *Mugil cephalus* (19); *Sander lucioperca* (12); *Perca fluviatilis* (11); *Lates niloticus* (9); *Chanos chanos* (8); *Heterotis niloticus* (8); *Rachycentron canadum* (8); *Clarias gariepinus* (7); *Solea solea* (7) and *Psetta maxima*. These organisms are all finfish, and come from marine, coastal and inland areas. Country Reports often listed just a genus of interest without listing a specific species. For example, *Epinephelus spp* was reported as having future potential by 14 countries, *Lutjanus spp* was mentioned by seven countries, *Macrobrachium spp* in six countries and *Centropomus spp* in five.

Pullin (2016) reviewed models for establishing priorities for future domestication that included growth and economic parameters that would be important when considering the farming of a new species. The models were not extremely good at predicting future use of a species in aquaculture, however. Pullin incorporated other criteria to identify species suitable for culture, such as maximum length, growth performance, indicative trophic level, water(s) inhabited, temperature tolerance and other general considerations, e.g. ease of culture. Interestingly, several of the papers reviewed by Pullin and his own prioritization identified species of river mullet – although not the same species as was identified in the Country Reports – as having future farming potential.

2.5.2 Technologies[11]

Genetic technologies, both in developing and in developed countries, can be applied in aquaculture for increased production, control of reproduction, improved marketability, more accurate and effective traceability in the supply chain, better disease and parasite resistance, more efficient utilization of resources, and better identification and characterization of Aquatic Genetic Resources (Table 2.7). Some technologies can be used for immediate short-term gain, whereas others are for longer-term gain with genetic improvements accumulating each generation. The basic requirement for the application of all genetic technologies is the ability to reproduce the species under controlled conditions, i.e. under farm or hatchery conditions.

[11] Much of the section on genetic biotechnologies was taken from the Draft Thematic Background Study *Genome-based Biotechnologies in Aquaculture* by Zhanjiang Liu. 2016 available at: www.fao.org/3/a-bt490e.pdf

Table 2.7. Genetic technologies for improving farmed types and indicative responses in farmed aquatic species

Long term strategies using selective breeding	
Growth rate salmon.(Tave 1989)	Around 50 percent improvement in time to market for after 10 generations in coho Gilthead sea bream mass selection gave 20 percent increase/generation (Hulata, 1995).
	Mass selection for live weight and shell length in Chilean oysters found 10–13 percent gain in one generation (Toro *et al.*, 1996).
Body confirmation	High heritabilities in common carp, catfish and trout (Tave, 1995)
Physiological tolerance (stress)	Rainbow trout showed increased levels of plasma cortisol levels (reviewed in Overli *et al.*, 2002).
	Increased resistance to dropsy in common carp (Kirpichnikov, 1981).
Disease resistance	Increased survival after challenge test against Taura syndrome in whiteleg shrimp (Fjalestad *et al.*, 1997).
Maturity and time of spawning	60 days advance in spawning date in rainbow trout (Dunham, 1995).
Resistance to pollution	Tilapia progeny from lines selected for resistance to heavy metals survived 3 – 5 times better than progeny from unexposed lines (Lourdes *et al.*, 1995).
Gene transfer/transgenesis	Coho salmon with a growth hormone gene and promoter from sockeye salmon grew 11 times (0 – 37 range) as fast as non-transgenics (Devlin *et al.*, 1994).
	Atlantic salmon containing a gene encoding growth hormone from Chinook salmon grows twice as fast as selectively bred fish (Fox, 2010).
Short-term strategies	
Crossbreeding (intra-specific mating – see box 2.4)	Improved growth seen in 55 and 22 percent of channel catfish and rainbow trout crosses, respectively (Dunham, 1995).
	Improved growth wild x hatchery gilthead seabream crosses (Hulata, 1995)
	Crossbreeds of channel catfish and common carp showed 30–60 percent improved growth
	Increased salinity tolerance and color in tilapia crossbreeds (Pongthana *et al.*, 2010).
	Oreochromis niloticus × O. aureus hybrids show a skewed male sex-ratio (Rosenstein and Hulata, 1993).
Hybridization (inter-specific mating)	Sunshine bass hybrids (*Morone chrysops*×*Morone saxatilis*) grew faster and had better overall culture characteristics than either parental species (Smith, 1988).
	Walking catfish hybrids (*Clarias macrocephalus* x *C. gariepinus)* exhibit morphological features which increase consumer acceptance (Dunham, 2011).
	All male tilapia show improvements in yield of almost 60 percent depending on farming system and little unwanted reproduction and stunting (Beardmore *et al.*, 2001; Lind *et al.*, 2015).
Sex reversal and breeding	All female rainbow trout grew faster and had better flesh quality (Sheehan *et al.*, 1999).
	Improved growth and conversion efficiency in triploid rainbow trout, channel catfish; triploid Nile tilapia grew 66–90 percent better than diploids and showed decreased sex-dimorphism (Dunham, 1995).
Chromosome manipulation	Triploid Pacific oysters show 13–51 percent growth improvement over diploids and better marketability due to reduced gonads (Guo *et al.*, 2009).
	Polyploidization makes certain interspecific crosses viable, i.e. produces sterile offspring (Wilkins al, 1995).

Box 2.4
Hybridization terminology

Hybridization is a term which can often generate some confusion. This box attempts to introduce a degree of standardization of terminology. Definitions of the terms discussed here are included in the definitions within the glossary associated with this publication. **Hybrids** and **crossbreds** are often used synonymously but are most usefully defined and distinguished as referring to inter and intra specific crosses respectively. A cross between two species (hybrids) or two strains of the same species (crossbreds) is known as an F1 (hybrid or crossbred). Crosses between F1s are known as F2s, between F2s as F3s, and so on. In F1s, F2s and F3s the average genetic contribution within the line remains at 50 percent from each of the original parental species but as the number of hybrid/crossbred generations progresses the phenotypes of the hybrids or crossbreds become less predictable and more variable. Also, hybrids or crossbreds may be backcrossed or crossed to another species or strain, changing the relative genetic contributions from the source species/strains and making the phenotypes even less predictable and more variable. It can thus be confusing to continue to refer to these subsequent generations within the lines as hybrids or crossbreds and it is proposed here that anything beyond an F2 hybrid or crossbred be referred to as an **introgressed** species or strain.

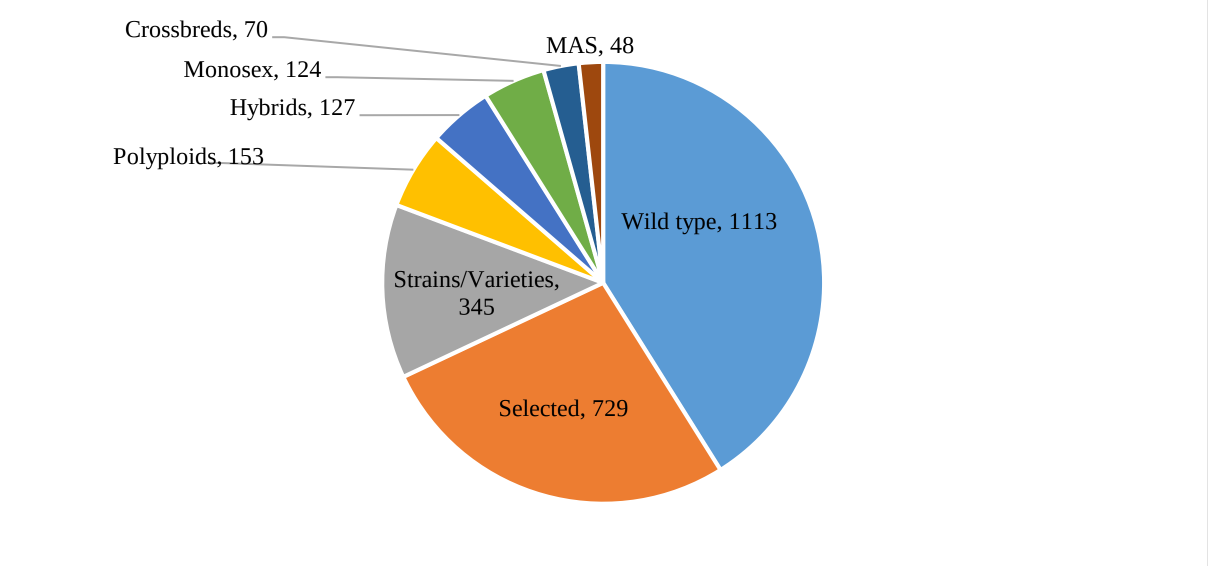
2.5.2.1 Farmed types

Several farmed types of aquatic organisms are available to aquaculturists. These farmed types include, in addition to selectively bred organisms, polyploids (Tiwary, Kirubagran and Ray, 2004), hybrids (Wohlfarth, 1994; Bartley, Rana and Immink, 2001) and mono-sex groups (Mair *et al.*, 1995). The general term ‘farmed type’ has been suggested (FAO 2016) as an inclusive term to include the diversity of genetically altered organisms available for aquaculture. Many aquatic farmed types are very similar to the wild type, i.e. the wild relative, and their genetic resources are not managed systematically. It has been stated that only about 10 percent of farmed aquatic species are subjected to genetic resource management in the form of an organized selective breeding programme (Gjedrem and Robinson, 2014). This has often been misinterpreted to mean that for 90 percent of farmed aquatic species genetic resources are not managed at all.

The Country Reports indicate that in fact genetic resources are being managed in about 60 percent of the responses (Figure 2.8). This is a substantial increase in the commonly cited figure that only 10 percent of aquaculture is using genetically improved or managed organisms. However, neither the Country Reports nor the data routinely reported to FAO allow analysis of how much production comes from wild types versus genetically improved types. Selective breeding has the longest history of use in aquaculture and was the most common form of genetic technology reported by countries (Figure 2.8). Selective breeding permits the accumulation of genetic gain in each generation. It is therefore a good long-term strategy for breed improvement and domestication.

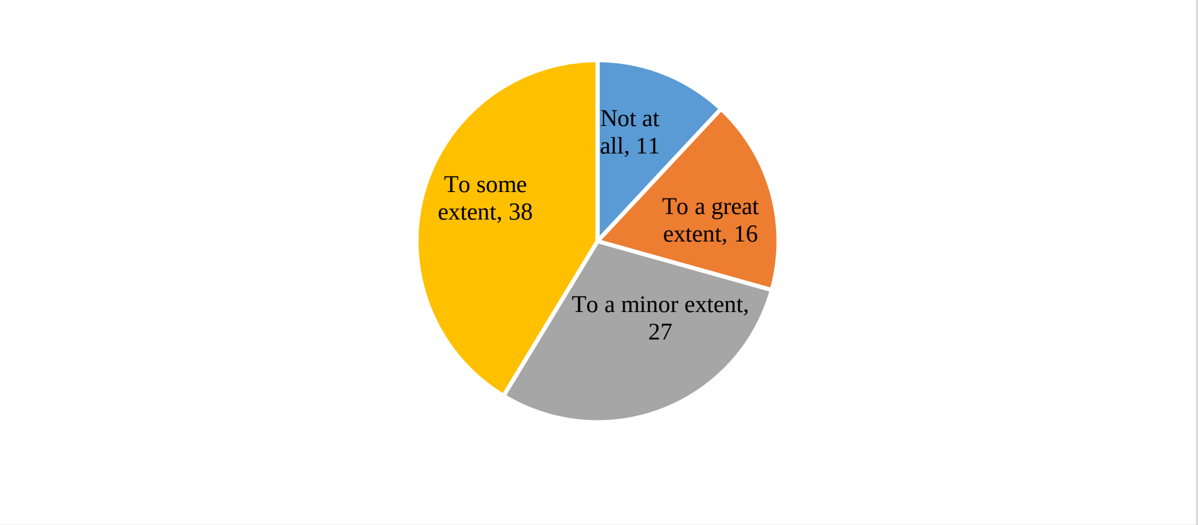
Selective breeding has proven to be very effective in enhancing traits of agricultural plants and animals through the use of genetics principles; selective breeding has also benefitted aquaculture species. For instance, the genetic gain has been greater than 12 percent per generation for growth rate and for disease resistance when challenge tests are applied (Gjedrem and Robinson, 2014). The main reasons for the large genetic gains observed for aquatic species are their relatively high fertility and high levels of genetic variation for economically important traits, both of which allows a very high selection intensity to be applied.

Figure 2.8. Genetic improvement used in aquaculture (number of responses)



In addition to farming wild types that may not be domesticated,[12] many aquaculture facilities depend on the organisms from the wild for a supply of seed, juveniles and broodstock in aquaculture or hatchery facilities. Overall, 89 percent of countries reported that aquaculture depended on aquatic organisms collected from the wild to some extent (Figure 2.9).

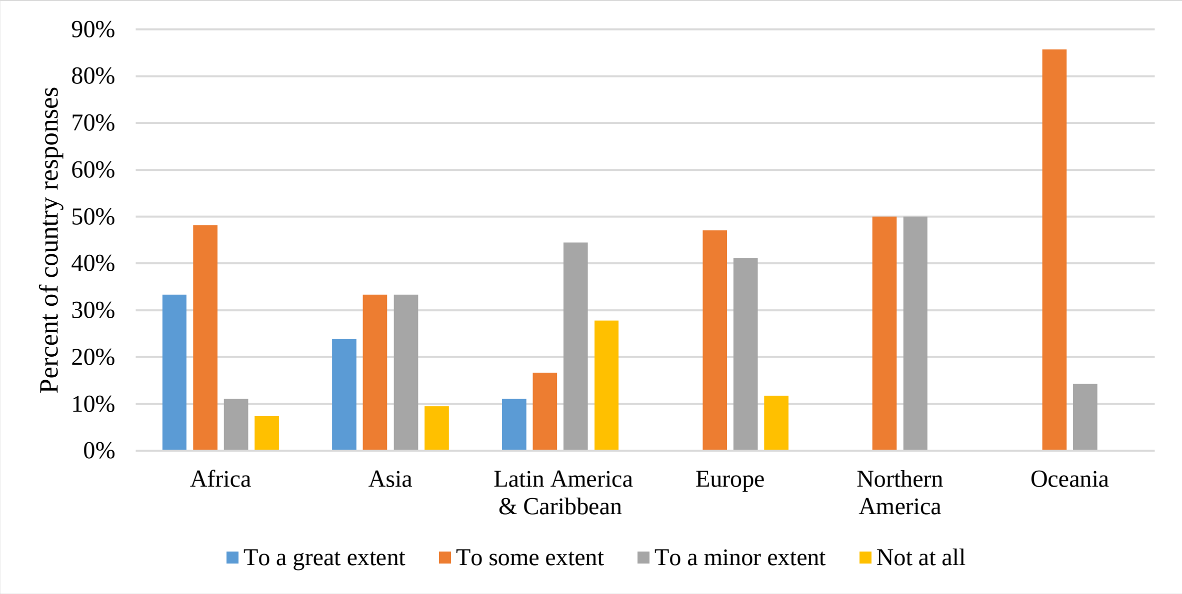
Figure 2.9. Extent to which aquatic organisms farmed in your country are derived from wild seed or wild broodstock (number of countries)



Analysis by region confirmed the importance of using AgGR derived from the wild (Figure 2.10). Analysis by economic and production level of countries did not reveal important differences in the extent that AqGR were derived from the wild (data not shown).

[12] Following Bilio (2008) three generations of mating under farm or hatchery conditions are required for an organism to be considered 'domesticated.'

Figure 2.10. Extent to which farmed aquatic organisms are derived from wild seed or wild broodstock



In spite of the reliance on wild types in aquaculture, almost 90 percent of the countries reported that genetically improved aquatic organisms contributed at least somewhat to national aquaculture production (Figure 2.11). Analyses by region and economic development revealed the same general result, i.e. that genetic resource management is occurring at some level in most cases. Analysis by major producer revealed that genetically improved organisms contributed to production more in the major producing countries, but contribution at least to some extent was reported in all countries (Figure 2.12)

Figure 2.11. Extent to which genetically improved aquatic organisms contribute to national aquaculture production

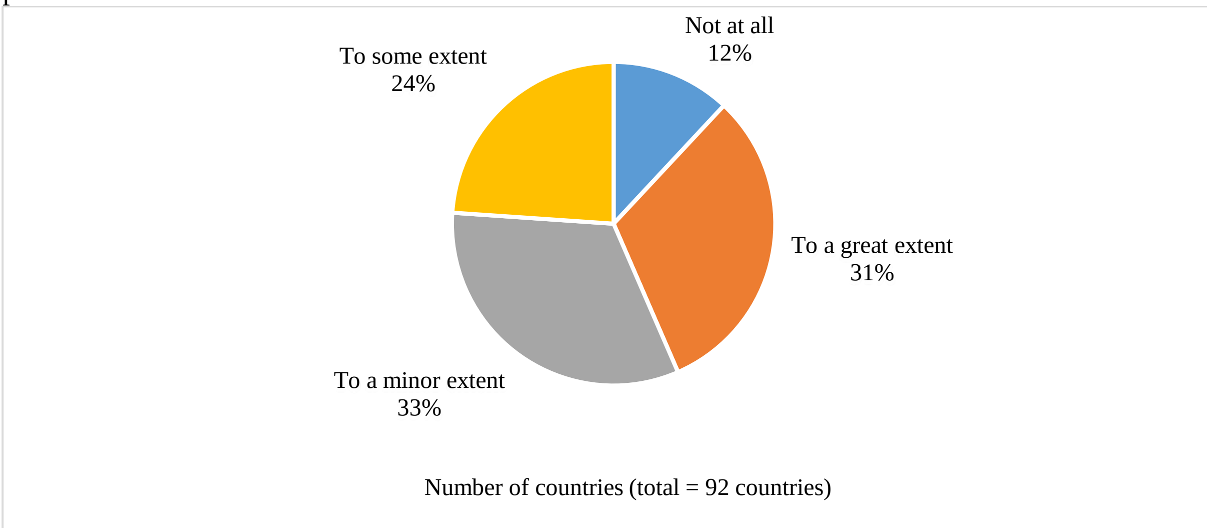


Figure 2.12a. Extent to which genetically improved aquatic organisms contribute to national aquaculture production by region

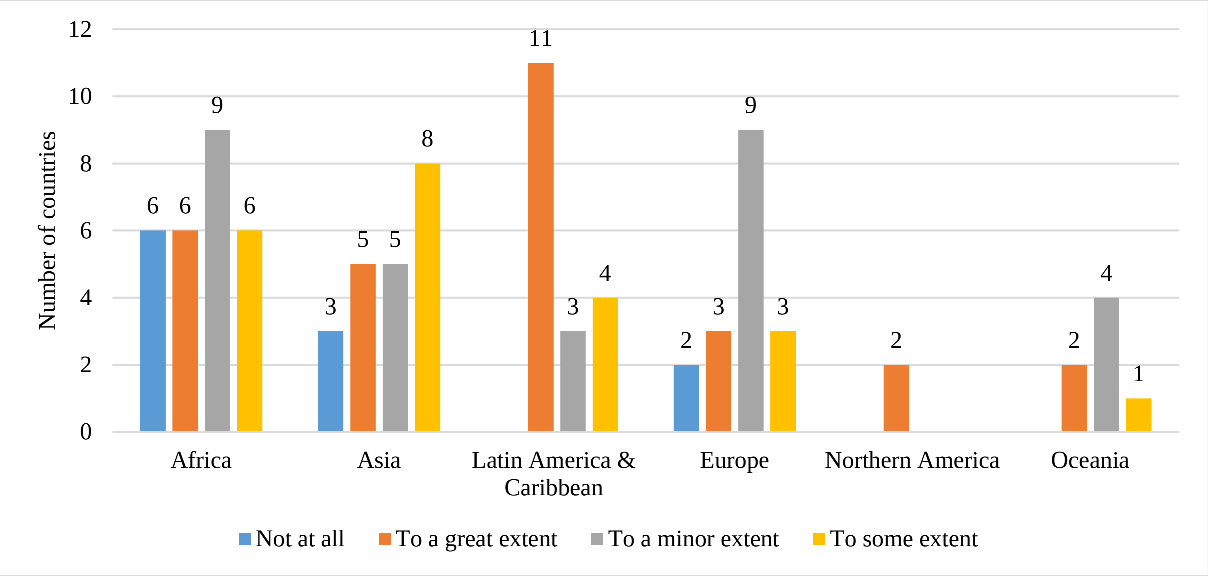


Figure 2.12b. Extent to which genetically improved aquatic organisms contribute to national aquaculture production by economic level

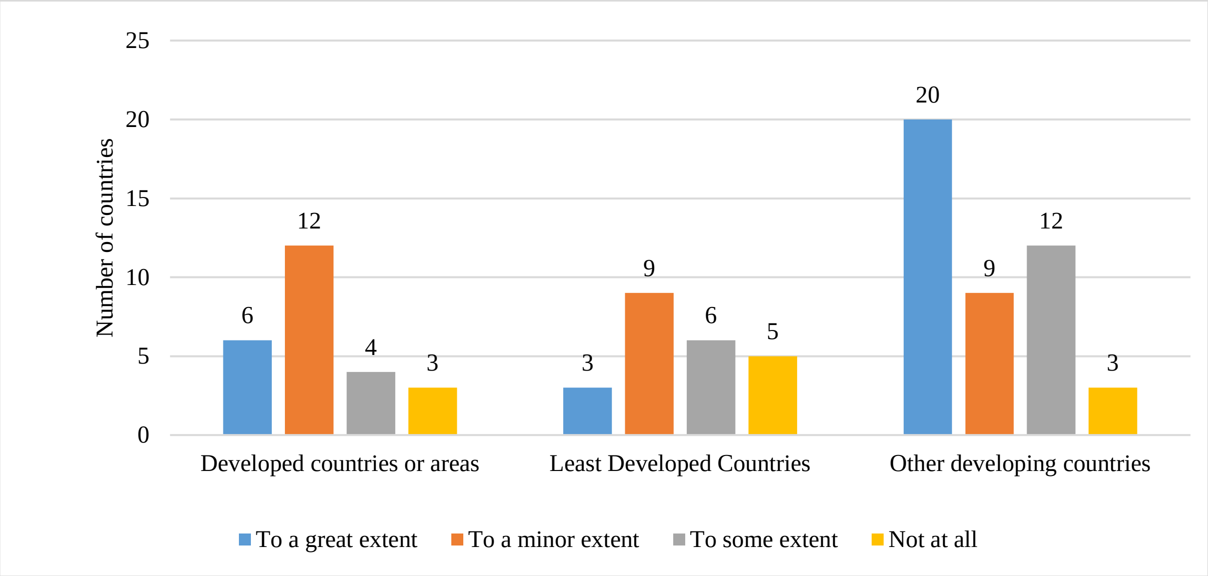
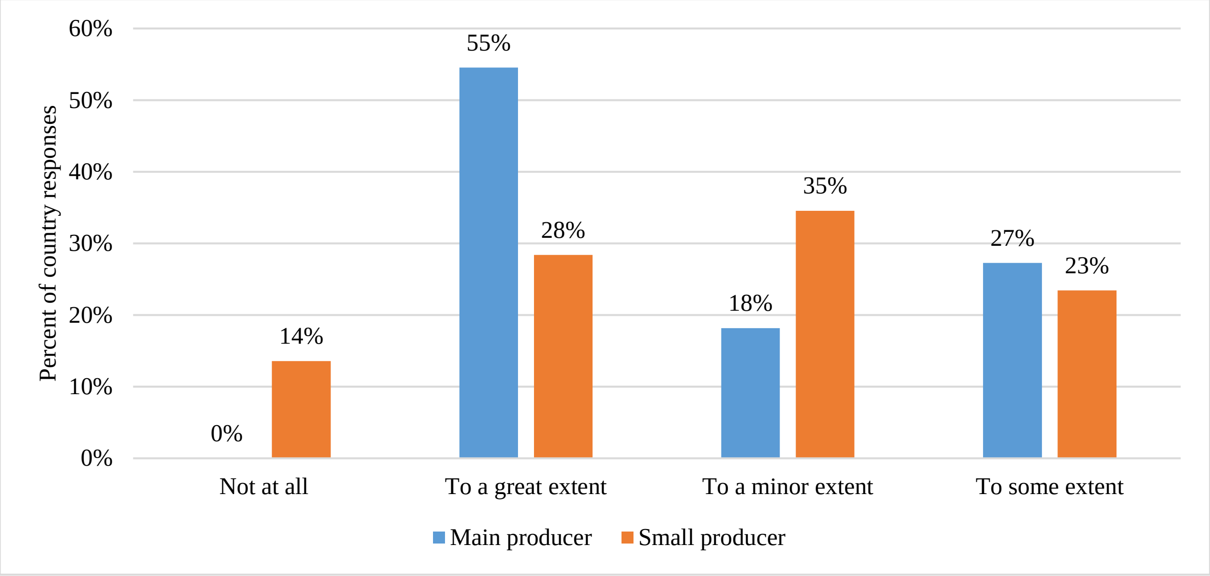


Figure 2.12c. Extent to which genetically improved aquatic organisms contribute to national aquaculture production by level of production



2.5.2.2 Extent of the use of genetics in aquaculture

The world's demand for seafood is expected to increase by about 2 percent per year over the next decades and genetic improvements from selective breeding produce increases of about 10 percent per generation. Aquaculture geneticists have stated that if all the farmed aquatic species were in traditional selective breeding programmes, aquaculture production could double by 2050 thus meeting the additional need for seafood with very little extra land, water, feed or other inputs (Gjedrem, 1997; Gjedrem, Robinson and Rye, 2012).

Clearly there are tremendous opportunities to increase food production through the use of genetic technologies. However, there are challenges.

Genetic data are more technically demanding and costly to collect (see above) and therefore may not often be available or used in management of farmed aquatic species. However, countries reported that in general genetic data were available and used in aquaculture (Figure 2.13). Analysis of the 'use' of genetic information revealed that only a few countries in Asia and Latin America used genetic information to a great extent (Figure 2.14a). Main producers used the information more than the minor producers (Figure 2.14b) and least developed countries used information on AqGR to a lesser degree than other countries (Figure 2.14c).

Figure 2.13. Availability and use of information on Aquatic Genetic Resources of farmed types Q4

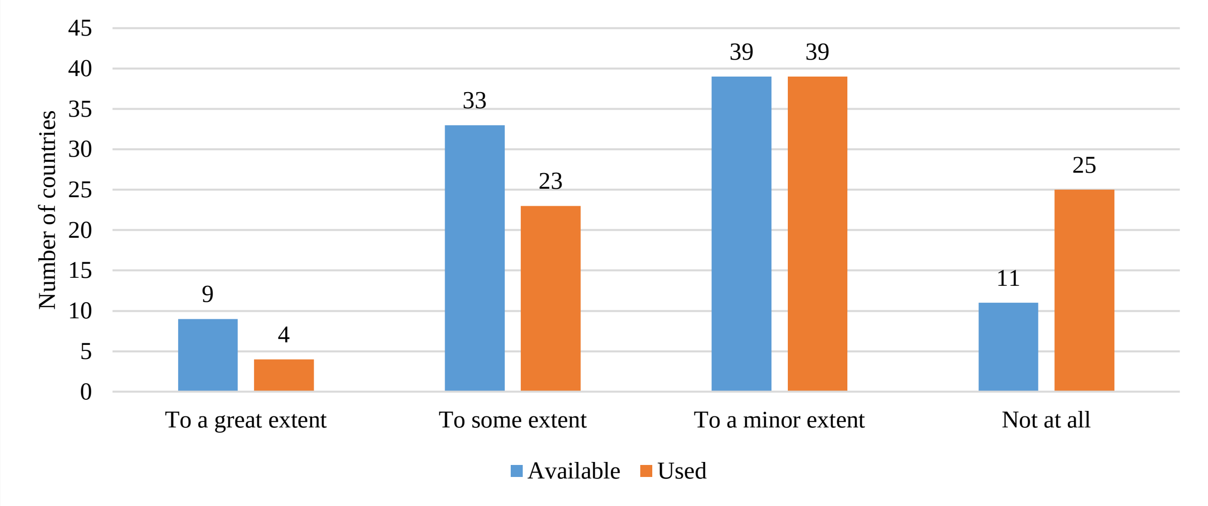


Figure 2.14a. Use of information on Aquatic Genetic Resources of farmed types by region

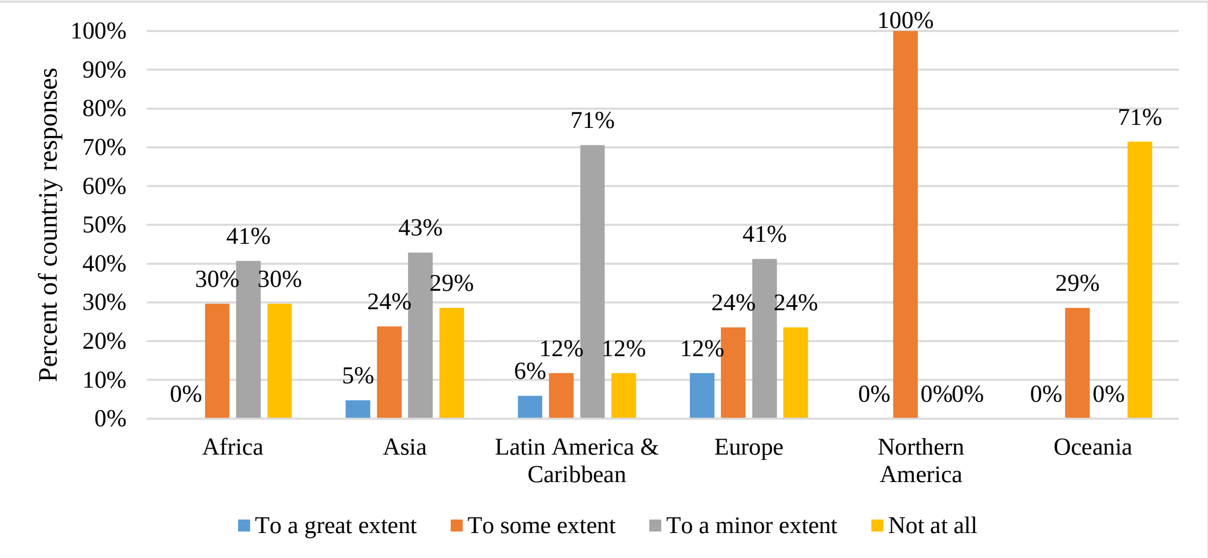


Figure 2.14b. Use of information on Aquatic Genetic Resources of farmed types by level of production

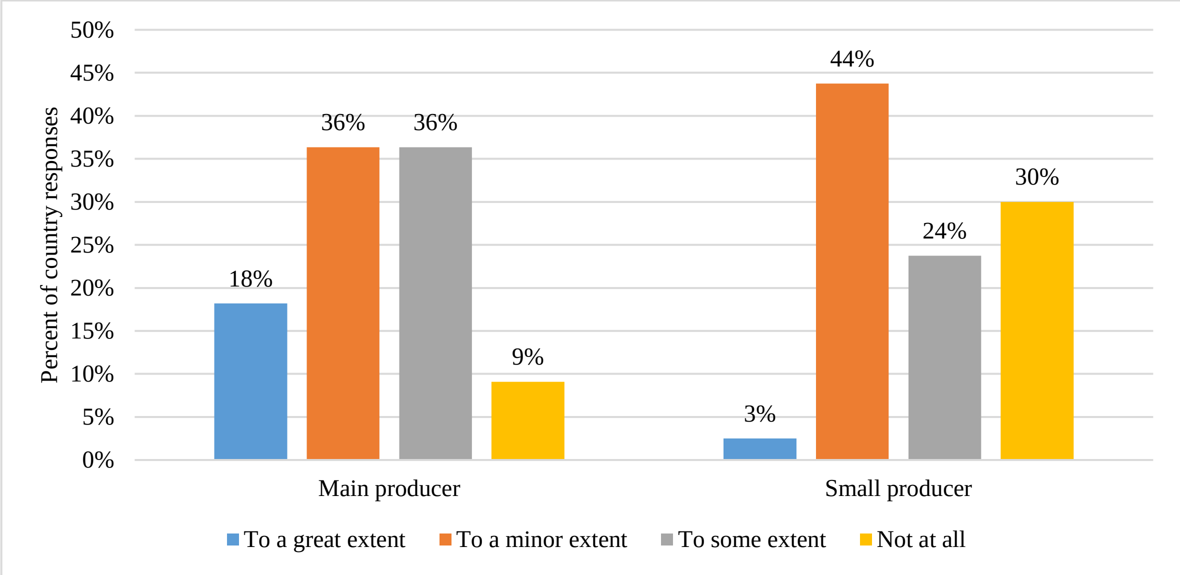
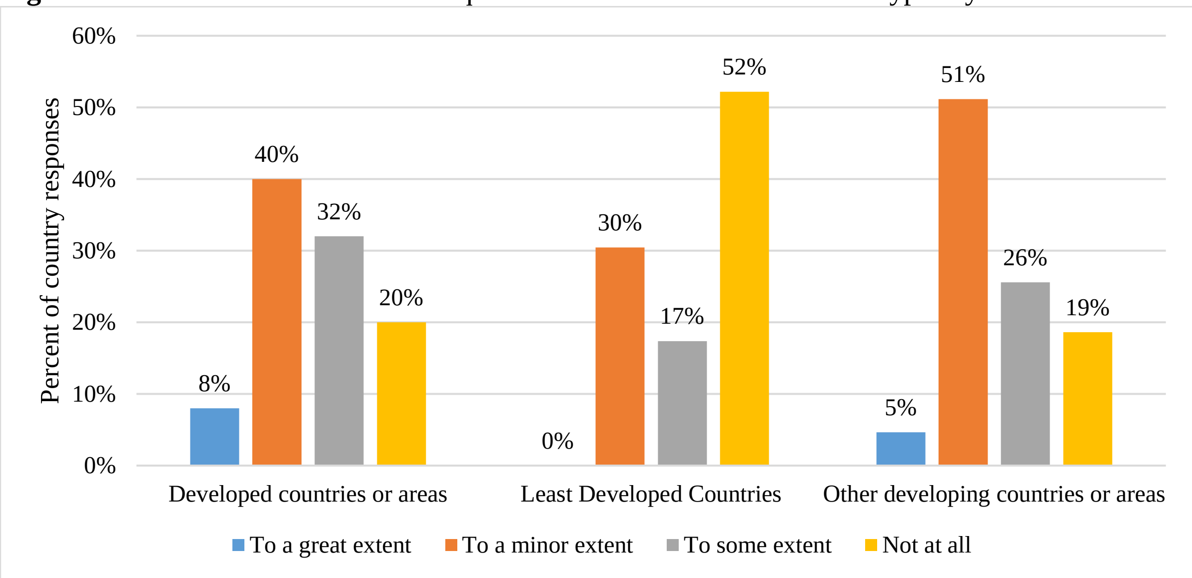


Figure 2.14c. Use of information on Aquatic Genetic Resources of farmed types by economic level



Although genetic resource management and breeding programmes provide increase production and profit, they are often difficult to fund and often require partnerships. WorldFish developed the Genetically Improved Farmed Tilapia (GIFT) in partnership with Asian Development Bank, the Philippines, United Nations Development Program (UNDP) and advanced scientific institutions (ADB, 2005; Ponzoni *et al.*, 2011). The impressive gains in farming Atlantic salmon in Norway were due in large to private public partnerships that also involved Scandinavian Airlines, a government research group (Akvaforsk) and other private companies.

The Country Reports revealed that the majority of breed improvement programmes in aquaculture dealt with selective breeding. For selective breeding, most of the programmes were funded by the public sector, but the private sector was the main funder of all of the other technologies (Figure 2.15a) although the differences between the numbers of responses for public and private funding were very slight. The fewest programmes were funded through public/private partnerships (PPP). Analysis by region indicated Asia reported the most public funded improvement programmes, both in relative and absolute terms (Figure 2.15b). Analysis by production level indicated that public support, i.e. finances, for genetic improvement programmes, was much more prevalent in the major production countries (Figure 22c). Given that 55 percent of the reported cases of genetic improvement were supported by the public sector

(Figure 2.15c) and the success of the GIFT programme (ADB, 2005) and the Norwegian Atlantic salmon programme, countries wanting to genetically improve AqGR could consider wider use of public funding and PPPs.

Figure 2.15a. Source of funding for genetic improvement programmes by improvement strategy

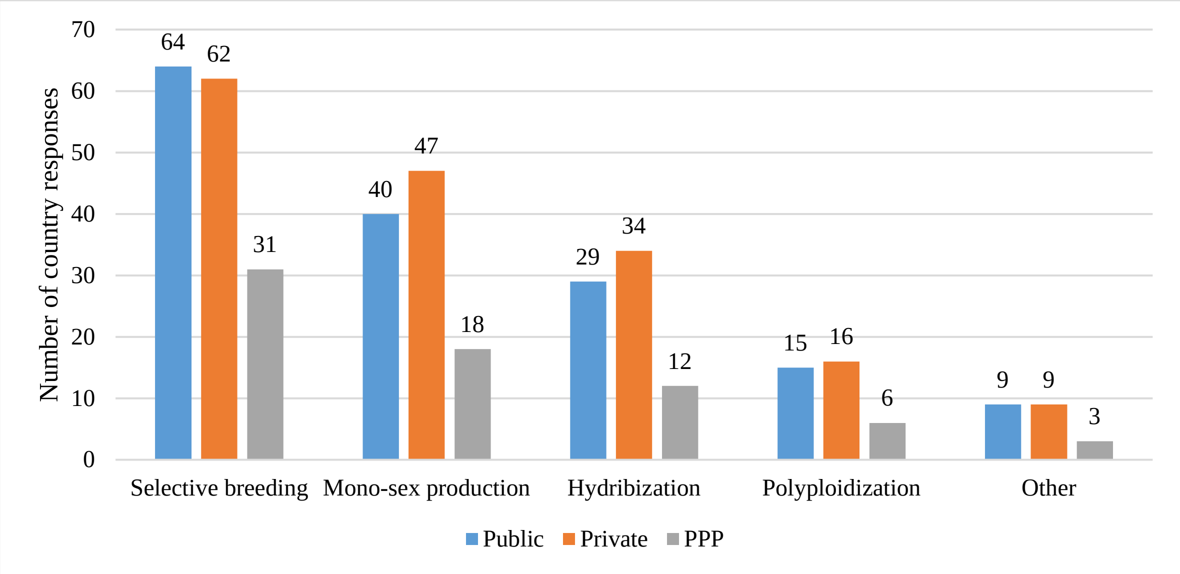


Figure 2.15b. Source of funding for genetic improvement programmes by region

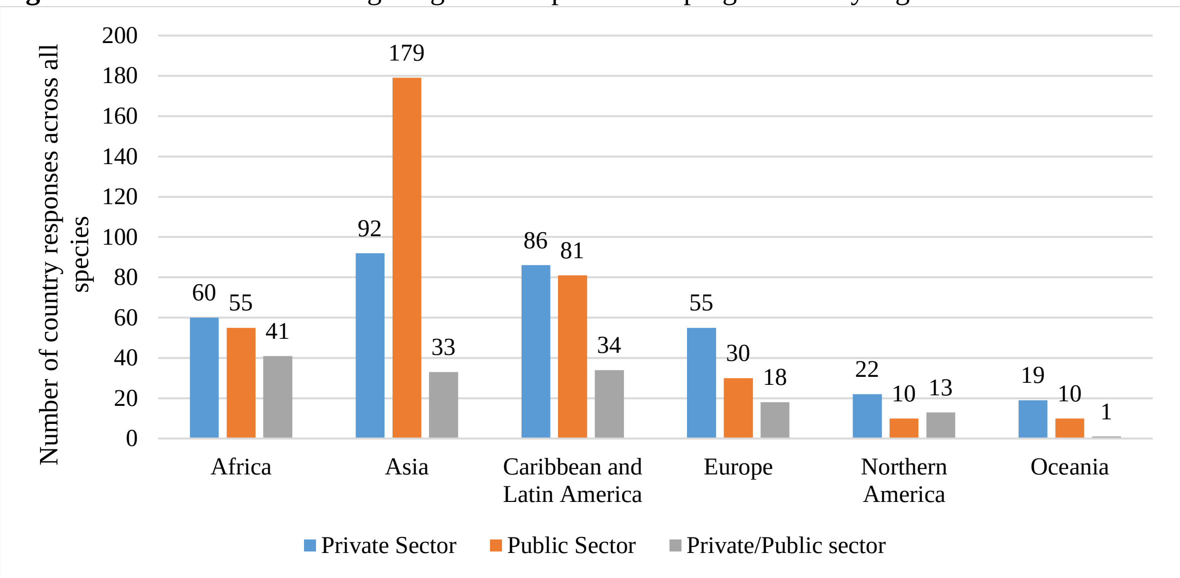
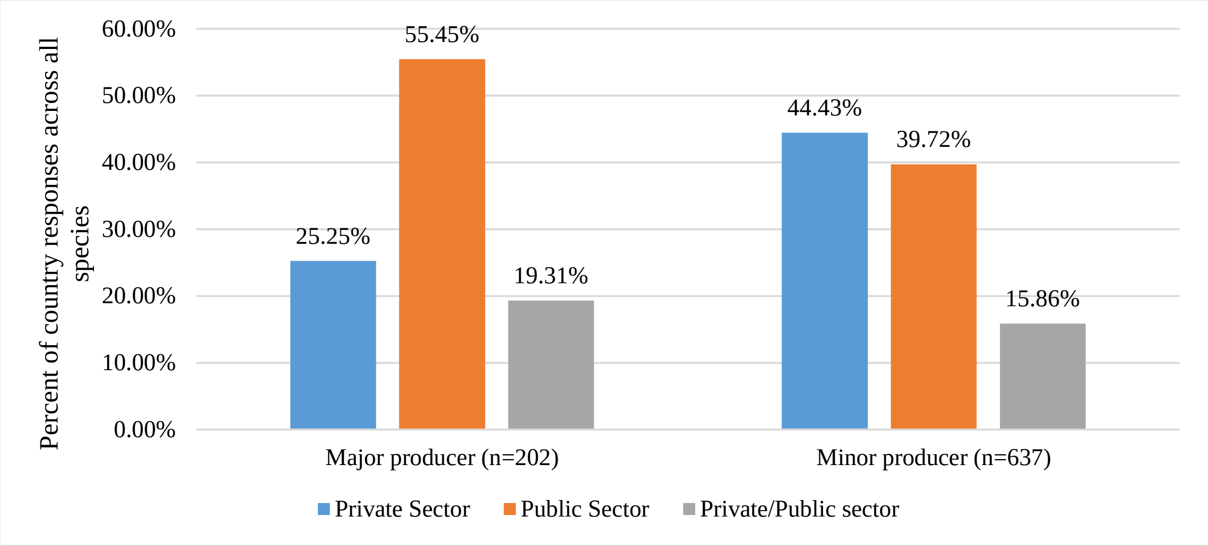


Figure 2.15c. Source of funding for genetic improvement programmes by level of production



2.5.2.3 *Biotechnologies for improved characterization of AqGR*[13]

Biotechnologies can be used to increase performance under farming conditions, but can also be important in characterizing AqGR in farmed types and wild relatives (Ruane and Sonnino, 2006). Improved characterization will facilitate monitoring and management of AqGR and will be necessary for incorporating genetic diversity into national reporting and monitoring programmes (See Section 2.4).

Genome technologies have been developed to study genome structure, organization, expression, and function, and to select and modify genomes of interest to increase benefits to humans. Of these genome technologies, DNA marker technologies have been intensely used to map the genome to understand genome structure and organization. These DNA marker technologies included:

- RFLP (restriction fragment length polymorphism) markers,
- mitochondrial DNA markers,
- DNA Barcoding,
- RAPD markers,
- AFLP markers,
- microsatellite markers,
- SNP markers, and
- RAD-seq markers (SNP markers per se).

Although these marker systems were used at various levels for various purposes, the microsatellite markers and SNP markers are currently the most important to characterize and monitor AqGR.

Various genome mapping technologies were developed including both genetic mapping and physical mapping methods. Genetic mapping is based on recombination during meiosis, while physical mapping is based on fingerprints of DNA segments. Although several variations of physical mapping methods are available such as radiation hybrid mapping and optical mapping, the most popular physical mapping method is the BAC-based fingerprinting.

The next generation sequencing technologies are especially powerful. The second and third generation sequencing technologies literally revolutionized the way science is conducted. These technologies now allow sequencing of the whole genome de novo, or mass sequencing of genomes of populations.

[13] *Cfr*. footnote 11. Fermentation and bioremediation are excluded except when genetic alteration of the microorganisms has occurred. Selective breeding is also excluded as a biotechnology because it is covered elsewhere.

Extension of their application allows characterization of the transcriptomes, and the non-coding portions of the genome and their functions.

Technologies for improved characterization of aquatic species are listed below in approximate time and sensitivity order, i.e. the earliest and least sensitive technologies are listed first.

- DNA Marker Technologies: genetic markers assist in the identification of useful stocks, strains, genes and even individuals. The markers differ in their sensitivity, i.e. some may only work at the species level while others can distinguish individual pedigrees.
    - Allozyme markers: Identification of species, strains and stocks based on protein analysis;
    - Restriction fragment length polymorphism (RFLP) markers: Analysis of genetic variation based on DNA fragment length differences after digesting genomic DNA with one or more restriction enzymes;
    - Mitochondrial DNA markers: Studies of genetic divergence within and among populations;
    - DNA Barcoding: Standard for species identification, especially in international trade and seafood labelling;
    - Random amplification of polymorphic DNA (RAPD): PCR-based multi-locus DNA fingerprinting technique for species identification, hybrid identification, strain differentiation, and to a much lesser extent, genetic analysis such as mapping;
    - RAD-sequencing (RAD-Seq) markers: Identification of genetic variants, phylogenetic analysis, germplasm assessment, analysis of population structure, linkage and Quantitative Trait Loci (QTL) mapping, and whole genome-based selection;
    - Micro-satellite markers: Microsatellites are simple sequence repeats (SSRs) of 1–6 base pairs. They are highly abundant in various eukaryotic genomes including all aquaculture species studied to date; and
    - Single Nucleotide Polymorphisms (SNPs): base substitutions along the DNA chain that reveal abundant genetic variations at the individual and population levels to be used for pedigree analysis, stock/strain identification, high-density linkage mapping, fine QTL mapping, and whole genome-based selection.
- Genome mapping technologies: The genomes of farmed fish vary from several hundreds of millions of base pairs to several billion base pairs. It is very difficult to study such large genomes without first breaking them to smaller pieces, and then sort out their relationships, which is the task of genome mapping. Genetic maps assist in knowing the location of sequences, markers or genes on the chromosome and how they may be inherited or manipulated.
    - Genetic linkage mapping: Identification of the position of known genes or genetic markers relative to each other in terms of recombination frequency;
    - Physical mapping: Identification of the position of known genes or genetic markers relative to each other in terms of physical distance on the chromosome;
    - Radiation hybrid mapping: Production of high resolution maps of DNA markers on all chromosomes;
    - Optical mapping: Construction of high-resolution restriction maps of a whole genome;
    - QTL mapping: Allows for locating genes underlining performance and production traits important for aquaculture.
- Genome sequencing technologies: Allows for the complete description of the molecular structure of DNA. Genomes of at least two dozen aquaculture species have been sequenced, or are now being sequenced including inter alia, tilapia, rainbow trout, Atlantic salmon, catfish, striped bass, and oysters, and shrimps.
    - First and Second-generation DNA sequencers: Identification of the precise base pairs along the strands of DNA and genes of potential interest for example in marker development for the identification of microsatellites or SNP markers, and for the identification of differentially expressed genes or co-induced genes; and
    - Third generation DNA sequencers: Identification of single molecule sequences (SMS).
- Transcriptome analysis: Gene expression analysis for identifying differentially expressed genes under different environmental conditions and gene expression regulation, shedding light on gene

functions. The complete sequence or composition of RNAs of an organism for genome level expression profiling, identification of differentially expressed genes or co-induced genes.

  - Expressed sequence tags (EST): ESTs can be generated for aquaculture species for the rapid identification of which genes are being expressed genes and under what conditions.

- RNA-Seq technologies is the analysis of gene expression profiling and identification of differentially expressed genes and gene-associated markers.

2.5.2.4 Biotechnologies for improved performance in aquaculture

There are numerous genetic biotechnologies for improving performance in aquaculture and for addressing consumer preferences in the market place (Figure 2.8; Table 2.7; Box 2.5).

Box 2.5
Biotechnologies in aquaculture[14]

A brief summary of the most important genetic biotechnologies for improved performance in aquaculture follows in hopes of promoting wider awareness and acceptance. Specific technologies in addition to selective breeding for improved performance include:

- **Polyploidy:** Polyploidy is lethal in mammals and birds, but has led to the development of many productive plant varieties such as domesticated wheat. Triploid fish are viable and are usually sterile, while tetraploid fish are usually viable and fertile. The performance of triploid fish varies. Triploidy can affect growth, feed conversion efficiency, disease resistance, and other traits. For growth, triploid fish can grow faster, the similar rate, or slower. However, even for those that grow faster, this advantage is not obvious until sexual maturity. It is apparent that the savings from sterile fish without spending energy on sexual development are converted into faster growth.
- **Gynogenesis:** Gynogenesis is a form of all-female inheritance. In fish species, ultraviolet (UV) irradiation has been used to inactivate the sperms, and such UV-inactivated sperms are used to trigger gynogenetic development without contributing the paternal genome to the progeny. One of the practical goals of gynogenesis is the production of clonal lines. Clonal lines have been produced with aquaculture species such as ayu (*Plecoglossus altivelis)*, amago salmon (*Oncorhynchus masou*) and hirame (*Paralichthys olivaceus*) their large scale aquaculture has not been realistic. The major purpose of gynogen production has been for research.
- **Androgenesis:** Androgenesis refers to all-paternal inheritance. Androgens can be produced by irradiating eggs and then doubling the paternal genome. Androgens are more difficult to produce than gynogens presumably because the extremely low survival rate of irradiated eggs. Like gynogenesis, it can be used to produce clonal populations or monosex populations for the purpose of breeding programs or to elucidate sex-determining mechanisms. Production of YY fish (all male) through androgenesis, followed by regular mating with a normal XX female fish, is a major way of producing all male populations in fish.
- **Sex reversal:** Sexual dimorphism for growth is very common with fish species. In some cases, males grow faster, while in other cases females grow faster. Monosex populations can be created by hormonal treatment. Although genotypic sex is established at the time of fertilization; the phenotypic sex can be altered by administration of estrogens or androgens during the critical period of sex determination. For instance, 17-methyltestosterone is widely used for sex reversal in fish. Several estrogenic compounds have been used to produce monosex female populations, of which 3-estradiol is the most commonly used hormone for feminization Females of soles, eels and many other species grow much faster than the males. In contrast, males grow much faster for tilapia, catfish among many other species. In addition to growth rate, sex also affects body shape, coloration and carcass composition.

[14] *Cfr.* footnote 11.

- **Gene transfer**: Gene transfer is a process to transfer one or a few foreign gene(s) into an organism. However, the foreign gene can be from other organisms or from the organism itself. A number of techniques have been developed for transferring genes of interest into fish including microinjection and electroporation. However, transgenic technologies suffer from several major lines of shortcomings: 1) The doses of gene transfer cannot be controlled; 2) the integration sites are random and such sites can be within a functional gene; and 3) the pleiotropic effect of genes cannot be controlled. Significantly enhanced growth rates and other characters were observed in goldfish, channel catfish, northern pikes, Atlantic salmon, rainbow trout, tilapia, carp, among many other species. In addition to enhancing performance traits of aquaculture species, fish have been considered for the production of pharmaceuticals as biological factories. To date, there is one transgenic fish being farmed commercially.[15]
- **Marker-assisted selection** (MAS) is a process whereby a selection decision is made based on the genotypes of DNA markers. MAS is especially useful for traits that are difficult or lethal to measure, exhibit low heritability, and/or are expressed late in development. MAS requires information of DNA markers that are tightly linked to QTL for traits of interest based on QTL mapping or association studies. For example, in the Japanese flounder a microsatellite locus, was near the major QTL for resistance to lymphocystis disease and another marker was near an IPN resistance gene in salmon; in both cases resistant populations were created that were favourably received in the market. Although MAS is theoretically very sound and attractive, little is known about the economic benefits gained from MAS in aquaculture species, with exception of the above cases where the phenotypes were controlled by a single gene, rather than by many genes.
- **Sex-linked markers** have been mapped for common carp, tilapia, catfish, Zhikong scallops, half-smooth tongue sole, white shrimps, kuruma prawns, and rainbow trout. These markers can help identify the desired sex for breeding or for grow-out to take advantage of sexual dimorphism. Sex-linked markers have been useful for the identification of sex without phenotypic data.
- **Genome 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 MAS. Although genomic selection has been successfully used in dairy cow and beef cattle and other livestock species, its use in aquaculture species has been slow.
- **Genome editing technologies** refers to the ability to make specific changes at targeted genomic sites. Zinc finger nuclease (ZFN), TALEN or CRISPR technologies allow introduction or disabling of any gene without much difficulty in any fish or shellfish species. The altered genome is able to pass on the genetic material to future generations. While it is clear that the genome editing technologies are different from gene transfer technologies, it is widely believed that government agencies should be regulating any commercial products generated using gene editing technologies. The techniques offer promise, with TALEN and CRISPR being used more than ZFN, for example in experimental studies on Atlantic salmon, carp, marine shrimp, tilapia and zebrafish.
    - Clustered regulatory interspaced short palindromic repeats (CRISPR/Cas); bacterial DNA that cuts DNA to help with immunity against invading viruses or plasmids. Cas9 is an enzyme that cuts DNA and CRISPR is a collection of DNA sequences that tells Cas9 where to cut.
    - Transcription activator-like effector nucleases (TALEN) are restriction enzymes that can be engineered to cut specific sequences of DNA. The restriction enzymes, when being introduced into cells, can be used for gene editing or genome editing.

An advantage of genetic biotechnologies is that they may be used in combination to increase their effectiveness in aquaculture. For example, sterilization by triploidization has been proposed for using with selective breeding and gene transfer to reduce the chance of escaped fish breeding.

Genetic biotechnology is also often referred to as genomics when it involves the study of gene

[15] www.theguardian.com/world/2017/aug/09/genetically-modified-salmon-sales-canada-aqua-bounty

identification and gene action. The fundamental goal of aquaculture genomics in the practical sense is to understand the genomic basis for performance and production traits. Because most aquaculture traits are complex traits that are likely controlled by multiple genes, QTL mapping is the core of applied aquaculture genomics. By coupling genome-mapping technologies with aquaculture trait evaluations, QTL mapping allows the identification of genes underlining the performance and production traits. Following mapping of QTLs, marker-assisted selection or genome selection can be conducted. Genomes can be edited or modified almost any way now as designed by scientists. Therefore, technologies are ready to make large contributions for improving aquaculture traits.

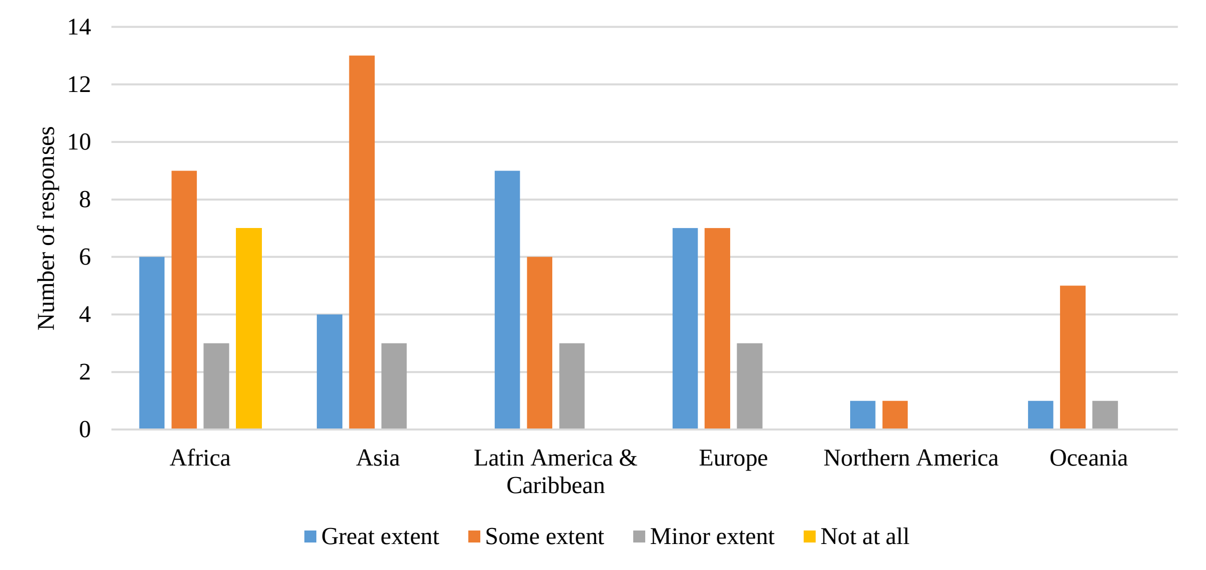
There are a number of challenges to the wider adoption of genetic biotechnologies in aquaculture including bioinformatics, i.e. how to collect and manage genetic information, lack of resources in some parts of the world, difficulties in working with individual farmers, and ethical and legislative challenges that must be overcome in order to have broad applications of genome technologies. In spite of the challenges a range of biotechnologies was used to improve AqGR according to Country Reports (Table 2.8 and Figure 2.16). An overall index of use for some selected genetic technologies was developed by assigning score to each 'extent of use' and then multiplying by the percentage and summing for each biotechnology (Table 2.8).

Table 2.8. Extent of use of selected biotechnologies (number of responses)

Extent of use	Selective breeding	Hybridization	Polyploidization	Monosex production	Marker assisted selection	Gynogenesis/ androgenesis
To a great extent	30	5		22	1	
To some extent	41	22	4	20	7	1
To a minor extent	13	27	26	23	19	18
Not at all	7	35	58	26	62	70
Index of use	3.0	1.9	1.3	2.4	1.4	1.2

Selective breeding was the most widely used biotechnology with 84 countries reporting its use to at least some extent (Table 2.8). The trend was evident when countries were analyzed by region, although the application of selective breeding was uneven within regions (Figure 2.16). The index of use indicated that after selective breeding, production of mono-sex animals and polyploidization was the most commonly used biotechnologies (Table 2.8). The more complex technical techniques of marker assisted selection and gynogenesis/androgenesis were not widely used in 62 and 70 of the total number of countries surveyed respectively, reporting they were not used at all.

Figure 2.16. Use of selective breeding by region



2.5.3 Wild relatives

Wild relatives of farmed species are defined here to be the same species living in the wild as the species being farmed, i.e. they are conspecifics (see Box 2.6). There are other species living in the wild that are closely related to farmed species, e.g. the same genus or family, and some of these have been identified as having aquaculture potential above or are important in capture fisheries. Wild relatives, in addition to having farming potential, are important components of many aquatic ecosystems and capture fisheries, and perform beneficial ecosystem services.

Box 2.6

Wild Relatives and interpretations of the term

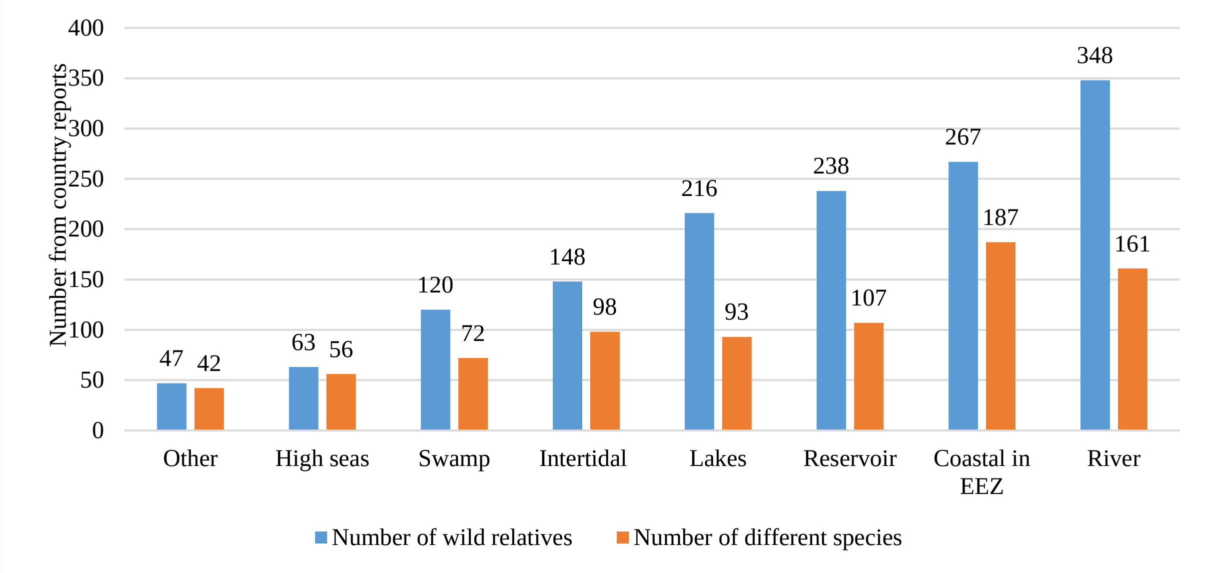
Wild relatives of farmed species are defined for this report as a species that occurs in the wild within a country, that is a con-specific of a species that is cultured anywhere in the world, including within the country itself. It is not intended to include closely related species, only con-specifics. Given that FAO's database on aquaculture production statistics, FishstatJ, reports 591 species cultured worldwide, there is a very large pool of cultured species from which wild relatives should be reported. Such a broad definition is applied to assist in building a picture of the genetic resources of cultured species that occur in the wild, irrespective of where they are cultured.

There are three questions in the Country Report that refer directly to wild relatives. Q12 requests a list of wild relatives for cultured species excluding those cultured in the country, Q13 concerns transfer and exchange of wild relatives and Q14 requested countries to complete a table of all wild relatives in the country with details on their management and utilization.

The Questionnaire did not clearly and fully define wild relatives and it is apparent that there was some ambiguity in the definition and thus some variation in the way in which countries have interpreted the term. It is further apparent that the numbers of wild relatives have been under –reported in the majority of Country Reports. For question 12, a third of reporting countries did not attempt to list wild relatives that are not cultured in their country. For Q14 nearly 90 percent of countries did report species but again numbers were low (averaging only 8.1) and nearly 40 percent of countries reported only wild relatives of species cultured within their country.

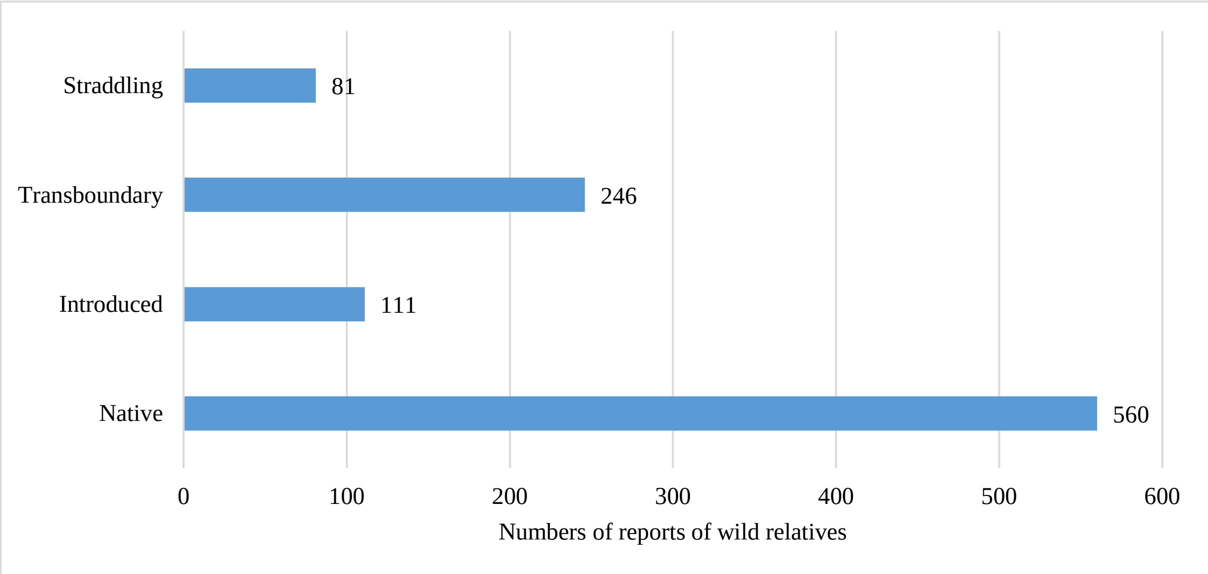
Thus we have clearly identified an issue with the reporting of wild relatives and this has been taken into account in this report in the interpretation of the data relating to questions 12–14.

Figure 2.17. Habitats of wild relatives of farmed aquatic species within national jurisdiction (number of responses for all species)



Wild relatives are found throughout aquatic ecosystems (Figures 2.17 and 2.18). River and coastal habitats were where most wild relatives were reported and where the highest diversity of taxa were found (Figure 2.17). For example there were 187 different species of wild relatives reported as living in coastal water and the EEZ The majority of wild relatives reported were native; countries reported 560 cases where the wild relatives were native. Several wild relatives were reported to be transboundary and straddling stocks; a wild relative could be native and straddling or transboundary (Figure 2.18).

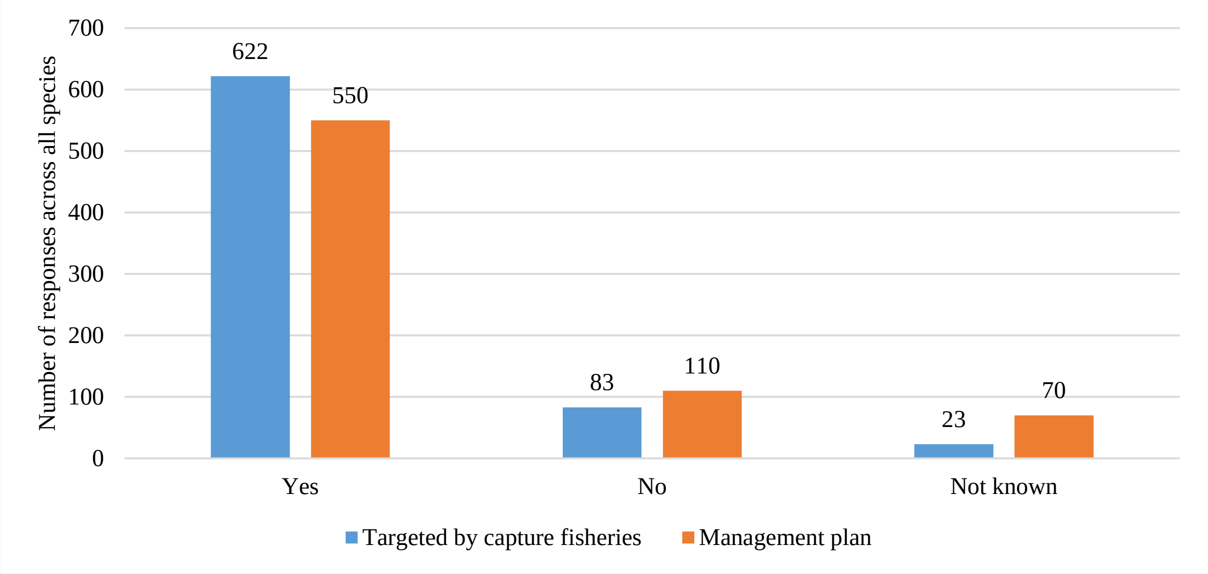
Figure 2.18. Geographic description of wild relatives of farmed aquatic species q14 col 1



2.5.3.1 *Use of wild relatives in fisheries*

The vast majority of the reports on wild relatives (622 out of 705) indicated that wild relatives contribute to capture fishery production and have fishery management plans (Figure 2.19). Many of the wild relatives not fished were species introduced for aquaculture purposes or fishes for which capture fisheries were highly regulated, e.g. sturgeons, due to their listing on CITES appendices. It is encouraging that so many fishery management plans exist, but populations of many wild relatives are declining (see below) which calls into question the efficacy of the management plans.

Figure 2.19. Occurrence of wild relatives in capture fisheries and whether a fishery management exists



2.5.3.2 Trends in abundance of wild relatives

Figures 2.9 and 2.10 reveal how dependent aquaculture still is on aquatic species found in natural ecosystems. However, countries reported numerous cases where the abundance of wild relatives was currently decreasing and is expected to decrease further in the future (Figure 20). The top five species reported with decreasing catch trends were *O. niloticus, Anguilla anquilla, Cyprinus carpio, Machrobrachium rosenbergii* and *Salmo trutta;* the wild relatives most often reported as being depleted in a country were *Acipenser gueldenstaedtii*, *Hucho hucho*, *Huso huso*, *Salmo salar* and *Salmo trutta*. For the depleted species, the sturgeons are very prominent along with large salmonids. There were reports of increasing catch trends and the top five species with an increasing catch trend were *Oreochromis niloticus*, *Clarias gariepinus*, *Mytilus galloprovincialis*, *Chanos chanos* and *Crassostrea gigas*. Interestingly, *O. niloticus* populations are seen as both increasing in some areas and decreasing in others.

Figure 2.20. Current and expected catch trends in wild relatives

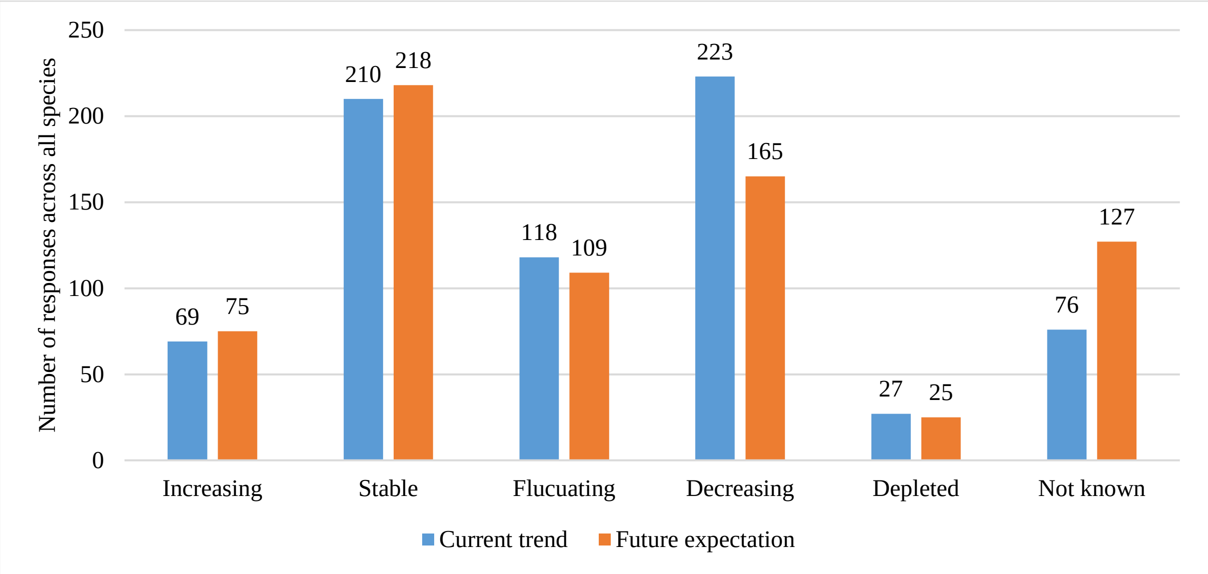
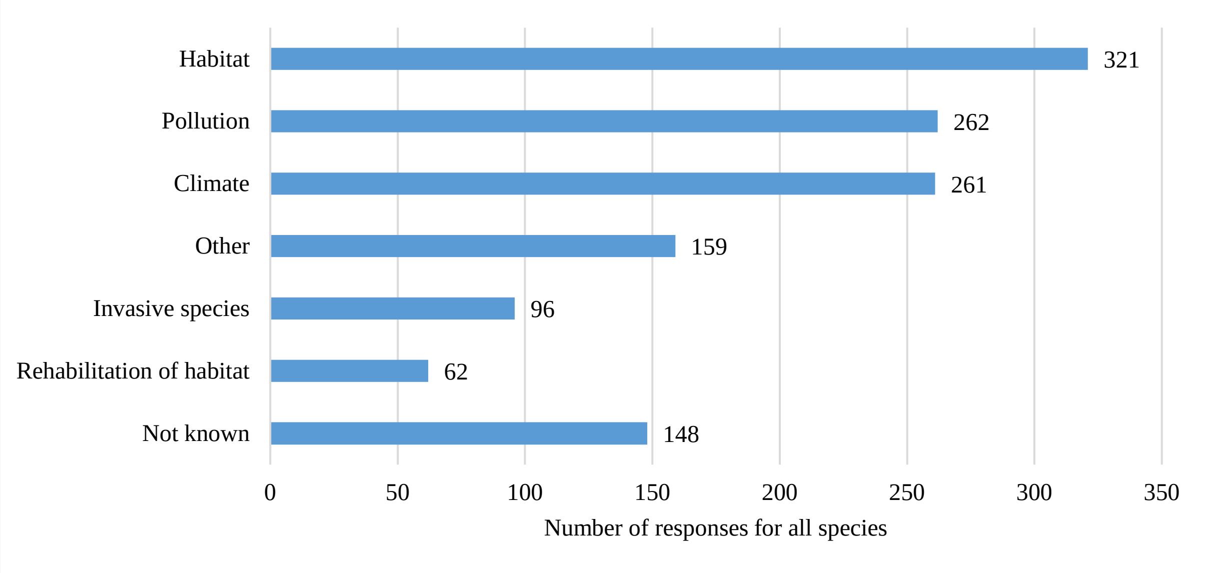


Figure 2.21. Reasons for change in abundance of wild relatives



Countries reported that the habitat for most wild relatives of farmed aquatic species was decreasing (Figure 2.22), and in only a few cases was habitat reported as increasing. Analysis by region indicated that a higher percentage of reports citing habitat as a determinant of change in numbers of wild relatives came from Asia (Figure 2.23a) and from Least Developed Countries (Figure 2.23b). These findings reinforce the need to protect natural populations of AqGR and suggests that protecting habitat would be a good strategy.

Figure 2.22. Trends in changes of habitat of wild relatives

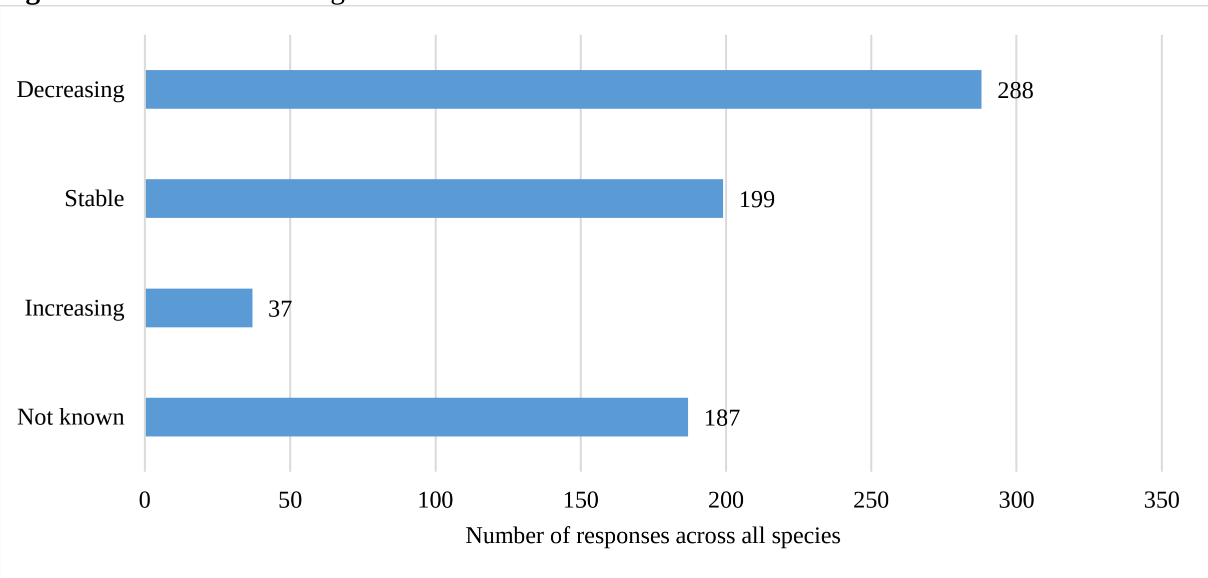
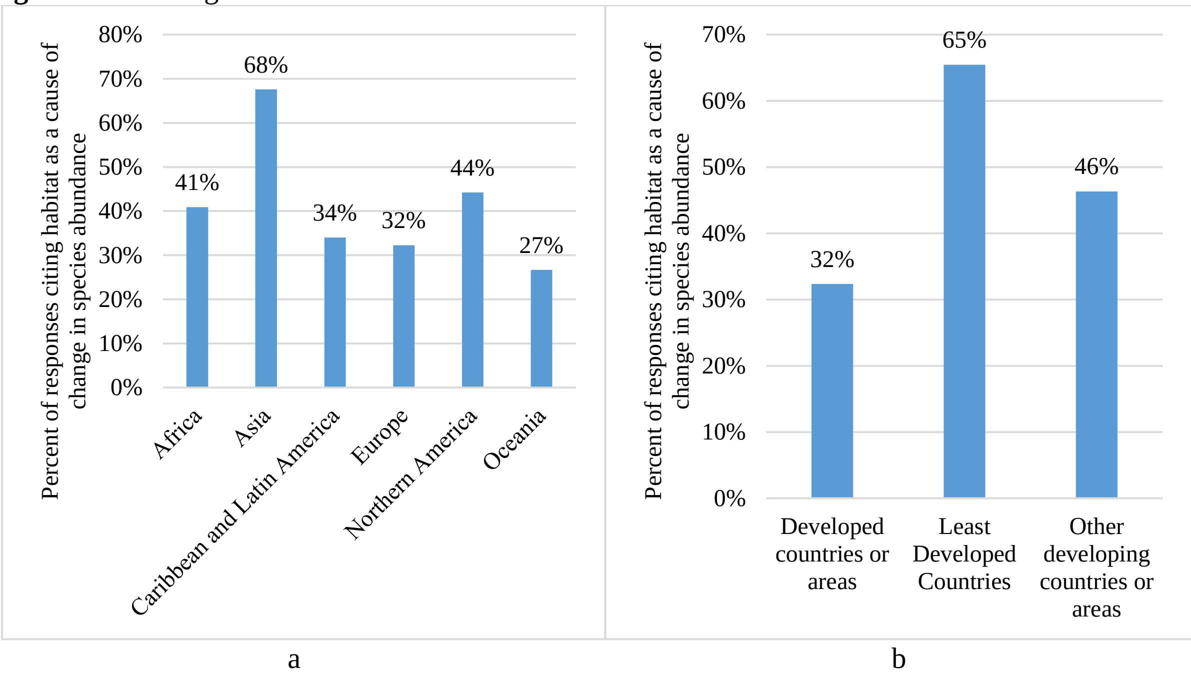


Figure 2.23. Changes in abundance of wild relatives due to habitat



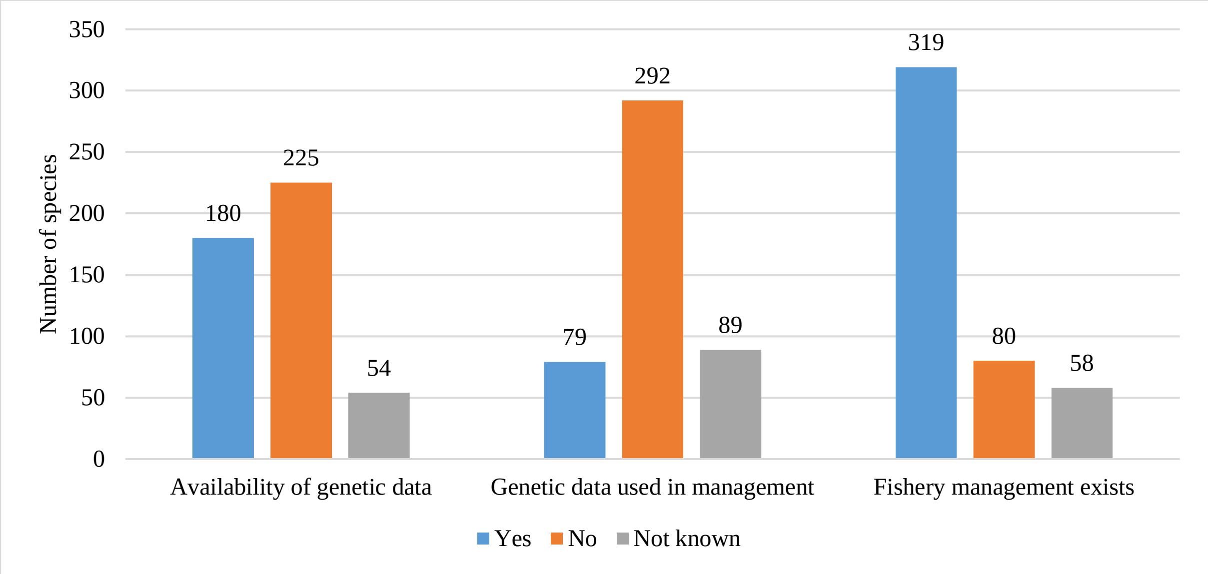
About one third of the responses from developed countries cited habitat a cause of change in numbers of wild relatives (Figure 2.23b). Comparisons of the importance of habitat loss by economic classification of countries can be misleading. In many developed countries the aquatic habitat for wild relatives was lost or degraded centuries ago because of economic development and the human communities became accustomed to this lack of fishery resources and lack of alternative food sources.

This phenomena is called the 'shifting baseline' (Pauly, 1995) and is used to explain peoples' short-term perspective on managing natural resources, i.e. people forget how things were in the past because they accept and have become familiar with the current situation.

The Country Reports did not indicate that fishing pressure was a major cause for the change in abundance of wild relatives of farmed species. For many inland capture fisheries factors outside of the fishing sector, e.g. draining wetlands and damming of rivers, have a much larger impact (SOFIA, 2014).

For many coastal areas a similar condition could occur where loss of coastal spawning or nursery habitat or land-based pollution could impact fisheries more than fishing pressure, especially in small-scale fisheries. Nonetheless for many wild relatives that are fished, fishery management plans exist. However genetic data are used to only a limited extent for most species (Figure 2.24).

Figure 2.24. Fishery management of wild relatives and the use of genetic information Q14



Examples do exist where genetic data are used in management of high value species or iconic species, such as Atlantic cod, Pacific salmon and Atlantic salmon (Ruane and Sonnino, 2006). For example genetic stock identification (GSI) helps set season, area and catch limits on commercially important species in North America and Europe based on the genetic profile of the fishery (Beacham *et al*., 2006).

However, GSI depends on an accurate genetic analysis of the potential stocks contributing to a fishery, as well as real time sampling and analysis of the fishery. As such, fishery management based on GSI may be beyond the financial and technical capacity of many government resource agencies.

2.5.3.3 Conservation of wild relatives

In light of the reports that many populations of wild relatives are decreasing information on the conservation status will be important to identify future actions for conservation. A decreasing fishery combined with decreasing habitat could provide a proxy indicator for level of endangerment for wild relatives. The level of endangerment would be even higher if the species had a restricted distribution or was limited to a specific habitat type, e.g. salt marshes or vernal pools.

Table 2.9 shows the top 10 wild relatives whose habitat was decreasing. A comparison with the IUCN Red List shows that only one species, European eel (*Anguilla anguilla*) was listed as critically endangered, one as near threatened, the clown knifefish (sp.), and one was listed as vulnerable, the common carp. Several are of least concern and the majority haven't been assessed and the population trend is unknown. The majority of these species are freshwater fishes or diadromous, e.g. European and Japanese eels (spp.). The European seabass is the only marine species in this group of top ten species.

Table 2.9. Top 10 species for which catch was reported to be declining, number of reports of habitat decrease and status on IUCN Red List

Species	**Common name**	**Number of reports of population decrease**	**Number of reports of habitat decrease**	**Red List**	**Population trend from Red List**
Oreochromis niloticus	Nile tilapia	7	9	NA	U
Anguilla anguilla	European eel	6	4	CE	D
Cyprinus carpio	Common carp	4	5	V	U
Macrobrachium rosenbergii	Giant river prawn	4	3	LC	U
Salmo trutta	Brown Trout	4	8	LC	U
Channa striata	Striped snakehead	3	3	LC	U
Chitala chitala	Clown knifefish	3	3	NT	D
Colossoma macropomum	Cachama	3	2	NA	U
Dicentrarchus labrax	European seabass	3	Not listed	LC	U
Lates calcarifer	Barramundi	3	2	NA	U

NA = not assessed; LC = Least Concern; DD = data deficient to assess; V = Vulnerable; NT = Near Threatened; CE = Critically Endangered. For population trend: D = Declining; U = Unknown

Although at the species level *O. niloticus* is not threatened, concern has been raised that many natural populations are being introgressed with genes from other stocks and species (ADB, 2005). Thus, the genetic differences between stocks of natural Nile tilapia may be lost. Brazil and Columbia reported populations of *Arapaima giga*s as declining. This species is listed in Appendix II of CITES, which includes species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled. CITES had data to suggest listing of *Arapaima* whereas IUCN said data were deficient. An improved global information system would help communicate authoritative information to help resolve such issues (See Table 2.1).

2.5.4 Use of non-native species in fisheries and aquaculture

As in terrestrial agriculture, non-native aquatic species (also called alien or exotic species) contribute significantly to production and value in fisheries and aquaculture (Gozlan, 2008; Bartley and Casal, 1998; Bartley and Halwart, 2006). Although Country Reports did not contain production statistics, production from non-native species was reported to be increasing in fisheries for wild relatives and in aquaculture (Figure 2.25). Production from non-native species was reported to be increasing substantially in the minor producing countries, but none of the major producing countries indicated an increasing trend in production from non-native species (Figure 2.25b). This result may be contrary to information provided to FAO however, e.g. China and Viet Nam reported increasing production from non-native species (X. Zhou, FAO Aquaculture Information Officer, personal communication. March, 2018).

Figure 2.25a. Current production trends in non-native species in fisheries and aquaculture overall

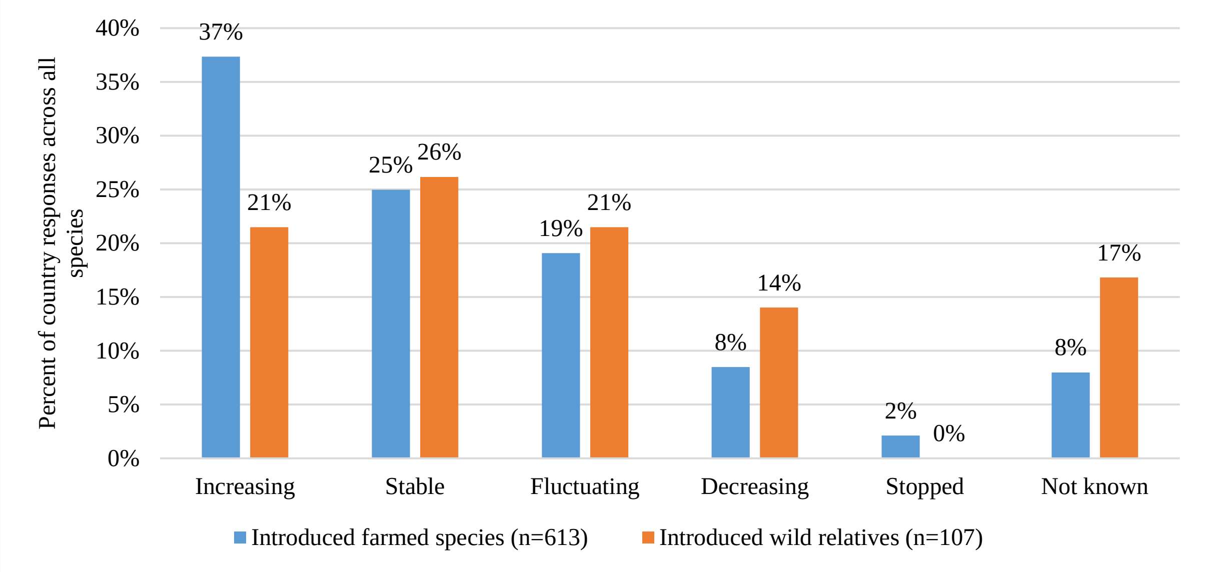
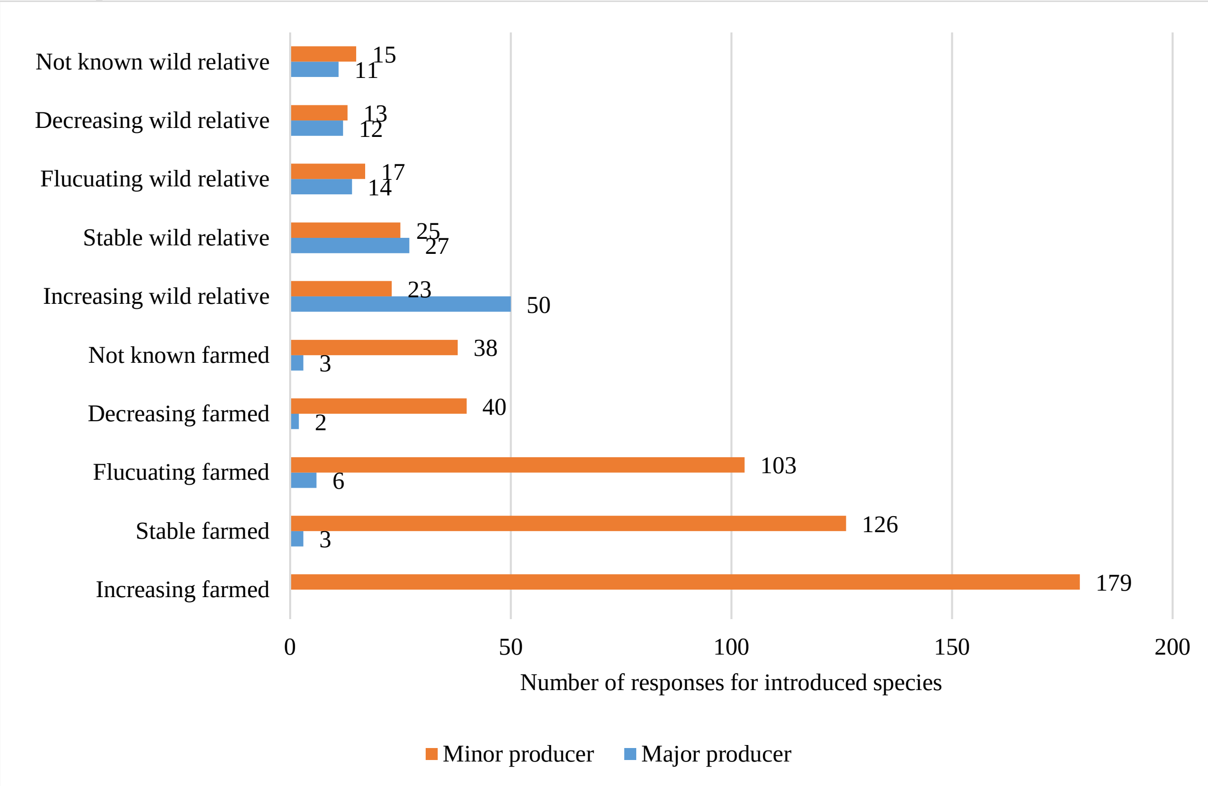


Figure 2.25b. Current production trends in non-native species in fisheries and aquaculture by country level of production



FAO maintains the Database on Introductions of Aquatic Species (DIAS) that contains records of introductions across national boundaries. The database may be accessed on line[16] and is linked to FAO production figures and species fact sheets.[17]

Analysis of DIAS revealed that carps, trout, tilapia and oysters were the most widely introduced aquatic species. Country Reports generally confirmed this analysis with the most often exchanged species (import

[16] www.fao.org/fishery/introsp/search/en
[17] www.fao.org/fishery/factsheets/en

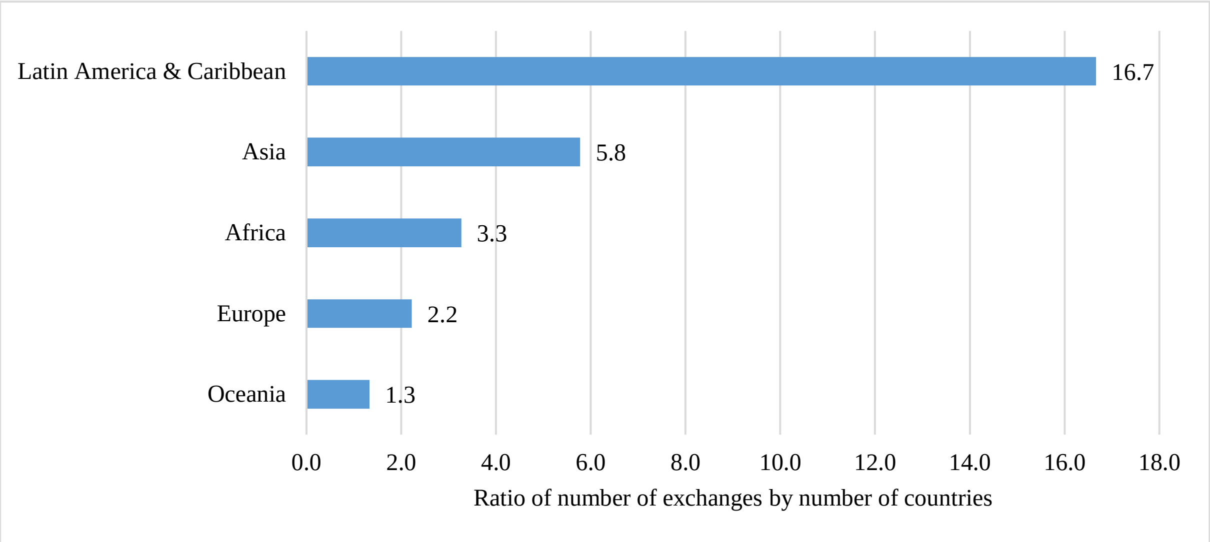
and export) being Nile tilapia, *Oreochromis niloticus*, followed by North African catfish, *Clarias gariepinus* (Table 2.10). Countries reported over 200 species had been exchanged across international borders (data not shown).

Table 2.10. Top 12[18] wild relatives exchanged by countries, includes both import and export

Species	Common name	Exchanges
Oreochromis niloticus	Nile tilapia	39
Clarias gariepinus	North Africancatfish	25
Piaractus brachypomus	Red-bellied pacu	9
Colossoma macropomum	Cachama (black pacu)	8
Eucheuma spp	Red algae	8
Crassostrea gigas	Pacific oyster	7
Salmo salar	Atlantic salmon	7
Mytilus edulis	Blue mussel	6
Penaeus monodon	Asian tiger shrimp	6
Ctenopharyngodon idellus	Grass carp	5
Cyprinus carpio	Common carp	5
Anguilla anguilla	European eel	5

Latin America and the Caribbean was the region exchanging most AqGR (Figure 2.26), whereas other developing areas (Figure 2.26b) and minor producing countries (Figure 2.26c) reported most exchanges on a per country basis. Generalizations from the results are difficult to make at present. The low ratio of exchange in major producing countries and in developed countries where aquaculture is generally declining could indicate that there is no more need to import or export AqGR, but then the low rate of exchange in Africa where aquaculture is developing would not be explained.

Figure 2.26a. Exchange of AqGR by region



[18] Common carp and European eel were included to allow comparison with Table 2.9.

Figure 2.26b. Exchange of AqGR by economic status

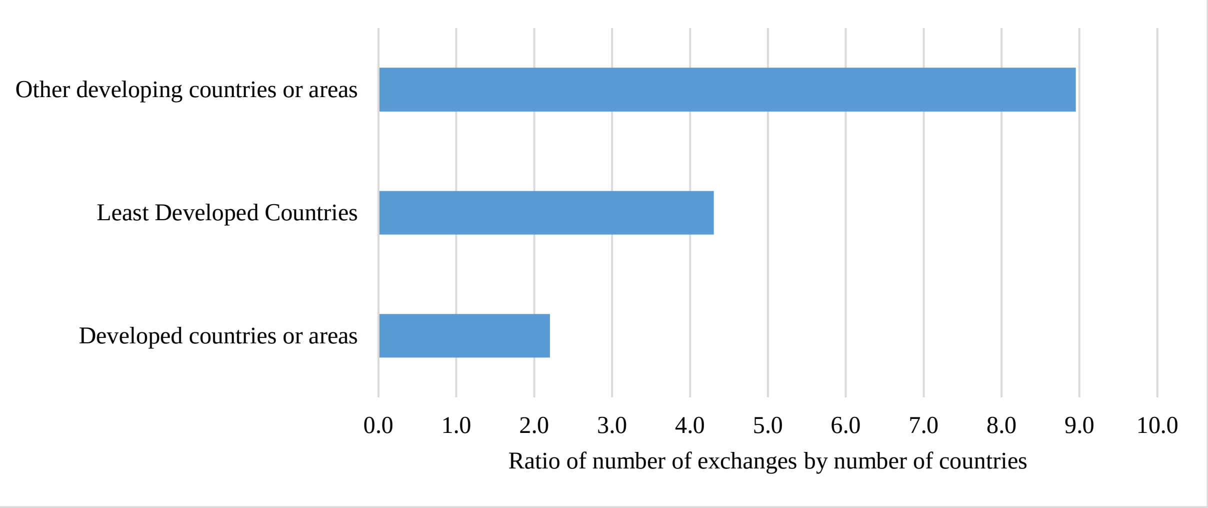
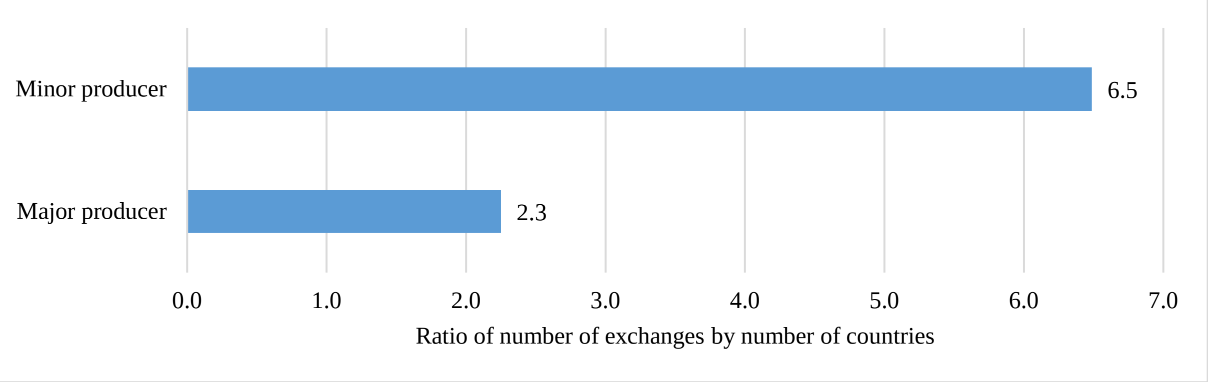
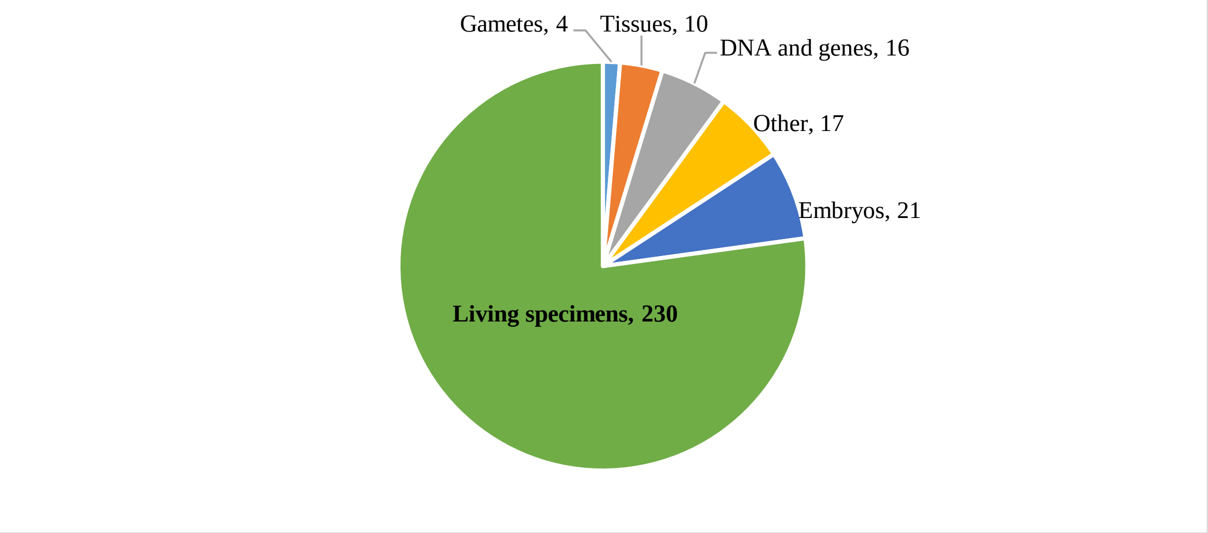


Figure 2.26c. Exchange of AqGR by level of production



As expected the most common form of genetic material exchanged was living specimens. Of the nearly 300 reported exchanges, about 77 percent were of living specimens, with about 7 percent exchanging embryos and only a very few countries reporting the exchange of other genetic material (Figure 2.27).

Figure 2.27. Types of genetic material exchanged, both imports and exports across all countries and species



An analysis of DIAS (Bartley and Casal, 1998; Gozlan, 2008) revealed that the majority of introductions of aquatic species have had negligible environmental impact on the surrounding ecosystem or biodiversity. Although some introductions have had serious adverse impacts, e.g. the golden apple snail in the Philippines or the crayfish plague in Europe that arrived with an introduced crayfish from North America, the records in DIAS further demonstrated that there have been more positive social and economic benefits from the introductions than negative environmental impacts (Bartley and Casal, 1998). More recent analysis with more records in DIAS supports the earlier findings, although the difference between positive social and economic impacts and negative environmental impacts was not as large as in the earlier work (FAO, in prep). The Country Reports did not indicate whether or not the introduction had positive or negative impacts.

However, non-native species can become invasive and have been identified as one of the major threats to biodiversity throughout the world. In order to minimize the risks and optimize the benefits from non-native species, the international community promotes codes of practice and risk analysis before an introduction is made (ICES, 2005; Chapter 6). The codes of practice and risk analysis include social and economic benefits as well as environmental risk (see Bartley and Halwart, 2006 for a collection of documents and international guidelines on non-native species, including DIAS).

2.6 Key findings and conclusions

AqGR exist at many levels	Aquatic Genetic Resources for food and agriculture include DNA, genes, chromosomes, tissues, gametes, embryos and other early life history stages, individuals, strains, stocks and communities of organisms.
	Unlike domesticated crops and livestock, where many breeds, varieties and cultivars have been well established and recognized for centuries or millennia, aquatic species have very few recognized strains and stocks.
The use of genetic information in management depends on accurate information and baseline data	Naming of aquatic species and farmed types was reported to be generally accurate and up to date for most countries although there are numerous cases where names of species and farmed types are not accurate.
	Current information systems such as the Aquatic Sciences and Fisheries Information System often do not have the capacity to record information on strains or stocks, or other kinds of genetically improved aquatic species.
	Although a global information system does not yet exist, potential elements of such a system have been developed.
	The information contained in the Country Reports could contribute to a new information system on AqGR
	Countries reported that in general genetic data were available and used in aquaculture with major producers using the information more than the minor producers and least developed countries used information on AqGR to a lesser degree than other countries.
Aquaculture and fisheries use a tremendous amount of AqGR	Countries reported farming of 694 species, or species items. Asia farms the most aquatic species and North America the fewest, although this is partially

	explained by more countries practicing aquaculture in Asia than in North America.
	Common carp was the species most often reported as being farmed followed by Nile tilapia, rainbow trout, grass carp and North Africancatfish.
	The 11 major producing countries on average farmed a higher number of species (26 species/country) than the 79 other countries (7 species farmed/country).
	The Country Reports identified over 250 species and species items that have not previously been reported to FAO.
	Many of the species not previously reported were ornamental fish (29 percent) and microalgae (25 percent).
	Major producing countries (i.e. those countries that contribute more than 1 percent to global aquaculture production) reported a higher use of genetically improved organisms than less producing countries.
	Countries reported that in general genetic data were available and used in aquaculture with major producers using the information more than the minor producers and least developed countries used information on AqGR to a lesser degree than other countries.
Coordination of national statistics on AqGR and aquaculture production is needed in some areas	The Country Reports usually reported a different number of species to FAO than was reported through the countries' regular processes.
	There are several reasons for this discrepancy, e.g. the species may • have limited production; • be primarily used in research; • have very localized niche markets; • be ornamental species; • be microorganisms; • have been misnamed or reported as strains or other type of non-standard nomenclature; • be new species being farmed.
Aquaculture is increasing in most areas and is expected to continue to increase for most species.	Aquaculture is still the fastest growing food production sector and is expected to play a major role in providing seafood in the future as production from many capture fisheries has plateaued.
	Countries reported over 640 cases where aquaculture is currently increasing while only reporting about 175 cases where it was decreasing or had stopped. For the future trend in production, in about 800 cases aquaculture production was expected to increase.
	Although the wild type was the most common farmed type used in aquaculture (in about 41 percent of responses) selective breeding was the technology most often used to improve aquatic species.
There is a large range of genetic technologies useful in improving production in aquaculture,	Technologies include selective breeding, hybridization, polyploidization, chromosome set manipulation, mono-sex production, marker assisted selection, transgenesis and gyno/andro genesis.

	However, tansgenesis was not reported by any country.
	Although the wild type was the most common farmed type used in aquaculture (in about 41 percent of responses) selective breeding was the technology most often used to improve aquatic species.
Public support was an important source of funds for genetic improvement programmes	Most of the programmes on selective breeding were funded by the public sector, but the private sector was the main funder of all of the other technologies although the differences between the numbers of responses for public and private funding were very slight.
	Public financing of genetic improvement programmes was much more prevalent in the major production countries than in the minor production countries
Non-native species play an important role in aquaculture and fisheries	Approximately 200 species or species items are reportedly farmed in countries where they are non-native.
	Nine of the 10 most widely cultured species are farmed in more countries where they are non-native than in countries where they are native.
	Production from non-native species was reported to be increasing in fisheries for wild relatives and in aquaculture, especially in the minor producing countries.
	Over 200 aquatic species were reported to have been exchanged (import and export) with the Nile tilapia and North African catfish the most exchanged species globally and Latin America and the Caribbean reporting the most exchanges by region.
	Living specimens was the most often exchanged type of AqGR accounting for about 77 percent of the reported exchanges.
Wild relatives also play important roles in aquaculture and fisheries	Aquaculture depends on AqGR from the wild in the form of early life history stages or broodstock to at least some extent in almost 90 percent of the responses.
	Wild relatives play a significant role in fisheries and aquaculture with rivers and coastal areas being the habitats from where most wild relatives were reported.
The abundance of many wild relatives is declining	For most wild relatives that are fished, a management plan exists, but over 200 cases of wild relatives were reported to be declining and almost 30 cases reported to be depleted.
	The main reason cited for the change in abundance of wild relatives was habitat loss and degradation followed by pollution.
	Habitat for most wild relatives was reported to be decreasing in the majority of Country Reports, however there was were a number of reports where the trend in change of habitat was not known.
	As with farmed aquatic species, genetic data may

	exist for wild relatives, but are often not used in management.
	For the top 10 wild relatives for which catch was reported to be declining, only three are listed as having any conservation concerns on the IUCN Red List and for only two has IUCN identified a trend in numbers.

2.7 References and key documents

On line resources

- FAO Aquatic Sciences and Fishery Information System: www.fao.org/fishery/collection/asfis/en
- FAO Database on Introductions of Aquatic Species (DIAS): www.fao.org/fishery/topic/14786/en
- www.fao.org/fishery/dias/en
- FishStatJ (2016): www.fao.org/fishery/topic/18238/en
- FAOSTAT (2016): http://faostat3.fao.org/home/E
- FAO Commission on Genetic Resources for Food and Agriculture: www.fao.org/nr/cgrfa/cgrfa-home/en/
- IUCN Red List of Threatened Species: www.iucnredlist.org/
- Global Invasive Species Database: www.iucngisd.org/gisd/
- Baltic Sea Alien species database: www.corpi.ku.lt/nemo/
- USDA invasive species: www.invasivespeciesinfo.gov/aquatics/databases.shtml

REFERENCES

ADB. 2005. *An Impact Evaluation of the Development of Genetically Improved Farmed Tilapia and Their Dissemination in Selected Countries*. Bangkok, Asian Development Bank. 124 pp.

Bakos, J. & Gorda, S. 2001. *Genetic resources of common carp at the Fish Culture Research Institute, Szarvas, Hungary*. FAO Fisheries Technical Paper 417. Rome, FAO.

Balon, E.K. 1995. *Origin and domestication of the wild carp, Cyprinus carpio: from Roman gourmets to the swimming flowers*. Aquaculture, vol 129. pp. 3–48.

Bartley, D.M. 1998. *Genetics and breeding in aquaculture: current status and trends*. Genetics and Breeding of Mediterranean Aquaculture Species. Cahiers OPTIONS, vol 68. pp 13–30.

Bartley, D. & Casal, C.V. 1998. *Impacts of introductions on the conservation and sustainable use of aquatic biodiversity*. FAO Aquacult. Newsl. 20:15-19. Also available at: www.fao.org/docrep/005/x1227e/x1227e15.htm

Bartley, D.M., Rana, K. & Immink, A.J. 2001. *The use of inter-specific hybrids in aquaculture and fisheries*. Reviews in Fish Biology and Fisheries, vol 10. pp 325–337.

Bartley, D.M. & Halwart, M. 2017. *Aquatic Genetic Resources*. Chapter 5 in: D. Hunter, L., Guarino, Spillane, C., & McKeown, P. C., eds. Rutledge Handbook of Agricultural Biodiversity. Earthscan Publications.

Bartley, D.M. & Halwart, M. 2006. *Responsible Use and Control of Introduced Species in Fisheries and Aquaculture* [CD RoM]. FAO, Rome.

Beacham T.D., Candy J.R., Jonsen, K.L., Supernault, J., Wetklo, M., Deng, L., Miller, K.M., Withler, R.E. &Varnavskaya N. 2006. *Estimation of stock composition and individual identification of Chinook salmon across the Pacific Rim by use of microsatellite variation*. Trans. Am. Fish. Soc. 135. pp 861–888.

Beacham, D., Beamish, R.J., Neville, C.M., Candy, J.R., Wallace, C., Tucker, S. & Trudel M. 2016. *Stock-Specific Size and Migration of Juvenile Coho Salmon in British Columbia and Southeast Alaska Waters*. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 8. pp 292–314. Also available at: https://doi.org/10.1080/19425120.2016.1161683

Beardmore, J.A., Mair, G.C. & Lewis, R.I. 2001. *Monosex male production in finfish as exemplified by tilapia: applications, problems, and prospects*. Aquaculture, vol 197. pp 283–301.

Bilio, M. 2008. *Controlled Reproduction and Domestication in Aquaculture*. European Aquaculture

Society.

Devlin, B.H., Yesakl, T.Y., Blagl, E.A. & Donaldson, E.M. 1994. *Extraordinary salmon growth*. Nature, vol 371. pp 209–210.

Dunham, R.A. 1995. *The Contribution of Genetically lmproved Aquatic Organisms to Global Food Security*. Thematic paper presented to the Japan/FAO International Conference on Sustainable Contribution of Fisheries to Food Security. 4 – 9 December. Kyoto, Japan.

Dunham, R.A. 2011. *Aquaculture and Fisheries Biotechnology: Genetic Approaches*. Second Edition. CABI Publishing. 495 pp.

FAO. 1997. *The State of the World's Plant Genetic Resources for Food and Agriculture*. Rome, FAO. Also available at: www.fao.org/tempref/docrep/fao/meeting/015/w7324e.pdf

FAO. 2007. *The First Report on the State of the World's Animal Genetic Resources for Food and Agriculture*. FAO, Rome.

FAO. 2015. *The Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture*, edited by B.D. Scherf & D. Pilling. Rome, FAO. Commission on Genetic Resources for Food and Agriculture Assessments. Food and Agriculture Organization of the United Nations. Also Available at: www.fao.org/3/a-i4787e.pdf

FAO. 2016. *Report of the expert workshop on incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives*, FAO Fisheries and Aquaculture Report No. 1173. Rome, FAO. Also available at: www.fao.org/3/a-bt492e.pdf

FAO. In prep. *State of the World's Inland Fisheries*. FAO Fisheries Circular 942. Rome, FAO.

Fox, G.L. 2010. *Transgenic salmon inches toward finish line*. Nature Biotechnology, vol 28. pp 1141–1142.

Fjalestad, K.T., Gjedrem, T., Carr, W.H. & Sweeney, J.N. 1997. *Final report:The shrimp breeding program. Selective breeding of Penaeus vannamei*. AKVAFORSK, Report no. 17/97.

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

Gjedrem, T. & Robinson, N. 2014. *Advances by Selective Breeding for Aquatic Species: A Review*. Agricultural Sciences, 5, 1152-1158. Also available at: http://dx.doi.org/10.4236/as.2014.512125

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

Gozlan, R.E. 2008. *Introduction of non-native freshwater fish: Is it all bad?* Fish and Fisheries, 9: pp 106– 115.

Guo, X., Wang, Y., Xu, Z. & Yang, H. 2009. *Chromosome set manipulation in shellfish*. pp.165–194. In: Burnell, G. & Allan, G., eds. *New technologies in aquaculture.* CRC Press. 1191 pp.

Harvey, B., Soto, D., Carolsfeld, J., Beveridge, M. & Bartley, D.M. eds. 2017. *Planning for aquaculture diversification: the importance of climate change and other drivers*. FAO Technical Workshop, 23–25 June 2016. Rome, FAO. FAO Fisheries and Aquaculture Proceedings No. 47. 166 pp.

Hulata, G. 1995. *The history and current status of aquaculture genetics in Israel*. Isr. J. Aquacult. Bamidgeh, vol 47. pp 142–154.

ICES. 2005. *ICES Code of Practice on the Introductions and Transfers of Marine Organisms*. International Council for the Exploration of the Sea. Denmark. 30 pp.

Kirpichnikov, V.S. 1981. *Genetic Basis of Fish Selection*. Springer-Verlag, Berlin.

Lind, C.E, Safari, A., Agyakwah, S.K., Attipoe, F.Y.K, El-Naggar, G.O., Hamzah, A., Hulata, G., *et al*. 2015. *Differences in sexual size dimorphism among farmed tilapia species and strains undergoing genetic improvement for body weight*. Aquaculture Reports, vol 1. pp 20–27.

Lourdes, M., Cuvin-Aralar, A. & Aralar, E.V. 1995. *Resistance to heavy metal mixture in Oreochromis niloticus progenies of parents chronically exposed to the same metals*. Aquaculture, vol 137. pp 271–284.

Mair, G.C., Abucay, J. S., Beardmore, J.A. & Skibinski, D. O. 1995. *Growth performance of genetically male tilapia (GMT) derived from YY-males in Oreochromis niloticus L.:* On station comparisons with mixed sex and sex reversed male populations. Aquaculture, 137. pp 313–323.

Nash, C.E. 2011. *History of Aquaculture*. Wiley-Blackwell, USA.

Overli, O., Pottinger, T.G., Carrick, T.R., Overli, E. & Winberg, S. 2002. *Differences in behaviour* *between rainbow trout selected for high- and low-stress responsiveness*. Journal of Experimental Biology, vol 205. pp 391–395.

Pauly, D. 1995. *Anecdotes and the shifting baseline syndrome of fisheries*. Trends in Ecology and Evolution, 10(10):430.

Pongthana, N., Nguyen, N.H. & Ponzoni, R.W. 2010. *Comparative performance of four red tilapia strains and their crosses in fresh- and saline water environments*. Aquaculture, vol 308, SUPPL.1. pp S109–S114.

Ponzoni, R.W., Nguyen, N.H., Khaw, H.L., Hamzah, A., Bakar, K.R.A. & Yee, H.Y. 2011. *Genetic improvement of Nile tilapia (Oreochromis niloticus) with special reference to the work conducted by the WorldFish Center with the GIFT strain*. Reviews in Aquaculture, vol 3. pp 27–41.

Pullin, R.S.V. 2016. *Diversification in aquaculture – farmed aquatic organisms and culture systems*. FAO workshop Diversification in Aquaculture. June, 2016. FAO, Rome.

Rosenstein, S. & Hulata, G. 1993. *Sex reversal in the genus Oreochromis: optimization of feminization protocol*. Aquacult. Fish. Manage., vol 25. pp 329–339.

Ruane, J. & Sonnino, A. 2006. *The Role of Biotechnology in Exploring and Protecting Agricultural Genetic Resources*. FAO, Rome.

Sahrhage, D. & Lundbeck, J. 1992. *History of Fishing*. Berlin, Springer-Verlag.

Sheehan, R.J., Shasteen, S.P., Suresh, A.V., Kapuscinski, A.R. & Seeb, J. 1999. *Better Growth in All-Female Diploid and Triploid Rainbow Trout*. Transactions of the American Fisheries Society, vol 128. pp 491–498.

Smith, T.I.J. 1988. *Aquaculture of striped bass and its hybrids in North America*. Aquacult. Mag. Vol 14. pp 40–49.

SOFIA. 2014. *State of World Fisheries and Aquaculture 2014.* Food and Agriculture Organization of the United Nations, Rome.

SOFIA. 2016. *State of World Fisheries and Aquaculture 2016.* Food and Agriculture Organization of the United Nations, Rome.

Tave, D. 1989. *The Domesea selective breeding program with coho salmon*. Aquaculture Magazine, Sept/Oct. pp 63–67.

Tave, D. 1995. *Selective Breeding Programmes in Medium-Sized Fish Farms*. FAO Fisheries Technical Paper 352. Rome, FAO. pp 122.

Tiwary, B.K., Kirubagaran, R. & Ray, A.K. 2004. *The biology of triploid fish*. Reviews in Fish Biology and Fisheries 14: 391402.

Toro, J.E., Aguila, P. &Vergara, A.M. 1996. *Spatial variation in response to selection for live weight and shell length from data on individually tagged Chilean native oysters (Ostrea chilensis Philippi, 1845).* Aquaculture, vol 146. pp 27–36.

Wilkins, N.P., Gosling, E., Curatolo, A., Linnane, A., Jordan, C. & Courtney, H.P. 1995. *Fluctuating asymmetry in Atlantic salmon, European trout and their hybrids, including triploids*. Aquaculture, vol 137. pp 77–85.

Wohlfarth, G.W. 1994. *The unexploited potential of tilapia hybrids in aquaculture*. Aqua. Fish. Manag., vol 25. pp 781–788.

CHAPTER 3
DRIVERS AND TRENDS IN AQUACULTURE: CONSEQUENCES FOR AQUATIC GENETIC RESOURCES WITHIN NATIONAL JURISDICTION

PURPOSE: The chapter explores the effects of different drivers on farmed and wild-relative Aquatic Genetic Resources. These drivers are: human population increase; competition for resources; strength of governance; increased wealth and development of economies; and changing human food preferences and ethical considerations. The chapter also considers the effect of drivers which impact ecosystems and thus have implications for both wild relatives and farmed types. These drivers are: habitat loss and degradation; pollution of waters; direct and indirect effects of climate change; establishment of invasive species.

KEY MESSAGES:

Human population increase

- Population increase will drive demand for seafood, especially aquaculture products, as capture fishery resources become limited. This will drive efforts to expand and diversify the farmed species produced and therefore Aquatic Genetic Resources.
- This will also place pressure on wild type stocks, either as broodstock or directly as food.

Competition for resources

- Demand for freshwater for use in urban supply, energy production and other uses will challenge aquaculture to become more efficient.
- Wild relatives will be threatened by changes in priorities on use of water.
- Pollution from industry, agriculture and urban sources all threaten the quality of water used for aquaculture and to sustain wild relatives.

Governance

- Increasing levels of good governance are seen as having an overall beneficial effect on Aquatic Genetic Resources in both farmed types and wild relatives.
- Impacts range from improved regulation of farms and their operations to greater professionalization within the sector.
- Impacts on wild relatives pertain to improved environmental management, better control over stocking and movements, and higher levels of conservation and protection.

Increased wealth and development of economies

- Increasing wealth and developing economies are accompanied by greater intra- and inter-regional trade and increasing urbanization and industrialization.
- There will be increasing consolidation and industrialization of large volume, internationally traded commodities.
- There will be increased emphasis on food safety and traceability, which presents challenges smaller operators.
- There will be continuous exploration of new species to satisfy the demand for new commodities and fill niche markets.
- Demand for ornamental species will increase, driving the development of farmed types as well as demands on wild relatives.

Changing human food preferences and ethical considerations

- With changing demographics, consumer attitudes towards fish are also changing.
- Fish consumption is increasingly recognized as part of a healthy and balanced diet, and increasing urbanization will drive demand for seafood.
- There remains concern over the use of GMO techniques in some markets, including consumer resistance.

- There is increasing awareness regarding the unsustainable exploitation of wild relatives, driving demand for farmed types.

Effect of habitat loss and degradation on ecosystems

- Changes in the use of land, water, coastal areas, wetlands and watersheds all have impacts on the quantity and quality of habitat for Aquatic Genetic Resources.
- Changes to watersheds are among the principal factors that affect aquatic systems. Aspects that impact Aquatic Genetic Resources include, among others: damming of rivers, drainage systems, flood control and flood protection, hydropower development, irrigation, partitioning of wetlands and road construction.
- The establishment of invasive species can have direct impacts on Aquatic Genetic Resources through competition or predation, as well as indirect impacts on food webs and ecosystems that support wild relatives.
- Water pollution has strong negative impacts, particularly in freshwaters, and affects both wild relatives and farmed types.

Direct and indirect effects of climate change

- Climate change will have impacts on freshwater availability and changing ambient temperatures, which will have both direct and indirect impacts on farmed and wild Aquatic Genetic Resources.
- Climate change will have a disproportionate effect in tropical regions.
- There are possible positive effects on farmed types, such as selection for climate tolerant traits.
- Impacts on wild relatives are likely to be negative or unknown.

3.1 Direct impacts on farmed types and wild relatives

Numerous drivers will impact AqGR and the people that depend on them. It is expected that human population growth, competition for resources, ability to achieve good governance, increased wealth and demand for fish and fish products, consumer attitudes (i.e. food preference and ethical considerations) habitat management and climate change will be the most significant drivers in the coming decades (FAO, 2014a). The growth of the aquaculture sector itself will depend on many of these drivers and will have a significant influence on food production (see Outlook section in FAO, 2014a).

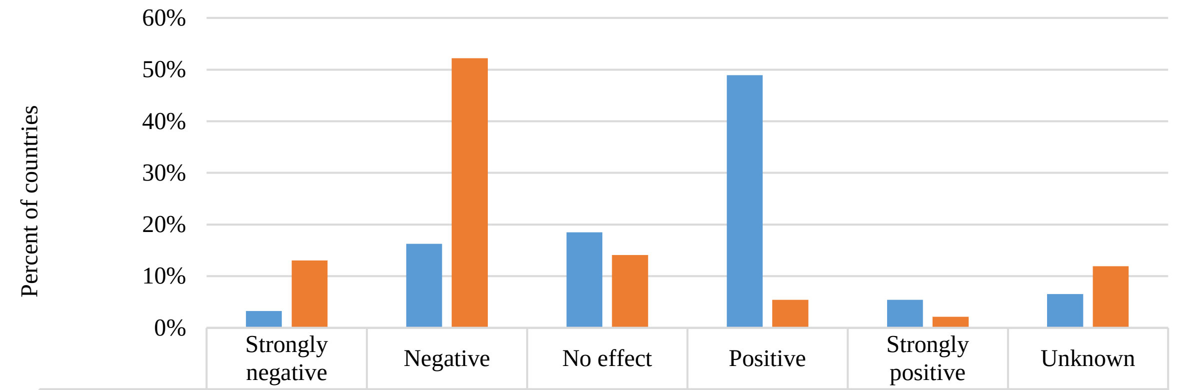
3.1.1 Human population increase

Projections of food consumption patterns and preferences, linked to population growth models, forecast significant increased demand for seafood products in the future. While total fish supply will likely be equally split between capture and aquaculture by 2030, projections indicate that 62 percent of food fish will be produced by aquaculture by 2030. Beyond 2030, aquaculture will likely dominate global fish supply, with global aquaculture production of food fish (excluding aquatic plants) expected to reach 93.6 million tonnes by 2030 (World Bank, 2013).

Over the past three decades, global aquaculture development has outpaced population growth, resulting in increased per capita aquaculture production in most regions (with few exceptions). Asia has led other regions in this regard, but even within Asia there is substantial variation (FAO, 2016). The overall growth in global aquaculture (including aquatic plants) has been stable at around 6 percent per year over the past 15 years (FAO, 2014b).

More than half (54 percent) of country responses regarding the effects of population growth on AqGR indicate that the impact is likely to be positive on farmed type genetic resources (Figure 3.1). This appears to be linked to the consequent increase in demand for aquaculture products that will occur as population increases. It is notable that some developed countries did not expect their population to rise significantly and thus there would not be a strong increase in demand. It is expected that diversity of farmed type genetic resources will increase, including the development of improved farmed types (tolerance to high density production, increased disease resistance; improved quality traits such as colour, shape, dress-out weight, head-tail ratio; phyco-colloid gel properties, etc.); and the search for new species to culture, also known as diversification.

Figure 3.1
Country responses on the impacts of population growth



	Strongly negative	Negative	No effect	Positive	Strongly positive	Unknown
Farmed	3%	16%	18%	49%	5%	7%
Wild relatives	13%	52%	14%	5%	2%	12%

Nineteen percent of respondent countries viewed population growth as likely to negatively impact farmed genetic resources and this was largely linked to pressures on resources. Pressures on water resources limits extensive aquaculture systems and the associated species that are used. Intensification and industrialization/rationalization may narrow the range of species that are cultured as commodities. This is a similar trend seen in the livestock sector as high performing breeds displace locally adapted breeds (FAO, 2007). The increasing intensification and globalization of movement of aquatic species will increase the risk of spread of diseases.

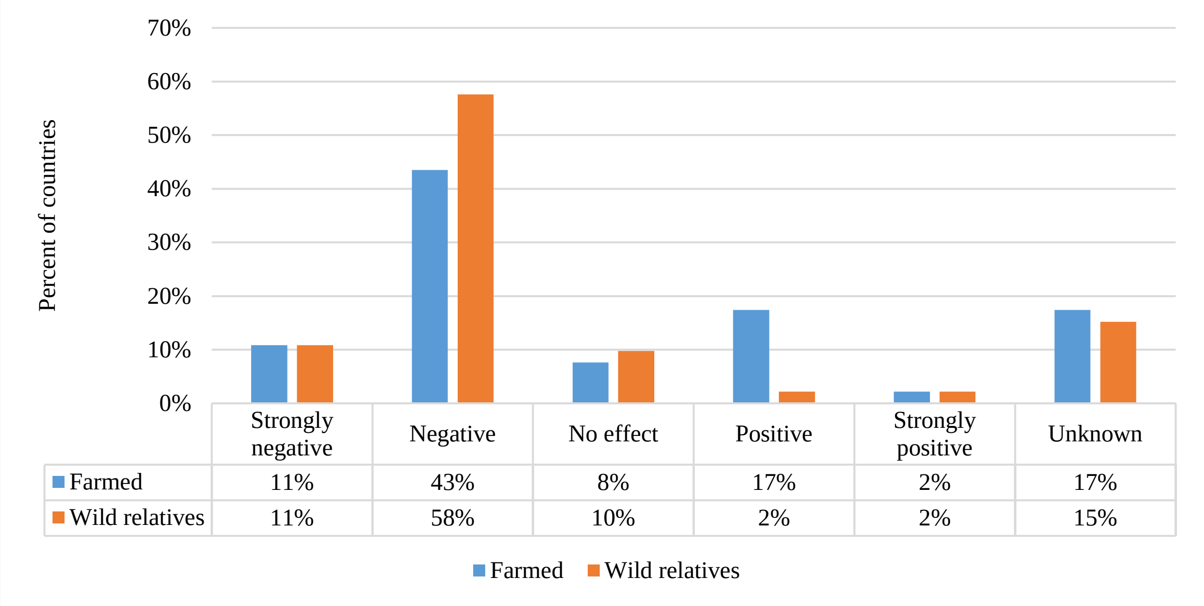
The impact of population pressure on wild relatives is foreseen as generally negative (65 percent) with only 7 percent of respondents considering there would be positive effects. The consideration was that increasing populations and consequent demand for fish would drive overfishing of wild relatives, as well as impacts on the freshwater ecosystems that support wild relatives. This would particularly affect the most vulnerable species if not managed effectively. Vulnerable species have life history traits such as late sexual maturation, low fecundity and/or complex breeding or migratory characteristics. Part of this complexity also means that these species are challenging or prohibitively expensive to domesticate and breed in captivity (e.g. Bluefin tuna, eel, lobster). This places an additional pressure on the wild relatives as the sourcing of seed for aquaculture is typically through the capture of wild juveniles.

Fishing pressure and gear selectivity may also have an effect on wild-relatives by driving selection in wild stocks, though the scale is unquantified (Hard *et al.*, 2008).

3.1.2 Competition for resources

Overall, more than half of the country responses (54 percent) considered that competition for resources would have a negative effect on farmed Aquatic Genetic Resources, against 19 percent considering the effects would be positive (Figure 3.2). These responses were overwhelmingly concerned with the availability of freshwater and competition for the former from other sectors such as agriculture, irrigation, recreational uses and drinking water supply. There were no regional or economic differences between the responses.

Figure 3.2
Effect on Aquatic Genetic Resources from competition for resources



The changing priorities on the use of water forces aquaculture to produce more with less. There is a general trend towards rehabilitation of inland waters in many countries and restoration of habitat and conservation of biodiversity. This in turn may limit the prospects for aquaculture expansion as the amenity value and increased demand for conservation and rehabilitation of the aquatic environment will limit available sites for aquaculture and increasingly impose limits on water abstractions and effluent discharges.

In many countries, it will be necessary to increase aquaculture production though intensification approaches that utilize feed, water and space more efficiently than at present. This has strong implications for domestication and breeding of easing aquaculture species as well as the interest to develop aquaculture systems for species, which are not currently cultured. Several country respondents noted that competition for resources would have a positive effect on the development of more efficient production systems that had reduced nutrient discharge footprints.

To look at the drivers affecting Aquatic Genetic Resources as a whole, the 2014 FAO aquaculture statistics are used. It is recognized that differences exist between these data and those reported through the Country Reports, and a discussion of the causes and implications of these differences is included elsewhere in this publication. In this chapter, the FAO aquaculture statistics are used to illustrate general trends related to taxonomic grouping, habitat and feeding level.

Using these data, a total of 322 aquatic species were farmed in marine waters in 2014; while only 208 species in freshwater and 45 species as diadromous fish were farmed for a grand total of 575 species recorded as farmed species (Table 3.1).

Table 3.1
A total of 575 farmed species (with production) are recorded in FishStatJ as of 2014

Aquaculture group	Production environment			
	Total	Marine	Freshwater	Diadromous
Finfish	359	134	180	45
Crustaceans	61	44	17	-
Molluscs	103	100	3	-
Other animals	15	9	6	-
Aquatic plants	37	35	2	-

Source: FAO, 2014b.

Freshwater aquaculture currently dominates finfish production (46 million tonnes versus 12 million tonnes in marine and brackishwaters) and increased expansion in this sub-sector will inevitably lead to competition for freshwater and land resources (Table 3.2). There remains an opportunity for aquaculture expansion (and thus expansion of Aquatic Genetic Resources of farmed types) in the development of systems and species in brackish and saltwater systems.

The higher number of species being farmed in marine and brackishwater environments is an indication of the diversity of these systems. It is worth noting that one of the advantages is that saline environments are one of the few areas where there is no direct competition with livestock and agriculture production for space and water, meaning that there is potential for increased cultured food production from these environments in the future.

Table 3.2
The breakdown of aquaculture production in tonnes, by production environment and by major division according to the International Standard Statistical Classification of Aquatic Animals and Plants

Aquaculture grouping	**Production environment**		
	Brackishwater	**Freshwater**	**Marine**
Aquatic plants	1 106 474	86 035	26 114 456
Crustaceans	3 662 912	2 737 268	514 893
Diadromous fishes	928 074	1 105 700	2 832 708
Freshwater fishes	1 116 463	41 500 547	71
Marine fishes	488 398	47 367	1 842 564
Miscellaneous aquatic animal products		1 979	46 402
Miscellaneous aquatic animals	110	520 900	372 558
Molluscs	103 876	277 744	15 731 575
Total production	**7 406 306**	**46 277 539**	**47 455 227**
Total aquaculture production excluding molluscs and aquatic plants	6 195 956	45 911 781	5 562 794
Total aquaculture production, excluding aquatic plants	6 299 832	46 191 505	21 340 771

Source: FAO, 2014b.

The rising price of key feed ingredients for aquaculture (especially fish meal and fish oil) is already driving the aquaculture sector to explore lower cost alternatives. Development of innovative feeds is one outcome, but the selection of species for improved performance (growth, feed conversion ratio) on these feeds is a parallel development. Considerable improvements in performance have been achieved for a number of species (salmon, channel catfish).

Although availability of aquaculture feed is an important concern regarding the future of aquaculture development, 50 percent of the world’s aquaculture production is cultured in systems that do not require the addition of feed. This is achieved mainly through the production of seaweed and microalgae (27 percent), filter-feeding finfish (8 percent) and filter-feeding molluscan species (15 percent) (FAO, 2014b). The production of un-fed aquatic animal species was 23 million tonnes in 2014 representing 23 percent of the world production of all farmed fish species (FAO, 2016). This trend has been reasonably consistent over the past decade. The trend in carnivorous species has risen very slightly (from 8 percent to 9 percent), over the past decade, but is greatly outweighed by the production of non-carnivorous species (Table 3.3).

The most important non-fed aquatic animal species include:

- two freshwater finfish species, silver carp and bighead carp (*tilapia in extensive systems are also able to filter-feed but are not included here);
- bivalve molluscs (clams, oysters and mussels, etc.); and
- other filter-feeding animals (such as sea squirts) in marine and coastal areas.

While many of these pressures could have a positive impact on farmed Aquatic Genetic Resources, the limitations imposed on water and land as well as the trend to rationalize systems may tend to reduce the diversity of farmed aquatic animals in some regions.

Table 3.3
Comparison of production (tonnes) of fed and unfed aquaculture 2004 to 2014

	Species	2004	2009	2014	% of 2014 Total
Unfed	Algae	10 382 167	14 823 908	26 839 288	27
	Molluscs	10 622 252	12 214 046	14 516 676	15
	Filter feeding carp	5 381 150	6 568 469	8 220 882	8
	Other filter feeding species	87 702	171 392	275 568	0
Fed	Herbivorous species	3 980 855	5 138 466	6 722 240	7
	Omnivorous species	17 991 921	26 541 037	33 347 307	34
	Carnivorous species	4 754 449	6 597 555	8 942 613	9
Unknown	Other species unknown	4 992 202	5 258 884	4 897 668	5
Totals	Total unfed	26 473 271	33 777 815	49 852 414	50
	Total fed	26 727 225	38 277 058	49 012 160	50
	Total unfed animals	16 091 104	18 953 907	23 013 126	23
	Total all species	**58 192 698**	**77 313 757**	**103 762 242**	
Percentage of annual total	% Unfed	50%	47%	50%	
	% Fed	50%	53%	50%	

The picture of competition for resources is clearer for wild relatives. Competition for resources was considered to be overall negative for 69 percent of respondent countries versus only 4 percent considering there would be positive effects.

The negative impacts on wild relatives are reduction in availability of freshwater, loss of habitat and competition over land and maritime space (in countries with mariculture). Changes to watersheds are among the principal factors that affect aquatic systems, with aspects such as damming of rivers, drainage systems, flood control and flood protection, hydropower development, irrigation, partitioning of wetlands and road construction. Environmental impacts on water that can affect wild relatives include land use changes and soil degradation impacting water quality, as well as agricultural runoff and unregulated urban and industrial discharges into water bodies.

There is an additional specific impact created by the demand for aquaculture feeds derived from capture fisheries, although the species targeted for aquaculture feeds (e.g. fish meal, low value/trash fish) are not typically wild relatives of aquaculture species (Table 3.4).

Table 3.4
Summary of impacts on wild relatives created by competition for resources

Typical impacts of habitat loss and degradation	Loss of wild habitat and water flows resulting from changes in rivers, wetlands and water bodies caused by changing land use, watershed development and drainage of freshwater wetlands. This reduces the available habitat to sustain populations, and impacts the function of habitats during critical seasons (e.g. over-wintering; dry season refuges).
	Physical obstruction and changing water flow regimes impacting upstream and downstream migration and reproduction of riverine species. This is caused by damming of rivers and loss of connectivity in waterways (e.g. low water control structures, weirs, irrigation structures).
	Changing ecosystem quality (driven by land management, watershed management) leading to increased soil erosion and sediment loads in water bodies. This directly affects species sensitive to poor water quality and can affect quality of spawning grounds or nurseries.
Impacts of pollution of waters	Direct effect of toxins and heavy metals from untreated industrial discharges.
	Indirect effect of effluents from urbanization leading to eutrophication and changed water quality and food chains.
	Direct impact on fish through feminization effects (oestrogen-analogues in effluents).
	Nutrients from agriculture runoff leading to eutrophication of water bodies.
	Pesticide runoff from agriculture directly affecting fish, or indirectly through ecosystem level impact on prey and/or food chains.

Impact of demand for seed or broodstock	Some aquaculture systems still rely on the wild relatives as the source of seed for stocking. This may be completely benign as in the form of capturing natural spatfall as in the case of molluscs (e.g. clams, oysters, mussels, cockles). The active fishing for seed for stocking may have greater impact if that activity takes place after there has already been significant mortality during recruitment. In this case there can be direct impacts on the wild population (e.g. collection of juvenile lobster or grouper for ongrowing). In other systems the collection of juveniles for stocking appears to have little or no impact on the wild population (e.g. Yellowtail (*Seriola*) seed collection in Japan).
Impact of demand for feeds	Capture fisheries that are specifically managed for production of fish for fishmeal are not typically comprised of wild relatives of aquaculture species. The use of trawl bycatch for fishmeal is more complex as the species targeted may be highly diverse. There are ecosystem effects of fisheries that are driven for this bycatch although the effect on wild relatives of aquaculture species is not quantified.

3.1.3 Governance

Governance factors were overwhelmingly perceived as having a positive effect on farmed AqGR (76 percent). There were no obvious regional or economic differences in the country responses. In general, country responses indicated the belief that a combination of more effective regulation of the sector, coupled to increased organizations and empowerment of aquaculture producers, was a desirable goal. Where indicated, countries reported that effective governance was a positive factor contributing to the management of Aquatic Genetic Resources. The development of specific regulations to manage importation of species, regulation of AqGR at farm level, and controls on the feed sector were identified as principal factors. Government investment in breeding programmes and the development of aquaculture development programmes (and agencies to promote this) were positive outcomes identified in the Country Reports. This had enabled more effective dialogue between producers and regulators as well as improved understanding of the issues relating to aquaculture production. This was extended to engagement with civil society, CSOs and environmental groups in some reports.

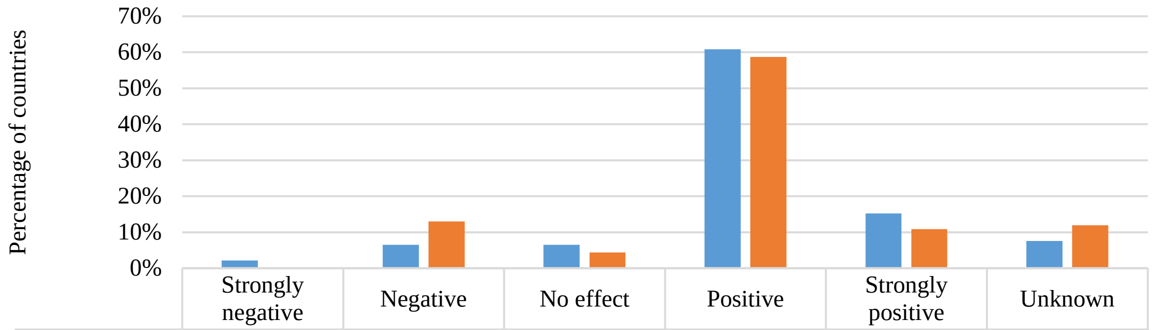
The need to encourage better dialogue concerning aquaculture and its use of AqGR as well as potential impacts or threats to wild relatives was noted as important. The prospects of governance for positively impacting farmed genetic resource were considered to be as follows:

- increased regulation and management of farmed types including licensing of hatcheries, can contribute to more systematic and effective controls over farmed Aquatic Genetic Resources;
- effective biosecurity systems to assess and manage risks of translocations, introductions of both farmed and wild species as well as possible pathogens and parasites;
- professionalization of the sector, including greater understanding and appreciation of good quality genetic stock;
- development of specific pathogen resistance in farmed types; and
- development of effective measures to enable exchange of material between countries (this is currently increasingly constrained by national legislation on genetic resources and biosecurity, see Chapter 6).

Only 9 percent of respondent countries considered that governance would have any negative effect. These responses were concerned with poor regulatory environments and limited research. Some concern was voiced that lack of government lead on aquaculture genetic resources left too much influence in the hands of the private sector, with implications for unregulated imports and movements.

A similar figure for positive impacts (70 percent) was expressed for wild relatives with responses (where provided) focusing on the importance of effective fishery management to protect wild relatives. There were no obvious regional or economic differences in the country responses. The existence of effective fishery assessment programmes was identified as an important element of being able to do this. Some specific examples highlighted the protection of specific habitats and development of protected areas and sanctuaries to preserve wild stocks (Bangladesh, Benin). For marine stocks, marine fishery management measures, including seasonal closures of the fishery, were mentioned. Rehabilitation of freshwater resources (including habitat) was also noted in some countries. The importance of effective relationships between the government regulatory bodies and fishers as well as fish farm operators to achieve positive environmental outcomes was indicated in some reports. (Figure 3.3).

Figure 3.3
Effect of governance factors on Aquatic Genetic Resources



	Strongly negative	Negative	No effect	Positive	Strongly positive	Unknown
Farmed	2%	7%	7%	61%	15%	8%
Wild relatives	0%	13%	4%	59%	11%	12%

While not strictly a governance issue, some of the problems of mis-management of AqGR in farmed types arise from the governance structures and degree of regulatory control, research and communication. There remains concern over the impact on wild relatives from escapees of farmed types, especially genetically modified organisms, and thus more stringent measures to prevent or reduce this in the future. This is linked to effective sector regulation and management, and is therefore related to the degree of effectiveness of governance of the sector. These management issues can be summarized as follows in Table 3.5.

Table 3.5
Aquaculture sector governance and management issues that impact aquatic genetic resources

Limited genetic diversity in founder populations	Limited numbers of broodstock fish are used in research centres as the techniques for breeding are established. Successful mass production sees this stock disseminated to other hatcheries for upscaling, without accessing large numbers of new broodstock. This may be a particular issue where the broodstock were non-native and introduced from another country.
Small private hatcheries with limited numbers of broodstock	In many developing countries, small-scale private or state operated hatcheries may have exceptionally small numbers of broodstock. The replenishment of broodstock may not occur for year or some time never, resulting in inbreeding and loss of performance. This can be corrected by national broodstock and improved AqGR dissemination initiatives.
Species disseminated worldwide from a relatively limited number of sources?	Specific farmed types may be held in reference centres and access to these farmed types may be limited by legal or financial constraints. Improved access may require cooperation or sharing agreements, and greater national financial support.
Limitations on refreshing genetic stocks from the wild	Replenishment of broodstock from wild relatives may be constrained in number of ways. One of the greatest threats is weak governance on the management of the habitats and stocks of wild relatives, which can lead to their decline in the wild and loss as a potential source of broodstock for the future.
Non-compliance with regulations by the private sector	It was noted in some country responses that private sector had the ability to bypass government controls on importation and movements of aquatic animals

Poor controls on accidental or deliberate release of cultured fish to the wild	Accidental or deliberate (in the case of stocking of open waters) release of domesticated species, hatchery bred and GMO material may impact wild relatives

Improved governance also benefits wild relatives by strengthening controls over biosecurity and limiting farm escapees, both of which have impacts of genetic pollution. The improvement of management of the environment and biodiversity may be an additional positive effect, contributing to more effective conservation of wild relatives.

- the establishment of well-managed conservation hatcheries to increase/maintain genetic diversity of wild relatives;
- reduction of risks of transmission of parasites and pathogens to wild relatives through effective biosecurity, especially in relation to introductions;
- prevention of the establishment of invasive species; and
- reduction of the risk of interactions between farmed and wild fish.

Reponses were fewer for the negative (9 percent farmed type; 13 percent wild relatives) related to governance. In some responses the delegation of implementation to the private sector or reliance on voluntary compliance were perceived as a weakness. An area that is quite commonly found in developing countries is a lack of effective assessment of risks on the introduction and movement of aquatic species, which can directly conflict with biodiversity and conservation policies, or simply undermine existing production systems and thus undermine policies on economic development, livelihoods and food security. This contrasts with those policies that are in place to promote aquaculture development, but doing so without adequate regulatory measures may result in unintended negative consequences in the future.

Some country responses indicated that a general negative aspect of weak governance was policy fragmentation and weak institutional coordination on water and the environment. This is common in many countries where the roles and jurisdictions of water management and development is spread across multiple agencies and the private sector. This typically includes: irrigation; drinking supply; hydropower; biodiversity and environmental management; fisheries and aquaculture; coastal zone management; protected areas and conservation. In the water sector the impacts of this can range from an inability to coordinate on the multi-purpose management and use of water and water bodies (e.g. for aquaculture, fisheries, recreation, conservation, drinking supply, irrigation), through to direct policy conflicts (e.g. power generation versus biodiversity conservation and food/livelihood security).

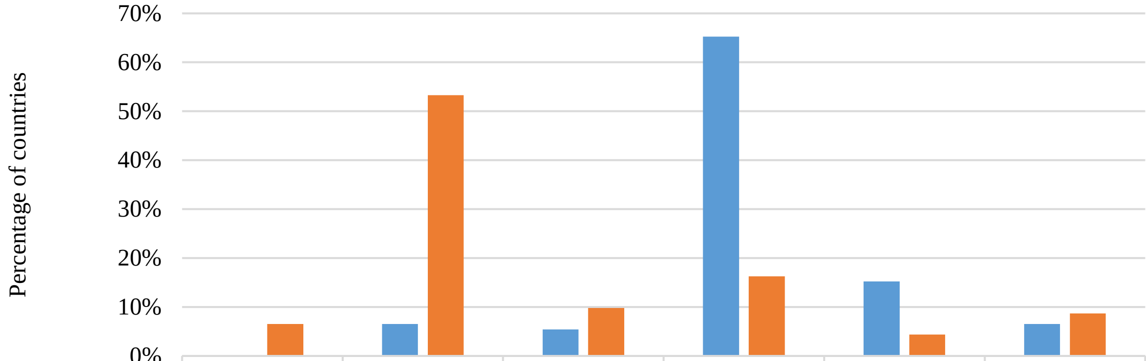
Modernization of legal frameworks and institutional reforms can assist to rectify this, especially in the area of water management, aquaculture zoning and biosecurity (see Chapter 8).

3.1.4 Increased wealth and demand for fish

Eighty percent of respondent countries considered that increased wealth would positively affect farmed aquatic genetic resources (Figure 3.4).

Expanding economies and increasing wealth drive demand for seafood products, and aquaculture products form part of this demand. There is some evidence that increasing urbanization leads to a slight decrease in the relative amount of fish consumed (relative to other meats), but overall total consumption increases as economies develop due to increased purchasing power (Delgado *et al.*, 2003). Long-term projections indicate a general decline in global per capita fish consumption, but this would be more than compensated by greater overall demand due to population increase (World Bank, 2013; Delgado *et al.*, 2003).The Country Reports indicated that positive impacts of increased wealth and national economic development are seen as driving demand for fish, which is often a more expensive food in many countries. This was evident in increasing wealth of urban populations (e.g. as diverse as China and the Democratic Republic of the Congo).

Figure 3.4
Effect of increased wealth on aquatic genetic resources



	Strongly negative	Negative	No effect	Positive	Strongly positive	Unknown
Farmed	0%	7%	5%	65%	15%	7%
Wild relatives	7%	53%	10%	16%	4%	9%

Increasing wealth and greater interest in healthy eating was considered by several country respondents to be driving the increased demand for seafood. This also promoted growth in demand for fish as a healthy food, particular in middle income families. Several countries noted that low incomes and poor economic conditions were a limiting factor in their population's ability to access fish.

The lowering of fish prices through aquaculture was also seen as a positive effect on affordability of fish. The growth in demand was seen as a positive commercial incentive for aquaculture development. One outcome was the introduction or development of aquaculture for commercial exotic and native species to meet new market demands.

There were limited examples of negative impacts with only 7 percent of countries reporting this outcome. Increased urbanization and standardization of aquaculture products may also have some negative impact on the range of species being cultured. This occurs as urban consumers purchase increased amounts of processed fish commodities (e.g. frozen white fish and salmon fillets, shrimp, surimi products), or convenience food (e.g. fish sticks), and hence there is less demand for a broad diversity of species, which may require more elaborate preparation. The change in preference from traditional freshwater species (e.g. cyprinids) to imported marine sourced seafood is another aspect of preference enabled by increased wealth and improved international value chains.

Some countries (e.g. Morocco) described the growth in demand for better quality fish. Increasing urbanization and economic development also see the emergence of longer value chains, supermarkets and increased processing and standardization of products. Aquaculture is well placed to meet the specific demands of supermarkets, which include: consistent quality, reliable supply, standard product form and dependable food safety.

There was also an increasing interest in indigenous species, especially as wild relatives become harder to obtain or more expensive. Growing affluence creates demand for luxury products and aquaculture responds to this demand. The rise of salmon, trout, shrimp and sturgeon (for caviar) aquaculture are classic examples of how aquaculture has been able to bring previously inaccessible and expensive foods into commodity chains available worldwide.

Over the last two decades (1995–2015) there has been a substantial increase in trade in many aquaculture products based on both low- and high-value species. New markets have emerged in developed, transitioning and developing countries. Aquaculture is now a significant contributor to the international trade in fishery commodities. This is dominated by high-value species such as salmon, seabass, seabream, shrimp and prawns, bivalves and other molluscs but also includes lower-value species such as tilapia, catfish (including *Pangasius*) and carps. These low-value species are traded in large quantities within and between countries in two main regions (Asia and Latin America) and are increasingly finding markets in other regions (e.g. *Pangasius*, tilapia) (SOFIA, 2014).

Increased wealth is also linked to increased interest in high value ornamental fish, where markets are largely found in cities and economically developed contexts. Trade in live fish includes ornamental fish, which are high in terms of economic value but almost negligible in terms of quantity traded (FAO, 2014a). It is probable that more than 870 freshwater and marine species are cultured for the ornamental trade,[19] but they are not officially reported at National and FAO levels in most cases.

The impact of increased wealth on aquatic genetic resources of farmed organisms is therefore greater attention to improving strains, diversification and experimentation with new species to address demands from niche markets.

Country responses were mixed as regarding the impacts of increased wealth on wild relatives. 60 percent considered there would be overall negative impacts. The country responses described increased demand would drive fishing effort with negative consequences for wild capture fisheries.

Increased wealth may drive demand for wild relatives of some species for food (e.g. Bluefin tuna, sturgeon caviar, live reef fish, sea cucumber) and for ornamental fish keeping (e.g. Arowana species, marine aquarium species). It was also considered that this demand would drive IUU fishing for some species, particularly those that are threatened or protected.

Twenty percent considered the effects of increased wealth were likely to be positive. The respondents' explanation was that increased wealth would boost consumption of fish from capture fisheries, but that consumers' increasing wealth would result in greater awareness concerning responsible and sustainable exploitation. There was some consideration that aquaculture was in a position to provide fish that were equivalent to the species currently obtained from wild stocks that were under pressure.

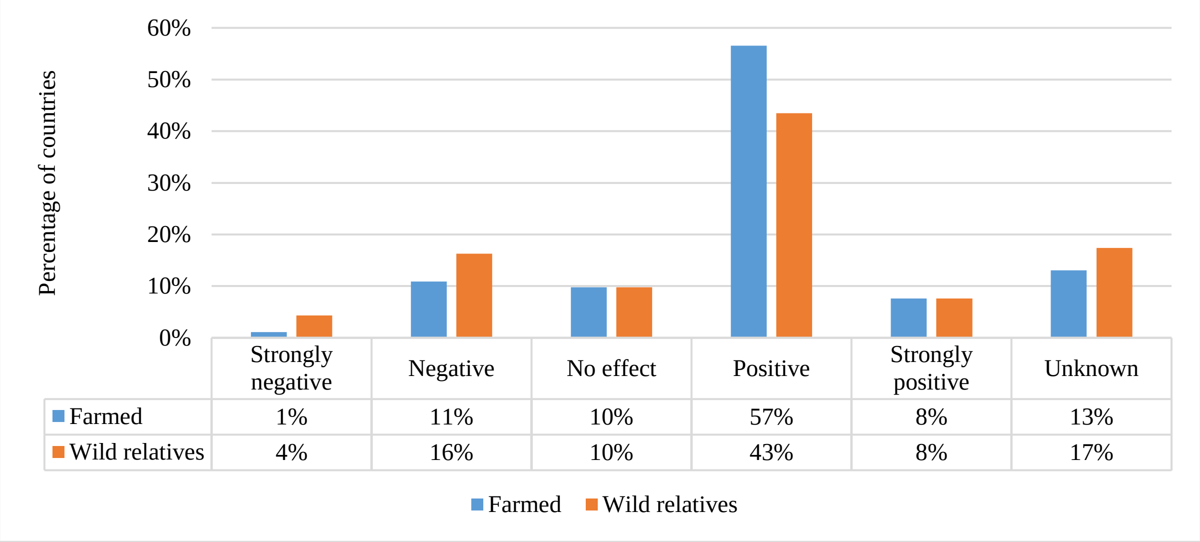
3.1.5 Human food preferences and ethical considerations

Sixty-five percent of responding countries considered that human preferences and ethical considerations would have a positive impact on farmed type aquatic genetic resources (Figure 3.5).

---

[19] Based on an assumption that 95 percent of freshwater species (>850 species) and 5 percent of marine species (~1 400 species) are cultured.

Figure 3.5
Effect of human preferences and ethical considerations on aquatic genetic resources



There is developing interest in fish as a healthy food and this drives an increasing demand for fish in the diet. When linked to population increase this becomes a significant driver in the global demand for fish. Consumer preferences and ethics will have an additional impact on which species of farmed type fish and their characteristics become the highest priority in the market. These consumer preferences will be quite diverse according to a range of socio-cultural factors, and will therefore affect the demand for particular farmed types including the preferences listed in Table 3.6.

Table 3.6
Features affecting consumer preferences and their relevance to genetic characteristics of farmed type aquatic genetic resources

Preference	Feature	Genetic and or culture characteristics
Appearance and taste	External colouration	Preference for red strains of tilapia over darker natural colouration A strong (fundamental) feature in the ornamental trade.
	Flesh colour	Preference for white fish and avoidance of yellow/grey flesh (note this can be affected by the diet. Different levels of red colouration in salmonids.
	Body shape	This is typically to maximize the fillet or dress out weight (or head to tail ratio in shrimp). In some cases there is a preference for a larger head (bighead carp) Body shape is a major factor in selection of fish in the ornamental trade.
	Taste and texture	Dependent upon the species (flesh qualities). Osmotic tolerance – salinity can influence the saltiness of the fish, and in the case of shrimp lower salinities can make the flesh taste sweeter as amino acids are used to maintain osmotic balance. Culture method and feeds used will influence the fat levels in the flesh.
	Processing	Increased interest in sashimi, smoked, dried forms of particular farmed types.
Cost	High value	High value species which are farmed types of high value wild relatives (tuna, grouper, halibut, lobster, shrimp, salmon, etc.). These may still be cheaper than wild relatives.
	Low value	Lower value species that are affordable and which can be produced in systems with low production costs per unit (e.g. tilapia, *Pangasius*, carp, catfish).
Fish welfare	Domestication	Manner of production, suitability for higher intensity of production
		Perceptions of stress to the animal.
		Reduced stress in the case of domesticated farmed types.
	Indigenous *vs.* exotic	A preference for indigenous species to avoid threat of introduced/exotic species.

Other environmental concerns		Organic certified production may require use of indigenous species
Genetic manipulation	Transgenic methods	General preference to avoid GMO is expressed in a number of Country Reports.
	Monosex/sex reversed	Preference for genetically manipulated monosex/sterile animals versus concern over use of hormones.

The price of fish is a strong driver concerning consumer choice between wild and farmed fish, as well as the particular species. The eventual price to consumers is dependent upon the cost of production and this can be strongly influenced by genetic characteristics of the farmed type being produced.

Twelve percent of the respondents considered that there would be negative effects on farmed fish. There are some consumer concerns regarding welfare of cultured fish. This has been accompanied by some regulation (e.g. European Union (Member Organization)) and the development of health standards by OIE for welfare, slaughtering and transportation.[20] It may be considered that successive breeding of captured stock results in a domestication process, whereby fish become more tolerant of crowding and the conditions imposed by cages, raceways or ponds than their wild relatives.

A major challenge in developing improved aquaculture breeds will be consumer perceptions and ethical concerns regarding the sustainability and ethical basis for modern aquaculture. This links to fish welfare, perceived environmental impacts and possibilities of escapees and their impacts on wild populations. Another emerging concern is the use of GMO and transgenic organisms. It is still unclear how consumer perceptions will influence developments here, and there is currently only one approved GMO/transgenic species (Atlantic salmon) being commercially farmed (in Panama) for food production in aquaculture.

There is general concern over the use of GMO and transgenic techniques in aquaculture and to date there are only a few examples of transgenic organisms being studied in research facilities. Limited examples are modification to increase growth rates and increased performance under cold temperatures (examples: Atlantic salmon, chinook salmon, rainbow and cutthroat trout, tilapia, striped bass, mud loach, channel catfish, common carp, Indian major carp, goldfish, Japanese medaka, northern pike, red and silver sea bream, walleye, seaweed, sea urchin and artemia) (Rasmussen and Morrissey, 2007; Beardmore and Porter, 2003). Transgenic fish have been produced for the aquarium trade (altering fluorescence or colouration).

Positive impacts on wild relatives (51 percent of respondents) are linked to increasing consumer concern over unsustainable extraction of species from the wild and increasing calls for sustainable management and sourcing policies. Changing attitudes were seen to be leading to increased efforts to preserve or sustain stocks of wild relatives, which is linked to the improved governance and impact on fishery management. Changing attitudes are also linked to the rise of eco-labelling and certification of capture fisheries.

Twenty percent perceived negative impacts on wild relatives. This was seen as the negative effect of demand or preference for wild stocks and unregulated poaching and fishing for food.

The retention of catch of wild relatives from recreational fisheries was identified as negative by a number of countries, but it was felt that changing attitudes would eventually resolve this in a positive way in the form of catch and release recreational fishing.

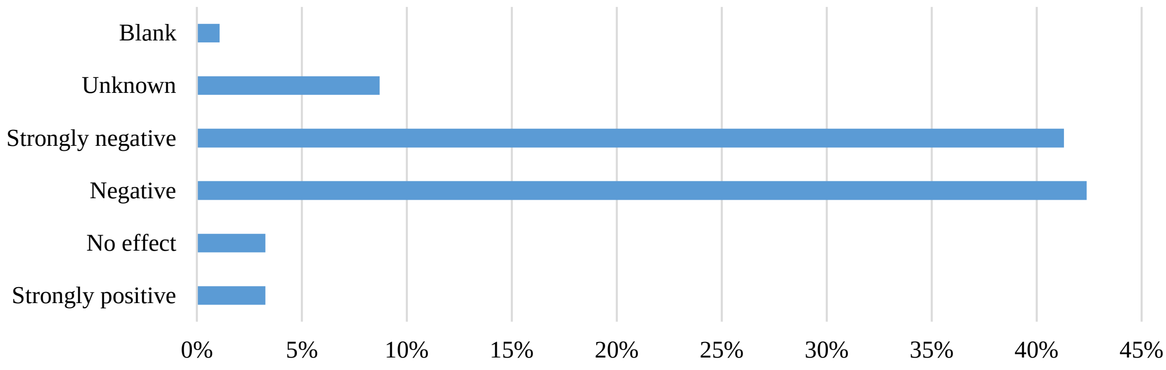
[20] The OIE Aquatic Animal Health Code (the Aquatic Code) sets out standards for the improvement of aquatic animal health and welfare of farmed fish worldwide, and for safe international trade in aquatic animals (amphibians, crustaceans, fish and molluscs) and their products. www.oie.int/international-standard-setting/aquatic-code/

3.2 Drivers that are changing aquatic ecosystems

3.2.1 Habitat loss and degradation

This was almost universally considered a negative impact by respondent countries (84 percent). The limited responses that considered habitat loss in a positive way, described how their country was activity addressing the impact of habit loss. In this regard it is interpreted that all countries viewed habitat loss as negative impact (Figure 3.6).

Figure 3.6
Effect of habitat loss and degradation on aquatic ecosystems that support aquatic genetic resources



	Strongly positive	No effect	Negative	Strongly negative	Unknown	Blank
Farmed	3%	3%	42%	41%	9%	1%

Percentage of countries

The types of habitat loss were variable between countries and generally related to the impact on the natural environment and wild relatives, rather than impacts on farmed types. This is presumably because the aquaculture environment is actively managed to avoid or mitigate these impacts.

Countries identified the need to address hydro-morphological degradation of the watercourses as a result of dyke construction as protection against flooding, obstructing features to regulate flow-off, water damming and energy generation measures. This is mainly owing to the impact of water management (irrigation, damming, flood control, hydro-electric power generation). To ensure water connectivity and maintenance of (near-) natural water flows, the need was recognized to promote the development of regulatory measures to ensure near-natural conditions and improved passability of the water bodies (e.g. European Union Water Framework Directive 2000/60/EC (WFD)).

Improving the management of water in large water bodies, including reservoirs, to ensure fish migrations was also noted. This is a particular mitigation of the impact of large dams on water flow and connectivity. Adjustment of the water level in reservoirs during spawning and supporting longitudinal permeability by functional fish ladders were noted as good management strategies.

Mitigating the impact of lost habitat connectivity in floodplains, rivers and other aquatic systems was identified by Country Reports. This is also an impact of water management, but also land use change, development of floodplains and urban and industrial development. Agriculture changes may also have a strong impact on floodplains and water connectivity. The development of improved connectivity between isolated areas and habitats through engineering of hydrology and provision of fish ways, and other courses for movement of aquatic animals are further recommendations.

Several strategies were identified for the mitigation of the loss of natural habitats through environmental degradation, water management and land use change. These include:

- Develop conservation and protection of critical breeding and nursery habitats.
- Delineate and protect breeding areas in the lakes and rivers and develop networks of spawning areas along the larger rivers.
- Establish fish sanctuaries and dry season refuges.
- Restore habitat in freshwaters seeks to restore environmental quality and habitat of spawning and juvenile grounds.
- Protect watershed land cover (vegetation) and riparian vegetation are important habit measures outside of the water.
- Restore river side arms to improve habitat quality for riverine fish.
- Revitalize riverbeds for improving flow/scouring.

Mitigation of impacts from overfishing focuses on recruitment and protection of broodstock, particularly through the establishment of protected areas/closed areas and implementing closed fishing seasons to protect nurseries and broodstock.

Stocking of degraded systems is an activity to which countries commonly referred, and can increase the potential production from degraded aquatic and marine systems. However, it needs to be undertaken responsibly to avoid further degradation or negative impacts. This includes responsible choice of stocking strategies, species used and how to manage the outcomes, all of which require effective planning and appropriate monitoring and evaluation. Stocking programmes are often poorly monitored and their outcomes are sometimes questionable (Cowx, Funge-Smith and Lymer, 2015).

Reduction of erosion, pollution and impact from land based sources (especially agriculture and forestry) are important for freshwater, as well as estuarine and delta, systems. This can be achieved by improved agriculture practices to reduce soil erosion (e.g. terracing, reforestation, conservation agriculture). Active promotion of agricultural practices which reduce soil erosion and the consequent improvement in the quality of water in streams and rivers can have a major impact on the health of aquatic ecosystems. This is also enhanced if there is limitation of waste water and land management to reduce external nutrient and solid substances load to waters.

Addressing pollution from all sources will have positive impacts on aquatic ecosystems and habitats, in particular from urban and industrial sources. The reduction of pesticide and nutrient runoff from agriculture is also an important outcome that can be promoted by improved regulation as well as relevant economic incentives.

Conservation of habitats in estuarine systems includes delta and mangrove systems. In the marine areas this principally focuses on the establishment of marine parks, coral reef and seagrass protection. Protection of critical habitats and breeding grounds outside of these environments (e.g. marine fishery spawning grounds and nursery areas) are also important actions. Development of artificial reefs to restore habitat may protect habitats from further degradation from human disturbances (active fishing gears).

Strengthened regulatory systems need to be put in places to achieve these outcomes. Steps include:

- effective EIA in place for all major infrastructure projects that may impact aquatic ecosystems;
- effective legal support for conservation of genetic resources in the planning of hydropower projects;
- establishment of protected areas;
- regulation on the prevention of escapees;
- general measures should aim at habitat conservation and restoration, as well as at establishing protected areas for aquatic genetic resources;
- implementation of community based management;
- spatial planning and zoning of aquaculture; and

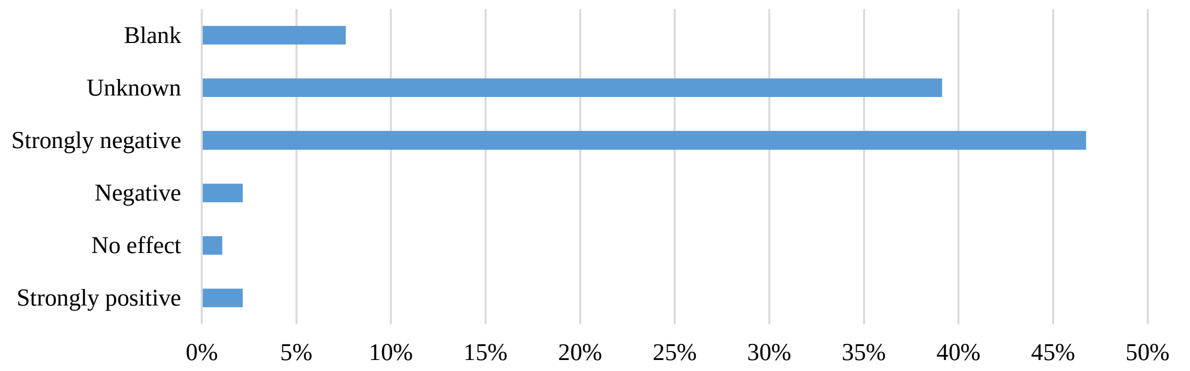
- more effective water management to balance needs for agriculture, drinking water and sustained aquatic ecosystems.

It should be mentioned that, for example, recreational fishing may have both positive and negative impacts on AqGR. There are drivers for improving the conservation of wild relatives both in terms of conserving their habitats as well as populations. In terms of reducing the fishing impact on wild relatives, most recreational fisheries have regulations aimed at conservation of the stock.

3.2.2 Pollution of waters

Eighty-six percent of respondent countries recognized the negative impacts of pollution on ecosystems and consequent effect on AqGR (Figure 3.7). Both freshwater and coastal waters are impacted to varying degrees by pollution, and this has a direct impact through acute toxicity or chronic, sub-lethal effects which can affect reproductive performance, causing mutations or deformities, or bio-accumulation.

Figure 3.7
Effect of pollution on aquatic ecosystems that support aquatic genetic resources



	Strongly positive	No effect	Negative	Strongly negative	Unknown	Blank
Farmed	2%	1%	2%	47%	39%	8%

Percentage of countries

Identified sources of pollution entering open waters were:

- urban sewage discharges;
- industrial discharges, including both routine and accidental spillages, as well as air borne contamination, leading to heavy metal, organic halogen compounds entering the water cycle;
- freshwater runoff from agriculture, logging, and development causing soil erosion and reduced water quality;
- runoff from agriculture leading to eutrophication and pesticide contamination; and
- radiation contamination in the case of leakage from nuclear power station accidents (Chernobyl and Fukushima).

There were comparatively few examples from the marine environment.

The impacts are more severe on wild relatives, but there can be indirect impacts on farmed types through contamination of water and sediments. It should be noted that only 3 percent of the countries identified this driver as positive on aquatic ecosystems of relevance for wild relatives of farmed aquatic species and less than 2 percent of the countries reported no effect.

Typically, aquaculture operations would not be sited where there is a risk of toxic levels of pollution that could cause the loss of stock. However, aquaculture is vulnerable to accidental release of pollutants (e.g. spillage/discharges in water) as well as to sub-lethal or chronic pollution (e.g. heavy metals or other organic pollutants in sediments and water that may not have been monitored or detected. This is an issue in countries where comprehensive environmental monitoring is not in place.

The specific negative impacts on AqGR vary according to the form of pollution, the sensitivity of the ecosystem fauna and flora and the degree to which the pollution present at acutely or chronic/sub-lethal concentrations. The risks of pollution are direct to fish in terms of poisoning or water quality impacts to aquaculture operations and wild relatives in water courses. There are also risks to consumers from long term consumption of contaminated fish. Table 3.7 below indicates the various type of impacts where pollutants directly affect AqGR (farmed type or wild relatives).

Table 3.7
Types of pollution and their potential impact on aquatic genetic resources

Source of pollution	Typical pollutants	Impacts on AqGR
Untreated or inadequately treated domestic sewage	Organic and inorganic, nitrogen and phosphates	Eutrophication and loss of water quality in of water bodies (ecosystem impact on wild relatives)
		Harmful algal blooms
	Some heavy metals and organic compounds	Sub-lethal effects on performance
		Oestrogen analogues causing feminization and disrupting reproduction
Improperly stored solid waste	Leachates from landfill	A wide range of pollutants from urban and domestic garbage directly toxic to aquatic life
Industrial organic and inorganic wastes	Mining wastes (heavy metals suspended solids)	Direct toxicity Sub-lethal effects on performance
		Clogging of gills, impacts on water quality, fouling of spawning areas
	Heavy metals, organic compounds in industrial wastewater discharges and accumulation in sediments	Direct toxicity in acute cases Heavy metal accumulation (possible impacts on breeding performance in wild relatives (Pyle, Rajotte and Couture, 2005)
Agricultural run-off and wastes	Nutrient runoff from agricultural fertilizers	Eutrophication and loss of water quality in rivers and water bodies (ecosystem shifts), loss of habitat impacts wild relatives
		Harmful algal blooms
	Pesticide runoff	Direct toxicity on wild relatives Indirect impacts on prey organisms
Soil erosion and sedimentation	Suspended solids/sediments	Clogging of gills, impacts on water quality, fouling of spawning areas
	Acidity	Direct acidification impacts
Oil/gas exploration	Oil and oil dispersant Heavy metals and organic compounds in drilling muds and cuttings	Direct toxicity on wild relatives Indirect toxicity on prey (especially in the marine environment)
Power generation	Waste heat (from industry and power generation)	Establishment of warm water invasive species Displacement of wild relatives
Aerosol and atmospheric pollution	Acid rain, acidified land and water runoff mobilizes heavy metals	Direct toxicity of mobilized metals and acidity
	Dioxins from industry/waste incineration	Accumulation in food chains with impacts on reproduction and performance of wild relatives Accumulation in fish used for fish meal
Radioactive waste	Radionuclide release from reprocessing or irresponsible disposal. Relatively point source	Accumulation of radionuclides in wild relatives

In all cases where countries indicated a solution, the response was the establishment of effective regulatory regimes to address pollution and its environmental impacts. These range from legislation to the establishment of water monitoring systems and environmental regulatory bodies. Water purification (of urban and industrial discharges) was noted as an important step and the use of bio-remediation was also noted by some countries.

3.2.3 Direct and indirect climate change impacts

3.2.3.1 Direct impacts of climate change

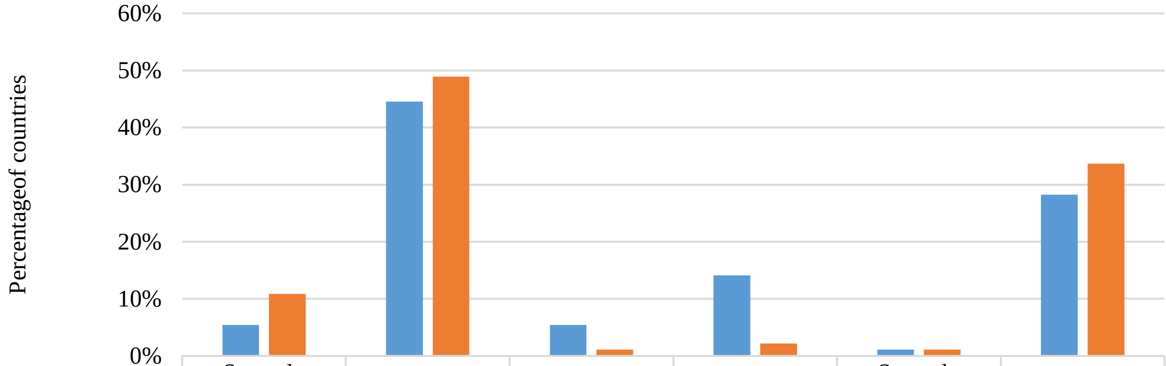
The challenge of climate change also has implications for aquaculture, especially in the warm tropics where species
may be already cultured at the upper end of their temperature tolerance range.

Fifty percent of respondent countries indicated that climate change would have a negative or strongly negative impact on farmed type genetic resources, and most of these felt this was likely to be a strongly negative impact (Figure 3.8):

- increased sea temperatures affecting growout (e.g. Finland; bivalves in Australia and Chile);
- increased incidence of stress and disease mainly as a result of temperature rise, but also changes in water availability and water quality (Honduras; Bangladesh; Canada; Guatemala; Malaysia; the Philippines; Morocco);
- water shortages drying out ponds or reservoirs impacting production or choice of broodstock for the next crop (Colombia; Malawi; Nigeria; Sri Lanka; Uganda; Zambia);
- water levels in reservoirs reduced to the dead zone with water quality issues and temperature rises (Cuba, Ghana);
- delayed rains and seasonal shifts impacting growout season (Venezuela (Bolivarian Republic of));
- combination of high temperature and increased salinity impacting brackishwater culture (Costa Rica);
- temperature and seasonal impacts on reproductive capacity with impacts on hatchery production (Lao People’s Democratic Republic, Benin);
- establishment of invasive species in areas that were previously too cold (e.g. grass carp and common carp in Sweden; Hypostomus plecostomus in Guatemala);
- extreme weather events impacting aquaculture facilities (Nam);
- increased flooding events affecting water quality (Belize, Benin; Sri Lanka) or impacting production facilities (United Republic of Tanzania); and
- abandonment of aquaculture owing to low productivity (Senegal).

There was also a reasonably high degree of uncertainty regarding the impact of climate change on farmed types (28 percent). The country responses indicated that this was largely due to lack of scientific information and consequent uncertainty over how changes in climate driven factors (particularly temperature rise) would impact aquaculture species.

Figure 3.8
Direct effects of climate change on aquatic genetic resources



	Strongly negative	Negative	No effect	Positive	Strongly positive	Unknown
Farmed	5%	45%	5%	14%	1%	28%
Wild relatives	11%	49%	1%	2%	1%	34%

In terms of positive effects, only 15 percent of respondents felt that there would be a positive or strongly positive effect on farmed types. In Hungary, this was attributed to slightly elevated temperatures giving better growth rates in temperate water aquaculture. In Iran (Islamic Republic of), it was considered that increased salinity opens opportunities for cultivation of marine species in lagoons and coastal areas.

There may be other opportunities for expansion of warm water systems into areas which were hitherto slightly too cold for some species. The development of cold tolerant, warm water species is already established (e.g. tilapia hybrids), selection for salinity tolerance (e.g. where there are threats of saline intrusion) and transgenic approaches have greatly increased growth rates in some cold water species (transgenic Salmon). In terms of wild relatives, higher water temperatures may extend the range of native species within large continental rivers and along coasts.

Many respondents (60 percent) considered there would be negative effects on wild relatives (Figure 3.8), generally driven by the ecosystem impacts such as:

- higher sea temperatures impacting ecosystems and reefs (Australia) (e.g. Box 3.1);
- shifting species distributions because of temperature or salinity changes, or inability to shift because of geographical features (bays, lagoons, gulfs), results in loss of stocks (China, Costa Rica, Dominican Republic, Morocco); similar impacts on distributions because of temperature are observed in freshwaters (Germany);
- physiological impacts on reproductive capacity (Mexico);
- loss of species (Burkina Faso, Cameroon, Togo, Cabo Verde);
- effects caused by changing environmental cues for migration, breeding and spawning (Brazil; Colombia; Malawi);
- increased stress leading to disease problems (Zambia);
- acidification impacts on estuarine and marine shellfish (Canada, Honduras, United States of America); and
- drying of dry season refuges and breeding areas (Malawi, Nigeria, Uganda).

There were an appreciable number of responding countries (34 percent) that felt the impacts were still unknown. This was related to an inadequate understanding of the how climate change would impact the complex interactions between ecosystems, wild relatives and their predators/prey, as well as reproduction and other physiological mechanisms. In this level of uncertainty indicates an area where there is a need for improved understanding of climate driven impacts on wild relatives.

Box 3.1

The potential effect of climate change on wild relatives: the case of Australian Abalone

In Feb/March 2011 a catastrophic 'marine heatwave' event occurred off the southwestern coast of Western Australia (WA). During this time surface temperatures rose more than 3°C above long term monthly averages with these being exceeded by 5°C in some locales at its peak. This heat wave coincided with a strong La Niña event and a record strength of local currents. This was regarded as a major temperature anomaly superimposed over a trend of long term ocean warming. Such events may become more common as global warming progresses (Pearce *et al.*, 2011). During this event, significant changes in population numbers were recorded for a number of important seafood species (Caputi *et al.*, 2015) but perhaps the most dramatic was that for Roe's abalone (*Haliotis roei*) for which there are important commercial and recreational fisheries (120-150 tonnes per annum). This species suffered mortality rates of up to 99.8 percent in the northern part of the fishery which represents the northern limit of the distribution of the species.

As a result of the heat wave, the hardest hit fisheries for the species in WA were closed and it was questioned whether the species could ever recover in these locations (Hart, 2015). Plans were made to promote recovery through translocation of surviving stock but prior to initiating such events it was necessary to characterise and understand the genetic structure of stocks. Next generation sequencing was used to develop over 30 000 SNP markers for the species (Sandoval-Castillo *et al.*, 2015). This resource can be used for a range of applications including association studies to identify traits underpinning performance in aquaculture and restocking, adaptation of populations to temperature changes and to understand how both natural selection and domestication selection influence the ability of populations to maintain genetic diversity and to respond to changing conditions. The screening of variation in samples collected from the wild show that 'neutral' SNPs (i.e. DNA markers that are not under the influence of natural selection) support the existence of one single highly connected population across the range sampled. However, when SNP markers under natural selection (i.e. non-neutral markers) were sampled, three genetically distinct groups of populations were identified. Analysis of levels of genetic variation in the remnant populations did not reveal significant loss of genetic variation yet, but this would seem likely in the longer term due to the severe genetic bottlenecks (Sandoval–Castillo *et al.*, 2015).

In the worst hit parts of the fishery, the remnant populations are unlikely to recover or may recover very slowly. Information from the genetic studies can inform the likely genetic implications of translocation or restocking (i.e. from hatchery produced stock) and help identify appropriate source populations. The markers could also potentially be used to identify genotypes that may be more resistant to future heat wave events. Without such intervention, the most likely future scenario is a shifting of production of this species eastward (Hart, 2015).

The only positive considerations of climate change on wild relatives concerned the pressure to develop aquaculture stocks of those species that were disappearing from wild catches. In one case perceived this as an opportunity to expand the range of brackishwater species in delta areas or in species that prefer warmer waters where migration is possible.

3.2.3.2 Indirect impacts of climate change through effects on ecosystems

The indirect effects of climate change are those that arise from changes to aquatic ecosystems that have consequent impacts on AqGR. These drivers are the increased frequency of extreme climatic events and long-term climate change. Sixty percent of respondents considered that the indirect effects of climate change through its impact on ecosystems would be negative (Figure 3.9). There was a relatively high level of uncertainty regarding impacts (33 percent). It was noted that there was a need to assess anthropogenic and environmental factors affecting aquatic ecosystems. The implications of climate change for fisheries and aquaculture should place emphasis on the ecological and economic resilience of fisheries and aquaculture operations to develop an effective and flexible fisheries management system in an ecosystem context.

Many of the impacts concerned terrestrial and freshwater ecosystems and coastal environments, with correspondingly less concern regarding marine systems. The impacts were typically related to the effects on wild relatives, but also included culture systems (farmed types) in some instances. General ecosystems level changes affect water availability, hydrological regimes and habitat. This has a variety of knock-on effects to aquatic genetic resources (Bangladesh; Benin; Brazil; Chile; the Democratic Republic of the Congo; Ecuador; Egypt; Honduras; Kazakhstan; Kenya; Panama), particularly the wild relatives. Impacts on ecosystems such as forests and grazing lands contribute to erosion, soil degradation and consequent impacts on water (Chad).

The most commonly identified threat was related to unseasonal or extreme weather conditions. Heavy rainfall leading to flash flooding was an identified threat. This can cause farmed type stocks to be washed out into the wild and increases the escapee risk/threat. Adaptation measures identified by respondents related to improving the biosecurity of flood prone aquaculture (pond and cage) as an important regulatory and management measure to be introduced.

Unseasonal rainfall and flooding (Cuba, Nigeria, Sri Lanka, the United Republic of Tanzania) can lead to flash flooding. This damages infrastructure but also impacts water quality. Several countries indicated that the restoration of forests and riparian vegetation was an important strategy to reduce flash flooding and erosion.

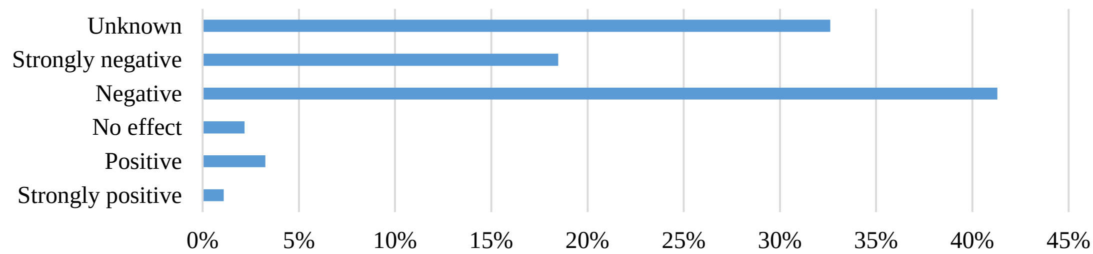
Stocking programmes are being considered for some large water bodies.

The converse of flooding is extended drought periods and unseasonal drying out of water bodies. Reduced water availability in rivers (Belize, Costa Rica, Dominican Republic, Hungary, Kenya) affects wild relatives and availability of water for aquaculture. This loss of water area and/or habitat can have serious consequences on wild relatives, as well as on aquaculture operations that are based in water bodies or dependent upon river flows for water. An extreme or unpredictable environment would drive aquaculture operations to be more self-contained, (e.g. recirculating, oxygenated and fed systems) with minimal contact with the environment.

The adjustment of stocking and harvesting cycles, together with temperature adapted species were proposed as ways to work around problems related to changing and less reliable seasonal weather. Improved efficiency production systems that conserved freshwater were another adaptation.

Sea-level rise and reduced freshwater flows in rivers (due to abstraction or irrigation, climate variability) results in seawater intrusion in delta areas (e.g. Mekong Delta in Viet Nam). This is seen as a negative impact, but it will drive interest to develop salt tolerant farmed types. It will also extend the range of brackishwater species in delta areas. In the coastal zone, mangrove re-afforestation was indicated as a strategy, presumably to improve coastal protection, but also to restore coastal habitats.

Figure 3.9
Indirect effects of climate change on aquatic genetic resources though impacts on aquatic ecosystems



	Strongly positive	Positive	No effect	Negative	Strongly negative	Unknown
Percentage of countries	1%	3%	2%	41%	18%	33%

Percentage of countries

Water temperature rise will enable species to extend their ranges in temperate areas and encourage the establishment of invasive species. Warming temperatures also increases the range of some non-native species or allowed their establishment in the wild. For example, the common carp and Chinese grass carp have become established in the wild in Sweden. This could be viewed as a negative impact on indigenous fauna. Warming can also lead to competition between indigenous species, in the case of brown trout being displaced by common carp in Hungary.

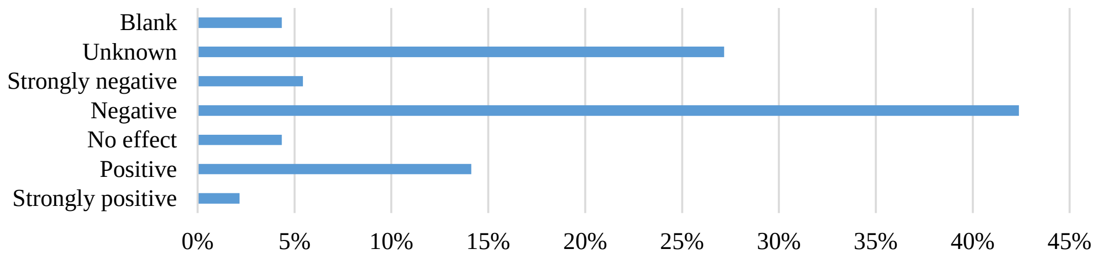
A major indirect impact of climate change is modification or loss of habitat (the Republic of Korea), particularly in floodplain and wetland systems (Burkina Faso, Cameroon, Chad, Romania) and mangroves and mudflats (Ghana, Senegal) can impact wild relatives. This occurs both in freshwater and brackishwater, with declining water coverage in water bodies or drying out of wetlands.

In marine environments, the demonstrable changes are seen in the form of coral bleaching and the consequent impacts on reef ecosystems, however these are not confined to tropical areas and warming waters see ecosystem species shifts in temperate zones, which also increasing the potential for the establishment of invasive species (shipping ballast water, etc.).

3.2.4 Impacts of purposeful stocking and escapees from aquaculture

Just under half of country responses (47 percent) indicated negative impacts on wild relatives due to ecosystem impacts from purposeful stocking and escapees from aquaculture (Figure 3.10). These responses were mostly related to the genetic issues of poorly managed stocking programmes and negative interactions of aquaculture stock with wild relatives. These negative interactions are both genetic (e.g. inter-breeding of escaped farmed types with wild relatives, transmission of disease) and ecosystem-type impacts (e.g. predation, competition for resources and space, etc.) as described in the section below on invasive species.

Figure 3.10
Impacts of purposeful stocking and escapees from aquaculture on wild relatives of farmed aquatic species



	Strongly positive	Positive	No effect	Negative	Strongly negative	Unknown	Blank
Percentage of countries	2%	14%	4%	42%	5%	27%	4%

Percentage of countries

Twenty seven percent of countries responded that there were unknown effects regarding the impact of this driver on aquatic ecosystems of relevance for wild relatives of farmed aquatic species. This highlights the existing gap regarding the scientific assessment of negative and/or positive effects (pathogen-related, socio-economic, environmental, ecological, and genetic effects) of purposeful stocking and escapees from aquaculture in natural aquatic environments. This is an important consideration noting that the stocking of open waters is considered a mitigation of impacts on fisheries or a fishery enhancement strategy in a number of countries.

Sixteen percent of countries considered there were positive impacts of purposeful stocking and escapees on wild relatives, and these responses were largely based on the perceived positive impacts of culture based fisheries and stocking to establish capture fisheries and species recovery programmes. Stocking programmes are rarely objectively evaluated (Cowx, Funge-Smith and Lymer, 2015).

Few countries (4 percent) considered there were no impacts.

The variability in the country responses is partly due to the combination of purposeful introduction and aquaculture escapees (which are typically an accidental event). This inevitably results in a range of responses from countries which consider culture based fishery and fishery enhancements as largely positive or having no overall impacts, versus those countries which had experiences of aquaculture escapees which they consider to be a negative impact. It is not possible to clearly disaggregate between these two issues. Future questionnaires will need to treat these two issues separately.

The extent of the movement of aquatic species between countries and regions is not well documented. FAO has initiated a Database on Introductions of Aquatic Species (DIAS), but it is now in need of updating to support a strengthened understanding of the state of the world's aquatic genetic resources. (Box 3.2).

Box 3.2

The useful information contained in the FAO Database on Introductions of Aquatic Species (DIAS)

The FAO Database on Introductions of Aquatic Species (DIAS) was initiated in the early 1980s. Initially, it considered primarily only freshwater species and formed the basis for the 1988 FAO Fisheries Technical Paper No. 294. Today DIAS has been expanded to include additional taxa, such as molluscs and crustaceans, and marine species. In the mid-1990s a questionnaire was sent to national experts to gather additional information on introductions and transfers of aquatic species in their countries.

The database includes records of species introduced or transferred from one country to another and does not consider movements of species inside the same country. The database contains more than 5 500 records of aquatic species introductions, which include minimum information such as the common and scientific name of the introduced species and the countries of origin and destination. Additional information, such as the date of introduction, the introducer, reasons for introduction, and detailed introduction features (status of the introduced species in the wild, establishment strategy, aquaculture use, reproduction features, ecological and socioeconomic effects, etc.) are also available for a certain number of records.

DIAS can be used to establish purposes for introduction and their subsequent outcomes. Comparisons can be made on the beneficial versus adverse impacts of introductions. This can be further broken down into the purpose of the introduction (including accidental introductions) and the pathway of that introduction. There is also information on the donor and recipient countries.

This database is now in need of considerable updating as the extent of movements has accelerated with the boom in aquaculture around the world and the increasing diversity of species being farmed. This is perhaps most notable in Asia, but trans-continental movements have also been increasing.

3.2.4.1 Impacts of purposeful stocking

Stocking through formal stocking programmes is generally recognized as an important tool to compensate for losses in fish productivity and fish species diversity. Stocking programmes are widely implemented in many countries across a variety of aquatic habitats but predominantly in inland waters. The major exceptions are salmon stocking programmes and marine ranching in specific countries such as Japan.

In developing countries, the emphasis of stocking is typically on food security and inland fisheries to maximize the supply of protein for human consumption. Since most inland water systems have now reached their maximum potential natural production, rising demand is now pushing fisheries managers to maximize yields in tropical waters through enhancement. In many countries this process is now advanced and the infrastructure to cope with the required production of fingerlings for stocking has been developed.

In developed countries there may be less emphasis on food fisheries and stocking is part of private or government sponsored programmes to sustain recreational fisheries or as part of conservation initiatives (Table 3.8).

Table 3.8
Differing strategies for management of inland waters for fisheries in developed and developing countries

	Developed (temperate)	Developing (tropical)
Objectives	Conservation Recreation	Provision of food Income/livelihoods
Mechanisms	Recreational fisheries Habitat restoration Environmentally sound stocking Intensive, discrete, industrialized aquaculture	Food fisheries Habitat modification Enhancement through intensive stocking and management of ecosystem Extensive, integrated, rural aquaculture
Economic	Net consumer Capital intensive Profit	Net producer Labour intensive Production

Source: after Welcomme and Bartley 1998a, b.

There are five different types of fishery enhancement system that utilize AqGR (Lorenzen, Beveridge and Mangel, 2012). These are either aquaculture-related activities using farmed type or hatchery-produced individuals for release, or have conservation or capture fishery objectives. In the latter case these will be targeting stocks or wild relatives. Each of these systems has a different primary purpose and involves quite different management practices (Table 3.9).

Table 3.9
The five types of fishery enhancement system that involve stocking

Enhancement type	Primary purpose(s)
Culture-based fisheries and ranching	Increased fish production
	Creation of recreational fisheries
	Bio-manipulation
Stock enhancement	Sustaining and improving fisheries in the face of intensive exploitation
	Sustaining and improving fisheries in the face of habitat degradation
Restocking	Rebuilding depleted populations
Supplementation	Reducing extinction risk
	Conserving genetic diversity
Re-introduction	Re-establishing a locally extinct population

Source: from Lorenzen, Beveridge and Mangel, 2012.

Provided that the conditions are conducive and the enhancement measures well-designed, these enhancements can be effective in increasing fisheries yields for food or income, or as opportunities for recreational fishing and wider socio-economic benefits. In practice, many enhancements are likely to be ineffective and some have caused demonstrable ecological damage.

More commonly, the need for introductions arises as a consequence of human activities. Many new reservoirs lack native species capable of fully colonizing lentic waters and there is interest in developing commercial fisheries through species introduction, for example:

- *Limnothrissa miodon* introduced in Lake Kariba;
- *Neosalanx taihuensis* (“Icefish”) introduced to many Chinese reservoirs;
- *Cyprinus carpio* (Common carp) in Lake Naivasha and Tana River hydro-electric power Dams (Kenya);
- economic impact of the establishment of *Lates niloticus* (Nile perch) fishery in Lake Victoria (Uganda/ Kenya); and
- *O. niloticus* and *O. mossambicus* (Tilapia) in Sri Lanka freshwater irrigation tanks and reservoirs.

Much of the stocking that takes place in the Asian region can be more narrowly classified as culture-based fisheries. Culture-based fisheries and ranching systems are used to maintain stocks that do not recruit naturally, i.e. they are not self-reproducing, and typically the seed for stocking is derived from aquaculture hatcheries. Some of these culture-based systems are relatively closed, take place in man-made water bodies or highly modified water bodies, and thus can be considered an extensive form of aquaculture.

Recently, there have been increasing concerns about the potential risks associated with the stocking and introduction of fish, particularly with respect to ecosystem functioning, changes in community structure and losses of genetic integrity. Although the stocking and introduction of species may have had obvious benefits, they are not without cost, and the issue of introducing fish species is highly controversial.

Many stocking activities, both deliberate and accidental, have had negative effects on indigenous fish communities and other fauna through predation, competition, introduction of pathogens and change in ecosystem dynamics. The effects of hybridization, loss of genetic integrity and reduction in biodiversity are also issues that must be considered.

Of particular concern are shifts in food-web structure and trophic status that may occur, and the impacts that these could have on indigenous flora and fauna. In addition, stocking or introductions may lead to competition with or predation on indigenous biota (Hickley and Chare, 2004; van Zyll de Jong, Gibson and Cowx, 2004; Lorenzen, 2014). This can have serious implications for waterbodies that are part of designated conservation sites or support protected plant or animal species. These impacts are summarized in Table 3.10.

Table 3.10
Potential detrimental impacts associated with stocking activities in a hierarchy from species-specific to ecosystem-wide outcomes

Impact	Cause
Increased intra-specific competition	Increased abundance of the species by the addition of hatchery-reared fishes
Shifts in prey abundance	Change in the abundance of prey species due to increases in fish predator abundance as a result of stocking
Prey-switching by wild predators	Changes in the targeted prey of wild predatory species, usually to focus on hatchery reared (naïve) fishes due to large numbers released
Starvation/ food limitation	Overstocking
Exceeding the carrying capacity of an ecosystem (swamping)	Continued stocking after recovery of a stock
Inter-specific competition	Competition between hatchery-reared fish and other species with similar ecological requirements. May lead to a reduction in abundances of competing species and prey species
Displacement of wild stock	Displacement by hatchery-reared conspecifics, although there are no well documented examples
Introduction of diseases and parasites	Poor hatchery management and husbandry of fish to be stocked
Genetic bottleneck	Lack of genetic management of broodstock within the production system of the fish to be stocked. A common problem of poorly designed stocking programmes.
Loss of genetic diversity and fitness	Certain alleles of wild fish may become rare due to the release of hatchery-reared fish with a low genetic diversity. This is of higher risk where the wild stock is reduced to low levels prior to stocking.
Extinctions	The loss of species due to increase in the abundance of released fish and ecosystem shifts
Ecosystem shifts	Shifts in the distribution of biomasses or other species, possibly resulting in the loss of other ecosystem values

Source: Adapted from FAO, 2015.

A major weakness of many stocking programmes is the failure to evaluate fully the outcomes of the activity or limiting the evaluation of their effectiveness, in terms of benefits as well as adverse impacts (FAO, 2015). An example of good practice in this regard is presented in Box 3.3.

Box 3.3
Case example of the value of effectively assessing national AqGR to inform stocking initiatives

It is important to have adequate knowledge of specific genetic features and characteristics in order to protect genetically independent populations from the harmful effects of stocking and resettlement measures. In this connection, the Federal Ministry of Food and Agriculture of the Germany (BMEL) is currently engaged in a pilot-type project for the molecular genetic documentation of genetic management units of crayfish, brown trout, lake trout, sea trout, barbel, burbot, grayling and tench. The knowledge gained during this project is to be incorporated in practical recommendations for the stock management of these species. The aim has to be to respect the genetic diversity in the entire distribution area of a species on population level, and to preserve such species as "evolutionary entities" with their regional genetic and phenotypical characteristics as well as to secure their stocks in the long term. This not only serves the purpose of species protection but also promotes fish stocks that are regionally well adapted to prevailing conditions. This information will also be made available in the Aquatic Genetic Resources Deutschland (AGRDEU) database for those active in the fish-related management of bodies of water.

3.2.4.2 Purposeful stocking in recreational fisheries

Recreational fishing has traditionally been a developed country activity, but it is becoming more popular in developing countries. Recreational fisheries are also engaged in the stocking of open waters and rivers to enhance recreation fisheries (e.g. trout, salmon) using material from aquaculture hatcheries. This may have some impact on interactions between wild relatives and the cultured stock. Some recreational fisheries introduce and translocate species. In some cases non-native species are introduced from recreational fishing for example:

Latin American species such as pacu, arapaima and redtail catfish have been introduced to Asia;
North American species such as rainbow trout and black bass introduced to Europe; and
the movement of the European catfish (Wels) has resulted in its subsequent establishment beyond its natural range within Europe.

3.2.4.3 Impact of escapees from aquaculture

Escapees from aquaculture have a range of potential impacts on AqGR, particularly with respect to wild relatives, although there are also threats to farmed types. Farmed types escapees from aquaculture operations in a number of ways and this has some bearing on how many escapees may get out and their consequent impact in the wild. Pathways for escapees are as follows:

- flooding of aquaculture ponds or ornamental fish ponds releasing fish into nearby waterways (this can result in massive releases, e.g. flooding of coastal shrimp farms);
- escape of farmed types during harvesting operations (usually relatively small numbers as farms take precautions not to lose stock);
- loss of larger numbers during emergency harvest or “dumping” of diseased stock;
- storm/cyclone damage to cages in the sea or freshwater bodies (can be considerable where cages are artisanal, poorly constructed and present in large densities);
- net damage in cages; and
- deliberate dumping of fish (aquarium species) into waterways.

The range of threats that these escapees present is summarized in Table 3.11.

Table 3.11
The range of threats presented by aquaculture escapees on wild relatives and farmed types

Affected	Nature of impact
Wild relatives	Genetic introgression as a result of genetically selected farm types breeding with wild relatives. Note that this has been shown in the case of large scale purposeful stocking, e.g. wild Thai Silver Barb in Thailand (Kamonrat, 1996), and arguably in the case of escaped Atlantic salmon, but there are few other clearly demonstrated examples of this resulting from farm escapees.
	Transmission of disease/parasites to wild relatives.
	Establishment in the wild (invasiveness). Establishment of escaped farmed types can compete with indigenous fauna.
	Maladapted farm types breed with wild relatives. Typical maladaptation in farmed fish include: selection for precocious breeding or out of season breeding (selection for early spawning, or later migration). Less obvious maladaptation for the wild may include less aggressive behaviour. Some of these maladaptations may limit the success of the escapee from successful breeding with wild relatives.
Farmed types	Transmission of disease or parasites between aquaculture farms.
	Establishment of naturalized fisheries that compete with farmed types in the market.

3.2.4.4 Escapees from the aquarium trade

While escapees from the aquarium trade are often limited to individuals and thus the risks of them becoming established are relatively low, the widespread movement of AqGR for the aquarium trade means that species are moved well beyond their range. The real threats are probably more closely linked to escapees from breeding and holding operations. This emphasizes the importance of effective regulation and monitoring of such operations and ensuring that they have adequate biosecurity controls in place. Urban-based breeding facilities are probably relatively low risk, but open pond based systems or riparian operations in peri-urban or rural areas may be vulnerable to flooding or other risks of escape and it is from this type of operation that escapees are more likely to become establishing in open waters.

3.2.5 Establishment of invasive species

There are numerous examples of non-native species that have become established accidentally or deliberately beyond their natural range. Some of these introductions have resulted in adverse environment and economic impacts, i.e. the introduced species became invasive or introduced pathogens into the production system. However, the majority of introductions recorded in DIAS had many more positive social and economic impacts than negative environmental impacts. (Bartley and Casal, 1998).

The FAO Database on Introduced Aquatic Species provides lists of known introductions according to purpose:

- accidental introduction
- aquaculture
- ornamental
- angling/recreational fishing
- biological control

Not all introductions result in the establishment of the species. The Global Invasive Species Database[21] lists 129 recognized invasive species of freshwater, marine and brackishwater ecosystems (Table 3.12).

[21] Global Invasive Species Database (2016). Downloaded from http://193.206.192.138/gisd/search.php (April 2016).

Table 3.12
Global Invasive Species Database list of invasive species of freshwater, brackishwater and marine ecosystems

Taxon	Number of species	Taxon	Number of species
Fish species	51	Ctenopherans (comb jelly)	3
Aquatic plants	17	Brachiopods	2
Bivalve molluscs	17	Echinoderms (starfish)	2
Gastropod molluscs	12	Calanoid	1
Decapod crustacean	6	Amphibian	1
Ascidians	6	Sponge	1
Ectoprocta (bryozoan)	4	Myxosporea (Myxobolus cerebralis)	1
Polychaete worm	3	Fungi (Aphanomyces astaci)	1
Cnidarians	3		

An example of an assessment of the number of species that have been introduced, or moved beyond their natural range within a country, is the United States of America. The United States Geological Service (USGS) lists 759 non-indigenous fish species or species translocated outside of their natural range inside the United States of America.[22] The impact of these non-native species on an ecosystem may range from undetectable, to major ecosystem changes through effects on their prey changes to food chain linkages or other aspects of their behaviour (e.g. burrowing). Sometimes the impact is not directly apparent, and the species is simply an unwanted species, less preferred than other similar native species. Examples of this are presented in Table 3.13:

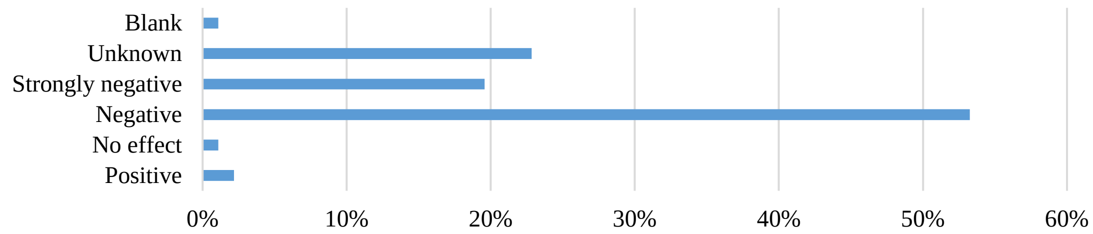
Table 3.13
Examples of impacts of non-native species on ecosystems and wild relatives and farmed types

Introduction of disease	Host for pathogens/parasites which impact native or native species
Effect on food webs	Direct predation of other species
	Predation of eggs of native species
	Transmission of parasites/disease to both wild and farmed types
	Predation on prey species (e.g. insects, zooplankton) of other native fish
Competition	Higher fecundity than native species
	Greater tolerance for adverse environmental conditions Exclude native species from breeding areas Compete for matings
Engineer ecosystems, undesirable behaviour or characteristics	Burrowing behaviour into river banks affecting stability etc.
	Increase turbidity Remove vegetation Crowd out native species
	Clog aquatic habitats impacting flow (e.g. water hyacinth) or benthic habitat (zebra mussel beds)

Seventy three percent of countries considered that the establishment of invasive species as negative, with only 2 percent reporting positive effects (Figure 3.11). This perhaps reflects that while the introduction of species of aquaculture is generally considered positive, the establishment of invasive species in the wild is not viewed in the same way.

[22] http://nas.er.usgs.gov/queries/SpeciesList.aspx?Group=Fishes (accessed April 2016).

Figure 3.11
Effect of establishment of invasive species on the wild relatives of farmed aquatic species



	Positive	No effect	Negative	Strongly negative	Unknown	Blank
Percentage of countries	2%	1%	53%	20%	23%	1%

Percentage of countries

As it is extremely difficult, if not impossible, to eradicate introduced species that become invasive, the best protection is the prevention through more effective biosecurity and control on translocations (Box 3.4). There is also a need to limit or prevent further movement within a country once a species has become established. This is a clear area where there is a strong justification for more effective and comprehensive monitoring of AqGR in general, and invasive species in particular (Germany, the Republic of Korea).

Box 3.4
Impact of invasive mussels on local genetic diversity

Marine mussels are among some of the more successful invasive marine species and there are numerous records of non-native species successfully colonising coastal areas, even across continents. There are a number of studies that have assessed the impacts of these invasions on genetic diversity of both the invasive and endemic species.

One of the impacts of the invasive species can be introgression with local species as has been documented in California. Here the Mediterranean mussel, *Mytilus galloprovincialis*, has been introduced through anthropogenic influences and has been present for several hundred years establishing extensive populations in the wild. In some locations these have displaced the native *Mytilus trossulus*. There are known to be incomplete reproductive barriers between *Mytilus* species. Saarman and Pogson (2015) studied the introgression of the two species across several hybrid zones, where both species occurred, using next generation DNA sequencing (ddRADseq). They identified that, despite the known reproductive barriers, introgression was occurring between the species in these hybrid zones. Heterogeneous patterns of introgression across the zones were consistent with the colonization history of *M. galloprovincialis*. Relatively few early and advanced backcrossed individuals were observed across the hybrid zone confirming the presence of strong barriers to interbreeding. The authors concluded that the threat posed by invasive *M. galloprovincialis* is more ecological than genetic as it has displaced, and continues to displace the native *M. trossulus* from much of central and southern California.

Genetic technologies can be used to inform and understand the nature and extent of invasions. South Africa has a number of invasive species of mussels although *M. galloprovincialis* is the only invader to have extensively colonized parts of the South African coast. Micklem *et al.* (2016) used mtDNA analysis to identify a single population of the invasive Asian green mussel *Perna viridis* in Durban harbour, with the phylogenetic technique capable of distinguishing it from the phenotypically similar indigenous *P. perna*. Zeeman (2016) used the same technique to analyse the origins of invasive mussels on the West Coast of South Africa, confirming the presence of *Semimytilus algosus* and further more indicating that this may have been introduced indirectly from Chile via natural spread from a colonization of the species in Namibia.

Countries also indicated the impacts of non-fish species which impact ecosystems or directly predate fish. Examples include invasive bird species that predate fish have impacts on wild AqGR (e.g. cormorant, *Phalacrocorax carbo sinensis* in Czechia). Mitigation would involve effective elimination of these invasive fish predators. Water hyacinth is a major pest species of water ways and water bodies (Ghana).

Controls and mitigation are achieved through strengthened biosecurity measures or more effective implementation of existing measures. In many developing countries there is a low level of awareness regarding the threat to aquaculture and wild AqGR from invasive species and transfer of aquatic pathogens through movements and introductions.

In several Country Reports there was a consistent theme of the need to develop national guidelines for transfers and introductions of AqGR, and establishment of more effective import risk analysis (risk assessment, risk management and risk communication strategies) for potential invasive species and health threats (Kenya, Thailand, Viet Nam). Examples of risk assessment and guidelines on use of non-native species do exist, indicating a lack of awareness in countries, for example the ICES code of practice (ICES, 2008) on introduction which has been adopted in principle by FAO's inland regional fisheries bodies (see Bartley and Halwart, 2006).

An example where regulations already exist is the EU regulation (REG (EC) No. 708/2007) concerning use of alien and locally absent species in aquaculture. This contains relatively strict provisions for the avoidance of risks associated with the use of alien species in aquaculture (e.g. fauna falsification and the introduction of diseases and parasites).

There have been various efforts to develop economic uses for established introduced species. This is partly to provide an economic incentive for their collection/removal from the wild. Examples include:

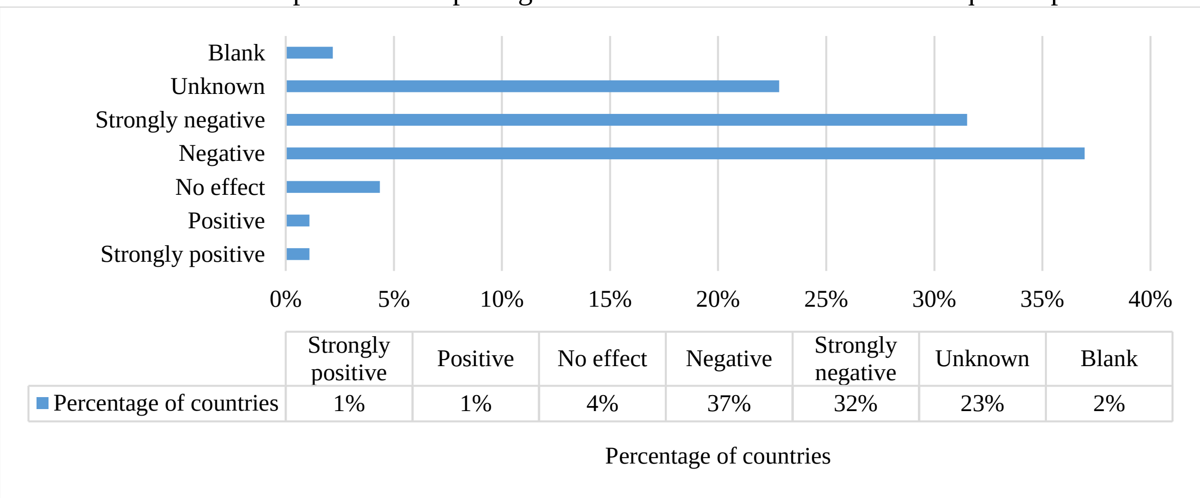
- use as fish meal (e.g. Silver carp in the United States of America; Knife fish in the Philippines); and
- use as aquaculture feeds (Golden Apple Snail in the and Bangladesh).

3.2.6 Introductions of parasites and pathogens

A majority (69 percent) of the surveyed countries reported a negative or strongly negative effect of introductions of pathogens and parasites in aquatic ecosystems of relevance for wild relatives of farmed aquatic species. Twenty three percent indicated an unknown effect for this driver indicating that there remains a knowledge gap on the impacts of pathogens and parasite introductions.

Accidental or purposeful introduction and transfer of aquatic species has been the main source of pathogen and parasite introductions, together with other minor reasons such as ballast water and migrations. Only 2 percent of countries felt the impacts were unknown (Figure 3.12).

Figure 3.12
Effect of introduction of parasites and pathogens on the wild relatives of farmed aquatic species



Species transferred between regions for aquaculture purposes have also resulted in the introduction of diseases, which have severely impacted aquaculture production or stocks of wild relatives. Examples include:

- The Noble crayfish (Astacus astacus) was decimated in the wild due to crayfish plague (Aphanomyces astaci), which was spread via introduction of the Signal crayfish (Pacifastacus leniusculus).
- The spread of Bonamia through European oyster stocks caused by the movement of non-native oysters in Europe, which were resistant to the disease.
- The spread of Penaeid shrimp diseases (Taura syndrome virus; White spot syndrome virus; Infectious hypodermal and hematopoietic necrosis virus; Yellow-head Virus Disease; Hepatopancreatic Acute Necrosis Syndrome) has resulted in massive losses of production periodically since the start of shrimp culture. This has largely occurred through the large-scale translocations of postlarvae or new species for aquaculture.
- Streptococcus in tilapia, and possibly a recently discovered virus in tilapia.
- The swimbladder worm (Anguillicola crassus) in eels introduced in the 1980s constitutes a serious threat to indigenous stocks of eel in Europe. Asian eels are tolerant to the disease but Dutch analyses show that problems with spawning migration of European eel can occur if the infestation is serious enough.
- Various carp viruses have been transferred through movements of fish for aquaculture as well as for the aquarium trade (e.g. Koi Herpes Virus, carp edema virus)
- Transmission of Viral Hemorrhagic Septicemia, Infectious Haematopoietic Necrosis, and Whirling disease in salmonids.
- Various diseases have affected the cultured salmon industry: infectious salmon anaemia and pancreas disease, Furunculosis, Gyrodactylus salaris.
- Wild stocks of Atlantic salmon in Norway (since 1975) have been seriously depleted in freshwater by the monogenean skin parasite G. salaris.
- Epizootic Ulcerative Syndrome introduced to a number of countries has impacted indigenous fish species (e.g. Puntius spp., Channa spp., Clarias spp., Mastacembelus spp.).

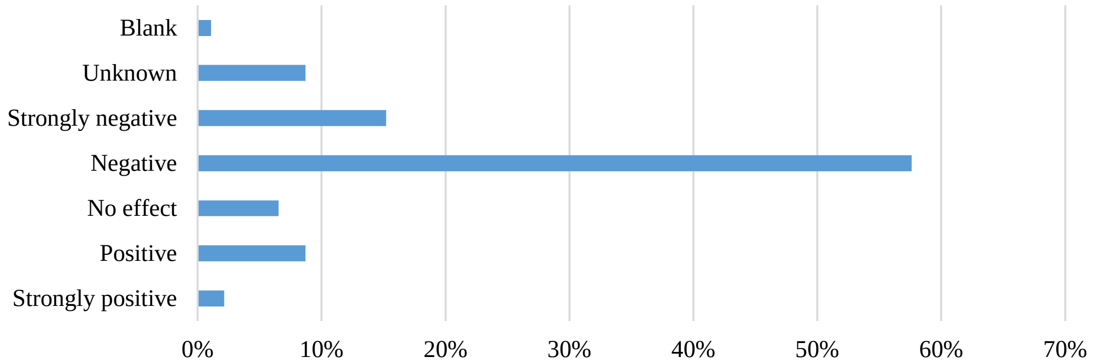
Management and controls to prevent or minimize impacts of spread of aquatic pathogens are similar to those which would be applied to introductions and movements of aquatic species. This is because the spread of invasive species and introduction of aquatic pathogens require similar procedures of monitoring, risk analysis and border controls.

A second level of biosecurity, which is equally important, is the extent to which a country is able to control movements and transfers within its boundaries. Once a disease or invasive species has entered a country, it can still be prevented from spreading between water bodies, watersheds or river basins.
In one country example, the cyprinid herpesvirus 3 (CyHV-3) is being actively considered as a biological control agent to reduce or eradicate populations of common carp from the Murray Darling River (Australia).

3.2.7 Impacts of capture fisheries on ecosystems and wild relatives

Capture fishery impacts on AqGR are most directly linked to impacts on wild relatives where they are directly targeted, and are generally negative (Figure 3.13). Seventy three percent of country responses considered these impacts to be negative or strongly negative.

Figure 3.13
Effect of capture fisheries on wild relatives of farmed aquatic species



	Strongly positive	Positive	No effect	Negative	Strongly negative	Unknown	Blank
Percentage of countries	2%	9%	7%	58%	15%	9%	1%

Percentage of countries

The threats to AqGR via ecosystem impacts are linked to the fishing pressure, the extent to which the fishery is effectively managed and whether the fishery targets vulnerable or critical life stages. In the latter case, fisheries which target juveniles (as in the case of glass eel fisheries) or breeding adults (sturgeon for caviar, targeting of grouper spawning aggregations) (Lovatelli and Holthus, 2008). Fisheries based around spawning migrations may have a disproportionate impact on the populations of wild relatives. This fishing activity may be for the purpose of food or for capture of juveniles for fattening in aquaculture systems (e.g. eel, bluefin tuna, yellowtail, grouper, marbled sand goby, etc.). Two examples of the relationship between aquaculture and wild relatives as a source of seed for aquaculture are explored in Box 3.5.

Box 3.5
Link between wild relatives and aquaculture that depend on wild seed

Spain has a thriving aquaculture sector for the Mediterranean mussel *Mytilus galloprovincialis* producing over 200 000 tonnes per year, making it one of the largest mussel producers in the world. The majority of this production occurs on ropes hanging from rafts, with the bulk of production in Galicia in the northwest of the country. This production is exclusively based on wild caught seed, which is either collected directly from mussel beds on rocky shores or via natural spatfall on collectors hung from the rafts (Camacho, Gonzalez and Fuentes, 1991). The success of this aquaculture sector is fully dependent on the health and viability of the natural populations, which have remained strong in these regions.

Another example of the interdependency of aquaculture and fisheries is the case of yellowtail or amberjack culture in Japan (Ottolenghi *et al.*, 2004). The Japanese have traditionally fished and cultured three *Seriola* species (*S. quinqueradiata*, *S. dumerelli* and *S. lalandii*) with the greater emphasis on *S. quinqueradiata*, known in Japan as the Japanese amberjack. In the decade from 1990 to 1999, aquaculture production of *S. quinqeradiata* ranged from 140 000 to 160 000 tonnes compared to wild catch production of 34 000 to 75 000 tonnes (Nakada, 2000). Aquaculture of *Seriola* in Japan has traditionally relied upon wild caught seed, and still does today, despite the global expansion of *Seriola* culture in other countries such as Australia being based primarily on hatchery reared seed. The main reasons for this are thought to be the reliability of supply and superior quality of wild caught seed and the relative cost of wild caught vs hatchery reared seed. The Japanese government regulates the number of juvenile *Seriola* captured in order to conserve and manage the resource which has the effect of limiting the scale of aquaculture production, but contributes to a relatively stable balance of production between aquaculture and wild catch.

More general fishing impacts on AqGR relate to unsustainable levels of exploitation which threaten the viability of wild populations and thus their future potential as a source of genetic material. Some fisheries may also impact AqGR that are not the target species. These may be “bycatch” issues or habitat impacts (as a result of gear interactions with habitat and consequent impact on a non-target species). An example of this sort of bycatch issue would be the capture of juvenile wild relatives in trawl and push net fisheries (FAO, 2014a).

Country comments on how to mitigate or prevent these impacts proposed the adoption of ecosystem approaches to fishery management that take into account broader ecosystem impacts of the fishing activity beyond the target stocks and which also incorporate habitat and environmental considerations. It was also emphasized for more effective measures be applied to prevent the impact of fisheries on critical life stages and habitats.

Eleven percent of countries considered that capture fisheries had a positive impact on the ecosystem and consequently AqGR (Figure 3.13). This was difficult to interpret, although based on country responses it was generally considered to be that effective fishery management measures were being put in place to address potential impacts on aquatic genetic resources.

Belize reports that fishing pressure on invasive tilapia was keeping the species under control. Bulgaria has implemented a sturgeon fishing ban which has driven aquaculture related sturgeon production. Germany reports that an effective fishery management framework ensures that capture fisheries poses little or no threat to aquatic genetic resources (these threats come from other sources). In the case of freshwater fisheries in Germany, there is an obligation of fishery management to achieve diversity of fish species adapted to that water body/fishery.

Responsibly managed fisheries, e.g. using an ecosystem approach, can be considered as *in situ* conservation (see Chapter 4). This also requires that the fisheries sector would be committed to the protection of aquatic habitats and the protection of aquatic species in addition to the species being targeted by the fishery. Another general consideration is that fishing pressure alone rarely results in the extinction of any fish species, however, it can have long term implications for genetic diversity of species and population causing bottlenecks and genetic drift. Extinctions or loss in the wild is typically more influenced by ecosystem type impacts and change, particularly loss of habitat and changing water quality and flow (in the case of freshwater).

Nine percent of the countries assessed the impact of captured fisheries as unknown.

3.3 Key findings and conclusions

The key findings of the analysis on drivers affecting aquatic genetic resources are summarized below.

Human population increase	Population increase will drive demand for seafood, especially aquaculture products as capture fishery resources become limited.
	This will drive efforts to expand and diversify the farmed species produced and therefore aquatic genetic resources.
	This will also place pressure on wild type stocks, either as broodstock or directly as food.
Competition for resources	A significant proportion of aquaculture production takes place in freshwater aquatic environments, in open water bodies or on land.
	Large open aquaculture systems compete for freshwater and space with other food production systems.
	Demand for freshwater for use in urban supply, for energy production and other uses will challenge aquaculture to become more efficient. This will drive the demand for breeds and systems adapted to lower resource-use footprints.
	Intensification of aquaculture operations will also require increasing attention to be paid to reduction of discharges. This will promote use of species more tolerant to reduced water quality in some systems.

	Rising prices of feed resources and the need to reduce production costs will place emphasis on lower trophic-level systems.
	Further development of marine and brackishwater systems may be driven by reduced opportunities for use of freshwater.
	Wild relatives will be threatened by changes in priorities on use of water (e.g. for irrigation, drinking water supply) and environmental flows in water bodies (especially rivers).
	Pollution from industry, agriculture and urban sources all threaten the quality of water used for aquaculture and to sustain wild relatives.
Governance	Increasing levels of good governance are seen as having an overall beneficial effect on aquatic genetic resources in both farmed types and wild relatives.
	Impacts on farmed types range from improved regulation of farms and their operations (including licensing and monitoring of hatcheries and farms, genetic management, biosecurity) to greater professionalization within the sector.
	Impacts on wild relatives pertain to improved environmental management, better control over farm escapees, improved controls on stocking and movement of aquatic genetic material, the increased use of risk assessment and higher levels of conservation and protection.
Increased wealth and development of economies	Increasing wealth and developing economies are accompanied by greater intra and inter-regional trade and increasing urbanization and industrialization. This drives the development of longer value chains and marketing channels for seafood. This is in response to increasing demand from a growing population (see above), their increased spending power and changing dietary preferences (see preferences and ethics below)
	It is expected that there will be increasing consolidation and industrialization of large volume, internationally traded commodities (e.g. Pangasius, tilapia, salmon, and shrimp). This will drive the development of new farmed types within these commodities.
	There will be increased emphasis on food safety and traceability, which presents challenges to smaller operators.
	At the same time, there will be continuous exploration of new species to satisfy the demand for niche markets, especially as substitutes for limited supplies from the wild. This will drive the development of new farmed types from species currently farmed in low volume, or the development of new farmed types from the wild relative resource.
	Demand for ornamental species will increase, driving the development of farmed types as well as demands on wild relatives.
Changing human food preferences and ethical considerations	With changing demographics, consumer attitudes towards fish are also changing.
	Fish consumption is increasingly recognized as part of a healthy and balanced diet.
	Increasing urbanization will drive demand for seafood as urban populations tend to eat more fish.
	There remains concern over the use of GMO techniques in some markets, including customer resistance. This may also spill over into resistance to other farmed types (e.g. hybrids, triploids).
	There is increasing awareness regarding the unsustainable exploitation of wild relatives and this will drive demand for farmed types (alongside increasingly limited supply from the wild).
	The issue of social license to operate for aquaculture is arising in developed countries and is linked to changing attitudes to animal welfare and perceptions of impacts of aquaculture on the natural environment.
Effect of habitat loss and degradation on ecosystems	Changes in the use of land, water, coastal areas, wetlands and watersheds all have impacts on the quantity and quality of habitat for aquatic genetic resources.
	Water regulation and land use change in watersheds are among the principal factors that affect aquatic systems. Aspects that impact aquatic genetic resources include, among others: damming of rivers, drainage systems, flood control and flood protection, hydropower development, irrigation, partitioning of wetlands and road construction.
	Changing land use can affect water quality and flows related to watershed development, loss of land cover, erosion, soil degradation, agricultural development.
	Water quality can be directly impacted by pollution from industry and urban development (nutrients, heavy metals organic pollutants, solid waste, micro-plastics etc.) and agricultural runoff (nutrients, pesticides).

	Changing land use in coastal areas affects available coastal wetland habitat, the hydrology and quality of coastal waters. This is compounded by impacts of land-based runoff (nutrients, pollution).
	The establishment of invasive species can have direct impacts on aquatic genetic resources through competition or predation, as well as indirect impacts on food webs and ecosystems that support wild relatives.
Direct and indirect effects of climate change	Climate change will have impacts on freshwater availability and changing ambient temperatures, and this will indirectly impact all AqGR through changing ecosystem functions, and directly impact AqGR through their ability to tolerate changes to ambient conditions in aquaculture and the wild, as well as changes to environmental cues to spawning and migration.
	This will have a disproportionate effect on equatorial/tropical regions where species are at the upper end of their thermal tolerance and is considered to be generally negative in terms of impact on aquatic genetic resources.
	Positive effects on farmed types would be thorough greater emphasis on: selection for thermal and low dissolved oxygen tolerance and for lower water use systems; increased geographical range of some farmed types expanding into previously cooler latitudes.
	Emphasis on lower carbon footprint systems will also drive selection of farmed types with lower trophic level feeding habits, increased food conversion efficiency and suitability for low energy systems.
	Impacts on wild relatives are likely to be negative or unknown.

The analysis of drivers and affecting aquatic genetic resources indicates where there are national gaps or room to improve or mitigate. Explanations and additional detail provided in the national reports indicated a wide range of actions that were either proposed or currently being put into place to correct or mitigate these drivers. These are summarized below.

Improving national monitoring of AqGR	Implement surveys of AqGR of both farmed type and wild relatives, and develop comprehensive national databases.
	Strengthen the monitoring within country on the use and movements of farmed types.
	Strengthen access to information on genetic diversity, environmental integrity and aquaculture practices.
	Monitor genetic variability of AqGR wild relatives, especially those threatened or affected by environmental disturbances (e.g. hydro-power plant construction; dams; loss of habitat).
	Update and maintain the Database on Introductions of Aquaculture Species (DIAS).
Improving national capacity to manage farmed type genetic resources	Establish/rehabilitate broodstock development facilities and breeding and hatchery facilities to provide quality broodstock and seed stock.
	Develop adequate supply of domesticated/captive broodstock for farmed type hatchery requirements.
	Enhance public-private cooperation to achieve national level security of supply for key commodity farmed types.
	Develop breeding programs directed to avoid inbreeding and improve record keeping.
Strengthening biosecurity	Establish measures to reduce risks of escapees from farms.
	Promote the use of biological (sterile animals) to reduce impacts of escapees.
	Regulate use and/or production of fertile inter-specific hybrids for aquaculture to avoid genetic introgression with wild relatives.
	Use risk analysis prior to importations, introductions and translocations, including assessments of invasiveness, genetic impacts and disease transmission.
	Ensure responsible stocking of open waters, including effective monitoring of post-stocking impacts.
	Develop effective quarantine systems.
	Improve veterinary surveillance of fish imports.
Promoting more efficient resource use in	Develop more efficient systems that are able to utilize less water per kilogram of production.

aquaculture systems	Develop farmed types with higher tolerance to intensive production systems (and the associated water quality parameters) such as has been achieved with carp, tilapia and Pangasius.
	Improve feed conversion ratio in farmed types to reduce feed demand and to utilize lower quality feeds.
	Develop and promote systems for low trophic level farmed types.
	Reduce reliance on wild seed in those systems that are currently dependent upon this.
	Protect sources of natural seed and their habitats.
Improving farm management	Improve management of farmed type escapees, especially in open water.
	Strengthen disease control systems, especially where there are interactions between farmed types and their wild relatives (bi-directional).
	Develop certification and associated guidelines for hatchery operators.
	Development and application of best management practices in fish farming.
Improving integration with irrigation and water management	Improve the function of water storage and irrigation systems such that they provide benefits to aquatic genetic resources.
	For farmed types, allocate adequate, good quality water and reform water pricing and allocation policies.
	For wild types, improve fish passage in partitioned systems (e.g. migration-friendly water management structures) and improve effective use of water storage bodies in support of sustaining habitat and conservation of stocks.
Reducing the impacts of pollution	More effective management of industrial and urban wastewater discharges.
	Rehabilitate degraded rivers and water bodies.
	Reduce impacts of agricultural fertilizer runoff (through more responsible fertilization methods).
Sustaining or improving habitat and environments for wild relatives	Improve harmonization of fishery and/or environmental legislation to strengthen conservation and protection of wild relatives.
	Develop compensation schemes to re-balance economic priorities in favour of critical habitats for protection of ecosystems supporting wild relatives (including other associated non fish species that depend on fish).
	Promote restoration of critical aquatic habitats.
	Cooperate with other sectors in land use and development or reduce impacts of erosion and deteriorated water quality from runoff.
	Establish freshwater and marine protected areas (e.g. sanctuaries, refuges and Reserves) for conservation and protection of wild relatives, based on genetic, ecological and demographic parameters to conserve genetically distinct populations.
	Implement effective regulatory measures for proper management of wild relatives.
	Use an Ecosystem Approach to planning and management of riparian and open water habitats.
Developing effective stocking programmes that take into account genetic diversity	Implement captive breeding programmes have become the major tool used to compensate the declining fish populations and simultaneously to supplement as well as enhance yields of wild fisheries.
	The genetic structure of the original wild population, which should be determined before any new fish are released into the waters ensuring that the stocked population has the same alleles as the wild population in order to minimize impacts on genetic structure of wild relatives.
Developing in-situ and ex-situ conservation programmes	Establish *ex situ* aquaculture facilities to maintain germplasm of threatened species used in aquaculture operation and restocking programs.
	Explore *ex situ* conservation methods such as: • live gene banks; • cryopreservation of fish gametes and embryos; • tissue banking (e.g. India has 15 000 samples); and • DNA barcoding.
Reducing impacts of capture fisheries on wild relatives	Strengthen fisheries legislation, promote co-management of fisheries resources and control fishing effort.
	Manage the impacts of fishing gears on vulnerable/sensitive habitats.
	Limit and/or manage capture fisheries which target critical life stages of wild relatives.

	Promote risk-analysis based responsible enhancement of fisheries in natural water systems.
Promoting research	Promote research into development of new farmed types.
	Identify new potential aquaculture species.
	Develop species-specific genetic markers (microsatellites or/and SNPs) for use in genetic monitoring.
	Focus on improvement of farmed type aquatic genetic resources to mitigate adverse impacts on those that are derived from wild relatives.
	Strengthen public private partnership in research and dissemination of aquatic genetic resources.
	Establish a Geographic Information System to assist in planning, developing, monitoring and mitigating aquaculture ecosystems (taking into consideration sensitive habitats and the impact of climate change).
Strengthening governance and regulation	Support investment into applied research, education and public awareness of importance of AqGR
	Integrate the conservation and management of AqGR into national fishery and environmental legislation.
	Develop cooperation and strategic partnership between aquaculture farmers, public sector and research institutes.
	Work to organize and professionalize aquaculture producers to improve their ability to maintain farmed types and reduce genetic risks.
	Develop zonation of aquaculture development areas to manage biosecurity, genetic and environmental risks.

3.4 References and key documents

Sources of information on invasive species

FAO Database of Introduced aquatic species (www.fao.org/fishery/dias/en)
Global Invasive Species Database (www.iucngisd.org/gisd/)
Baltic Sea Alien species database (www.corpi.ku.lt/nemo/)
USDA invasive species (www.invasivespeciesinfo.gov/aquatics/databases.shtml)

Bartley, D. & Casal, C.V. 1998. *Impacts of introductions on the conservation and sustainable use of aquatic biodiversity*. FAO Aquaculture Newsletter 20:15-19. Also available at: www.fao.org/docrep/005/x1227e/x1227e15.htm

Bartley, D.M. & Halwart, M. 2006. *Responsible Use and Control of Introduced Species in Fisheries and Aquaculture.* [CD-ROM]. Rome, FAO.

Beardmore, J.A. & Porter, J.S. 2003. *Genetically modified organisms and aquaculture*. FAO Fisheries Circular. No. 989. Rome, FAO. 38 pp.

Camacho, A.P., Gonzalez, R. & Fuentes, J. 1991. *Mussel culture in Galicia* (NW Spain). Aquaculture, 94(2-3). pp. 263-278.

Caputi, N., Feng, M., Pearce, A., Benthuysen, J., Denham, A., Hetzel, Y., Matear, R., Jackson, G., Molony, B., Joll, L. & Chandrapavan, A. 2015. *Management implications of climate change effect on fisheries in Western Australia*, Part 1: Environmental change and risk assessment. FRDC Project No. 2010/535. Fisheries Research Report No. 260. Western Australia, Department of Fisheries. 180 pp.

Cowx, I.G., Funge-Smith, S.J. & Lymer, D. 2015. *Guidelines For Fish Stocking Practices In Tropical Freshwater Fisheries* in FAO (2015) *Responsible stocking and enhancement of inland waters in Asia*. Bangkok, FAO Regional Office for Asia and the Pacific. RAP Publication 2015/11. 142 pp.

Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S. & Mahfuzuddin, A. 2003. *Fish to 2020: Supply and Demand in Changing Global Markets*. World Fish Center Technical Report 62, International Food Policy Research Institute. Penang, The WorldFish Center.

FAO. 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*, edited by Barbara Rischkowsky & Dafydd Pilling. Rome, FAO. 524 pp. Available at: www.fao.org/3/a-a1250e.pdf

FAO. 2014a. *APFIC/FAO Regional Expert Workshop on "Regional guidelines for the management of tropical trawl fisheries in Asia"*. Phuket, Thailand. 30 September – 4 October 2013. Bangkok, FAO Regional Office for Asia and the Pacific. RAP Publication 2014/01. 91 pp.

FAO. 2014b. Fisheries and aquaculture software. FishStatJ – software for fishery statistical time series. In: FAO Fisheries and Aquaculture Department [online]. Rome. [Cited 8 March 2018]. Available at: www.fao.org/fishery/statistics/software/fishstatj/en

FAO. 2015. *Responsible stocking and enhancement of inland waters in Asia.* Bangkok, FAO Regional Office for Asia and the Pacific. RAP Publication 2015/11. 142 pp.

FAO. 2016. *The state of world fisheries and aquaculture 2016*. Contributing to food security and nutrition for all. Rome, FAO. 200 pp. Available at: www.fao.org/3/a-i5555e.pdf

Hard, J.J., Gross, M.R., Heino, M., Hilborn, R., Kope, R.G., Law, R. & Reynolds, J.D. 2008. *Evolutionary consequences of fishing and their implications for salmon*. Evol Appl.; 1(2). 388-408.

Hart, A.M. 2015. *Roe's Abalone (Haliotis roei).* In: N. Caputi, M. Feng, A. Pearce, J. Benthuysen, A. Denham, Y. Hetzel, R. Matear, G. Jackson, B. Molony, L. Joll, A. Chandrapavan. *Management implications of climate change effect on fisheries in Western Australia* Part 2: Case studies. FRDC Project No. 2010/535. Fisheries Research Report 261. Western Australia, Department of Fisheries. pp. 77–85.

Hickley, P. & Chare, S. 2004. *Fisheries for non-native species in England and Wales: angling or the environment?* Fisheries Management and Ecology, vol. 11. pp. 203–212.

ICES. 2008. *Report of the ICES Advisory Committee, 2008*. ICES Advice, 2008. Books 1–10. 1 842 pp. Also available at: www.ices.dk/sites/pub/Publication%20Reports/ICES%20Advice/2008/ICES%20ADVICE%202008%20Book%201.pdf

Kamonrat, W. 1996. *Spatial genetic structure of Thai silver barb Puntius gonionotus (Bleeker) Populations in Thailand*. PhD Thesis. Halifax, Canada, Dalhousie University. 209 pp.

Lorenzen, K., Beveridge, M.C.M. & Mangel, M. 2012. *Cultured fish: integrative biology and management of domestication and interactions with wild fish*. Biological Reviews. Volume 87, Issue 3. pp. 639–660.

Lorenzen, K. 2014. *Understanding and managing enhancements: why fisheries scientists should care*. Journal of Fish Biology, vol. 85. pp. 1807–1829.

Lovatelli, A. & Holthus, P.F. eds. 2008. *Capture-based aquaculture. Global overview.* FAO Fisheries Technical Paper. No. 508. Rome, FAO. 298 pp.

Micklem, J.M., Griffiths, C.L., Ntuli, N. & Mwale, M. 2016. *The invasive Asian green mussel Perna viridis in South Africa: all that is green is not viridis.* African journal of marine science, 38(2). pp. 207–215.

Nakada, M. 2000. *Yellowtail and related species culture*. Encyclopedia of aquaculture. pp. 1007–1036.

Ottolenghi, F., Silvestri, C., Giordano, P., Lovatelli, A. & New, M.B. 2004. *Capture-based aquaculture. The fattening of eels, groupers, tunas and yellowtails*. Rome, FAO. 308 pp.

Pearce, A., Lenanton, R., Jackson, G., Moore, J., Feng, M. & Gaughan, D. 2011. *The "marine heat wave" off Western Australia during the summer of 2010/11*. Fisheries Research Report No. 222. Western Australia, Department of Fisheries. 40 pp.

Pyle, G.G., Rajotte, J.W. & Couture, P. 2005. *Effects of industrial metals on wild fish populations along a metal contamination gradient*. Ecotoxicol Environ Saf. 2005 Jul;61(3). pp. 287–312.

Rasmussen, S. & Morrissey, M.T. 2007. Biotechnology in Aquaculture: Transgenics and Polyploidy. Comprehensive Reviews in Food Science and Food Safety. Volume 6, Issue 1. pp. 2–16.

Sandoval-Castillo, J., Robinson, N., Strain, L., Hart, A & Beheregaray, L.B. 2015. *PDRS: Use of next generation DNA technologies for revealing the genetic impact of fisheries restocking and ranching*. Australian Seafood CRC Project No. 2012/714. 47 pp.

Saarman, N.P. & Pogson, G.H. 2015. *Introgression between invasive and native blue mussels (genus Mytilus) in the central California hybrid zone*. Molecular ecology, 24(18). pp. 4723–4738.

SOFIA. 2014. *The State of World Fisheries and Aquaculture 2014*. Rome. 223 pp. Also Available at: www.fao.org/3/a-i3720e.pdf

Van Zyll de Jong, M.C., Gibson, R.J. & Cowx, I.G. 2004. *Impacts of stocking and introductions on freshwater fisheries of Newfoundland and Labrador*. Canada, Fisheries Management and Ecology, vol. 11. pp. 183–193.

Welcomme, R.L. & Bartley, D.M. 1998a. *Current approaches to the enhancement of fisheries*. Fisheries Management and Ecology, vol. 5. 351–382 pp.

Welcomme, R.L. & Bartley, D.M. 1998b. *An evaluation of present techniques for the enhancement of fisheries*. FAO Fisheries Technical Paper (FAO). Also available at: www.fao.org/docrep/005/W8514E/W8514E01.htm

World Bank. 2013. *Fish to 2030: Prospects for Fisheries and Aquaculture*. World Bank report number 83177-GLB. 102 pp. Available at: www.fao.org/docrep/019/i3640e/i3640e.pdf

Zeeman, S.C.F. 2016. *Genetics and ecosystem effects of the invasive mussel Semimytilus algosus, on the West Coast of South Africa*. PhD thesis. University of Cape Town. 253 pp.

CHAPTER 4
IN SITU CONSERVATION OF FARMED AQUATIC SPECIES AND THEIR WILD RELATIVES WITHIN NATIONAL JURISDICTION

PURPOSE: The purpose of this chapter is to review the current status and future prospects for the *in situ* conservation of genetic resources of farmed aquatic species and their wild relatives.

KEY MESSAGES:

Major findings from an examination of Country Reports and an examination of other information sources include:

- *in situ* conservation is the preferred method of conserving AqGR according to international agencies such as the Convention on Biological Diversity (CBD);
- *preservation of aquatic genetic diversity* and *maintain good strains for aquaculture production* were the main priorities reported from *in situ* protected areas although there were slight regional differences;
- *to help adapt to impacts of climate change* and *to meet consumer and market demands* were reported to have the lowest priorities for aquatic protected areas;
- countries reported on over 2 300 protected areas with almost 2 100 reported as being very or somewhat effective, however these results are heavily influence by a few countries reporting large numbers of very effective aquatic protected areas;
- policies exist that explicitly state conservation as an objective in about 50 percent of the responses for aquaculture facilities and fishery management;
- fisheries and aquaculture were seen to be effective mechanisms for *in situ* conservation in about 90 percent of the responses;
- the collection of broodstock and early life history stages from the wild was also seen as providing *in situ* conservation and for maintaining habitats at least to some extent in between 50–100 percent of the responses from the regions; and
- *in situ* conservation on farms in aquaculture is rare and difficult to distinguish from *ex situ* conservation due to the relatively recent development of aquaculture and domestication of aquatic species.

4.1 Introduction

In situ conservation as defined by the Convention on Biological Diversity (CBD) includes areas both on farm and in nature.

In situ *conservation means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.*[23]

In light of the fact that all wild relatives of farmed aquatic species still exist in nature and that the farming and fishing of wild types (or near wild types) play an important role in food production (See Section 2.5.4), maintenance of the aquatic habitats supporting wild relatives is essential for their *in situ* conservation.

Habitat rehabilitation has been undertaken in efforts to improve fishery production and conserve aquatic biodiversity and there are a variety of strategies available that can improve aquatic ecosystems (Roni *et al.*, 2005). However, the efficacy of many habitat rehabilitation programmes for fish production has not been adequately evaluated on a global scale (Roni *et al.*, 2005).

[23] https://www.cbd.int/convention/articles/default.shtml?a=cbd-02

The CBD states that *in situ* is the preferred method for conserving biological diversity. Preservation or maintenance of habitat, whether on farm or in nature is crucial because it allows organisms to continue to be connected to their environment in order to adapt to *in situ* conditions.

In situ conditions could be a fish farm, pristine aquatic ecosystems or those ecosystems impacted by development, such as habitat degradation, damming of rivers or coastal erosion, as well as the various impacts of climate change. It has often been said that to conserve something humans must use it. Therefore the extent to which the use of AqGR through aquaculture and fisheries contributes to its conservation is evaluated.

There are numerous examples of *in situ* conservation of aquatic genetic resources. The most widely cited are marine protected areas (MPA), freshwater protected areas (FPA), Ramsar[24] sites and the IUCN[25] categories of protected areas. In addition to geographically defined protected areas, certain types of fishery management would also qualify as *in situ* conservation. This chapter reviews the current status and future prospects for *in situ* conservation of farmed AqGR and their wild relatives and includes both on farm and in nature conservation areas, as well as fisheries management.

4.2 *In situ* conservation of wild relatives of farmed aquatic species

Aquatic protected areas, both MPAs and FPAs have been strongly promoted as a method for conserving biological diversity. The Aichi Targets of the CBD have called for countries to establish protected areas in 17 percent of their terrestrial and inland waters and 10 percent of their marine areas by 2020. Recognizing that there are various levels of 'protection', the World Conservation Union (IUCN) defined six categories of protected area (Box 4.1).

Box 4.1

IUCN Protected Areas Categories System

IUCN protected area management categories classify protected areas according to their management objectives. The categories are recognized by international bodies such as the United Nations and by many national governments as the global standard for defining and recording protected areas and as such are increasingly being incorporated into government legislation.

Strict Nature Reserve:

Category Ia are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.

Wilderness Area:

Category Ib protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

National Park:

Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.

[24] Ramsar Wetlands Convention: www.ramsar.org/sites-countries/the-ramsar-sites
[25] IUCN categories of protected areas:
www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/

Natural Monument or Feature:

Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.

Habitat/Species Management Area:

Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.

Protected Landscape/ Seascape:

A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

Protected area with sustainable use of natural resources:

Category VI protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management.

These categories reflect different objectives of a protected area or of *in situ* conservation.

The Country Reports also expressed differing objectives for *in situ* conservation with *Preservation of aquatic genetic diversity* and *Maintain good strains for aquaculture production* being the highest priority objectives reported; *To help adapt to impacts of climate change* and *To Meet consumer and market demands* overall being the lowest priorities (Table 4.1a).

These priorities for *in situ* conservation vary somewhat among economic classes but in all cases *Preservation of aquatic genetic diversity* had the highest priority. It is surprising that *Meeting market demands* scored so low, even in developing and least developed countries, and perhaps countries do not see the role that the conservation of genetic diversity *in situ* has in meeting consumer demands and preferences in the market, or that other methods are easier and less costly.

Analysis by region revealed a similar trend with the exception that North America listed *Maintain good strains for aquaculture production* and *Future breed improvement in aquaculture* as the highest priorities (Table 4.1b).

Table 4.1a
Ranking of objectives for *in situ* conservation of AqGR by economic classification of countries (1= highest priority; 10= lowest priority)

Objective	Rank			
	Overall	Developed countries	Least developed countries	Other developing countries
Preservation of aquatic genetic diversity	1.9	2.3	1.9	1.8
Maintain good strains for aquaculture production	2.9	3.3	2.7	2.8
Meet consumer and market demands	4	4.7	3.7	3.8
To help adapt to impacts of climate change	4	4.7	3.7	3.8
Future breed improvement in aquaculture	3.2	3.7	3	3.1

Table 4.1b
Ranking of objectives for *in situ* conservation of AqGR by region (1= highest priority; 10= lowest priority)

Objective	Rank					
	Africa	**Asia**	**Latin America and the Caribbean**	**Europe**	**North America**	**Oceania**
Preservation of aquatic genetic diversity	2.1	1.4	1.7	2.5	3	1.3
Maintain good strains for aquaculture production	2.7	2.8	2.8	3.5	2.5	2.9
Meet consumer and market demands	3.4	3.8	3.6	5.4	3.5	4.9
To help adapt to impacts of climate change	3.4	3.7	3.4	5.6	3	5.4
Future breed improvement in aquaculture	2.9	2.8	3.1	4.1	2.5	4.3

Other high priority objectives reported by individual countries were:

- conservation of endemic species;
- maintain national heritage species;
- promote sustainable wild populations of aquatic organisms;
- maintain and recover resources for commercial and recreational fishing; and
- conserve and restore wild stocks of genetic resources, especially those are listed on endangered species lists.

The responses for major and minor producers were extremely similar and followed the same general trend above (data not shown).
The Ramsar Convention in 1996 at its Sixth meeting of the Conference of the Contracting Parties adopted criteria based on fish for identifying wetlands of international importance thus allowing wetlands that support traditional fisheries and fishing communities to be included in the listing of wetlands of international significance. The Ramsar List is the world's largest network of protected areas with over 2 200 wetlands of international importance; these sites provide an excellent means of *in situ* conservation of AqGR. (Box 4.1).

Formally designated protected areas have been shown to be effective at conserving biological diversity in popular and scientific literature. Country Reports confirmed this general statement (Figure 4.1 and Table 4.2). Overall countries reported on 2344 protected areas with over 2 100 reported as being very or somewhat effective (Table 4.2 and Box 4.2). The trend was consistent regardless of economic class or if a country was a major or minor aquaculture producer. There was no important difference between the responses from major or minor producing countries (Table 4.2). Because of the large difference in numbers of major and minor producers, the percentage of responses is reported in Table 4.2. The results are heavily influenced by the reports from Canada, Columbia, the Philippines and the United Republic of Tanzania, where a large number of protected areas were reported as being extremely effective.

Figure 4.1
Effectiveness of *in situ* protected areas for conservation of AqGR (total number of protected areas per group)

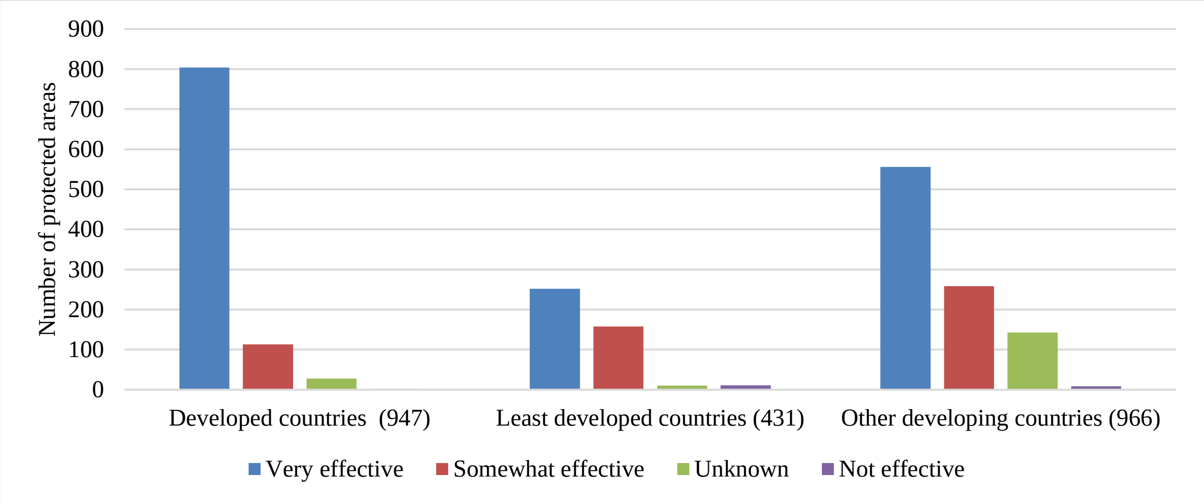


Table 4.2
Effectiveness of aquatic protected areas by region (number of responses) and by level of production (percent of responses)

Effectiveness	Africa	Asia	Latin America and the Caribbean	Europe	North America	Oceania	Total by effectiveness	Major producer (%)	Minor producer (%)
Very effective	104	296	394	7	797	14	1612	53	70
Somewhat effective	217	156	70	85		1	529	33	21
Not effective	11		8	2		1	22	0	1
Unknown	11	37	115	16		2	181	13	7
Total by region	**343**	**489**	**587**	**110**	**797**	**18**	**Total number of protected areas 2344**		

Box 4.2
***In situ* conservation example (Q22) Australia, Bulgaria and China**

Australia:

One example of an on-going activity for in-situ conservation is that National Recovery Plan for the Murray Cod (*Maccullochella peelii peelii*). This plan is supported by the Federal government and all state governments with jurisdiction over the Murray Darling River basin (MDB) to which the fish is endemic. The Murray Cod was a very important species in this large river basin supporting both commercial and recreational fishing. The objectives of this plan include:

1. determine the distribution, structure and dynamics of Murray Cod populations across the MDB.
2. manage river flows to enhance recruitment to Murray Cod populations;
3. undertake risk assessments of threats and evaluate benefits of recovery actions on Murray Cod populations for each Spatial Management Unit;
4. determine the habitat requirements of Murray Cod life stages and populations;
5. manage the recreational fishery for Murray Cod in a sustainable manner while recognizing the social, economic and recreational value of the fishery;
6. encourage community ownership for Murray Cod conservation; and
7. manage Recovery Plan implementation.

This plan includes a review of knowledge of population genetics and current and future gene flow and identification of any particular genetic units that need preservation.

Bulgaria:

According the Habitat Directive, a number of water areas of Bulgaria are set as special Areas of Conservation due to fish species of Community importance and described in Annex 2 of the Directive. The effective management of protected areas with fishes from Annex 2 requires the creation and implementation of monitoring programs to ensure adequate assessment, both in terms of their conservation status, and in terms of their spatial distribution.

Protected areas under Natura 2000 in Bulgaria cover 35 percent of the country's area. In connection with the implementation of the commitments of the Republic of Bulgaria in accordance with Article 8 of Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, a national framework for priority action under Natura 2000 (NFPA) 2014–2020 was developed. The purpose of NFPA is to better define priorities for Natura 2000 at national and regional level, and to determine the financing needs. This document will facilitate the integration of the above mentioned needs into future programs financed by European Union (Member Organization) financial instruments.

China:

In recent years, the biomass of spawning stock of Gymnocypris przewalskii decreased obviously in compare with the time before 1970s, and most of fish size are below 25 cm, mature individual size became shorter obviously. The species has been listed in Red Name List of Species in China, assessment degree is endangered. In order to protect the resources, Chinese government put the species as a key protecting species, and to close the lake for breeding as well as established catch limit. Through a number of years close the lake and other management and protection measures, the Gymnocypris przewalskii resources gets some recovery. The main protection measures are:

1. input water into the lake from outside source to keep the balance of water in the lake, and paid attention on environment of water area;
2. protect and extend spawning ground of Gymnocypris przewalskii;
3. conduct river training, and rebuild vegetation in the lake area;
4. increase the number of artificial enhancement station for the species;
5. continue to close the lake for fish to breed; and
6. regulate the standard and operational procedure for living beings and environment inspection in the lake.

In addition, Rescue Centre for Gymnocypris przewalskii was established. The centre has key laboratory to study the species, national levelled the species stock seed farm, the species artificial enhancement station. The centre completed the work of reproduction biology of the species, protospecies saving, freshwater farming, germplasm inspection, protospecies breeding, stock enhancement, resources dynamic monitor, survey of Qinghai Lake water area and environmental physical and chemical factors, and effectiveness evaluation of stock enhancement.

Fishery management can be considered *in situ* conservation under certain conditions. For example, if the objective of the fishery management plan is to maintain natural populations and the ecosystem that supports them, then this would qualify as *in situ* conservation (see below).

The Ecosystem Approach to Fisheries (EAF) (FAO, 2003) encompasses this broad view of fishery management; fishery managers around the world are adopting such an approach. However, policies and fishery management plans should explicitly state conservation as an objective. The objectives of a fishery management plan or an aquatic protected area should be clearly stated and would indicate whether they would be considered as *in situ* conservation. Fishery management plans that call for the introduction of non-native species, e.g. the introduction of non-native rainbow trout into high mountain lakes where they could prey on local fauna, or that support the selective removal of components of aquatic biodiversity, e.g. the removal of sea stars to enhance scallop growth, may increase the financial value of a fishery, but would not be a conservation measure.

Countries reported that policies largely exist that explicitly include conservation as a goal for aquaculture facilities or for fishery management (Figure 4.2). This trend was also evident when countries were analyzed by economic, regional and level of production classifications (data not shown).

Figure 4.2a
Conservation as an objective of aquaculture and fisheries policies. Total for all countries

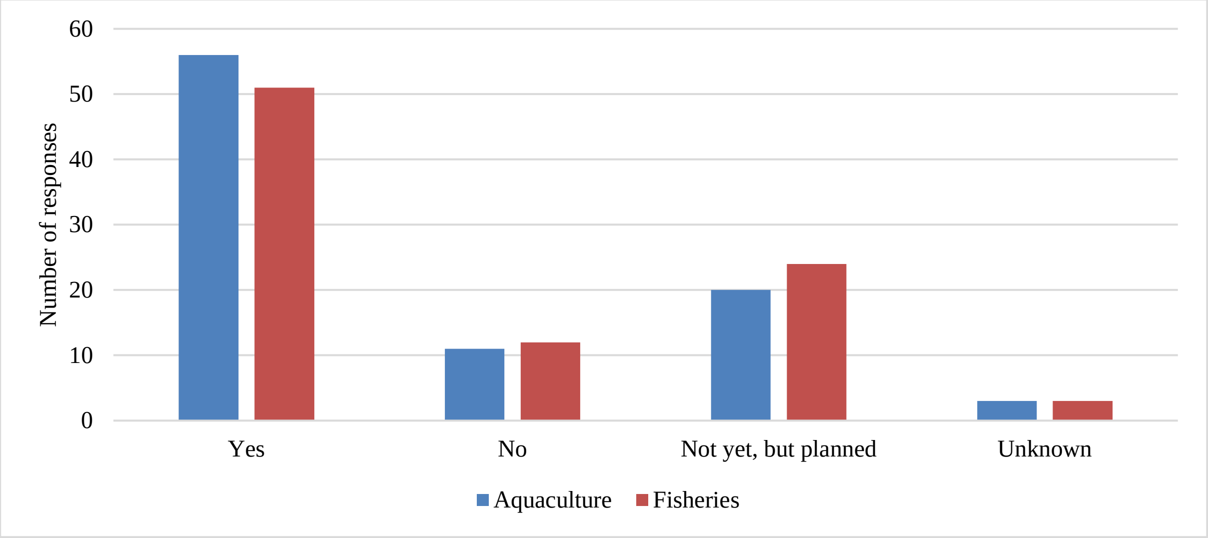


Figure 4.2b
Conservation as an objective of aquaculture and fisheries policies. Aquaculture by region

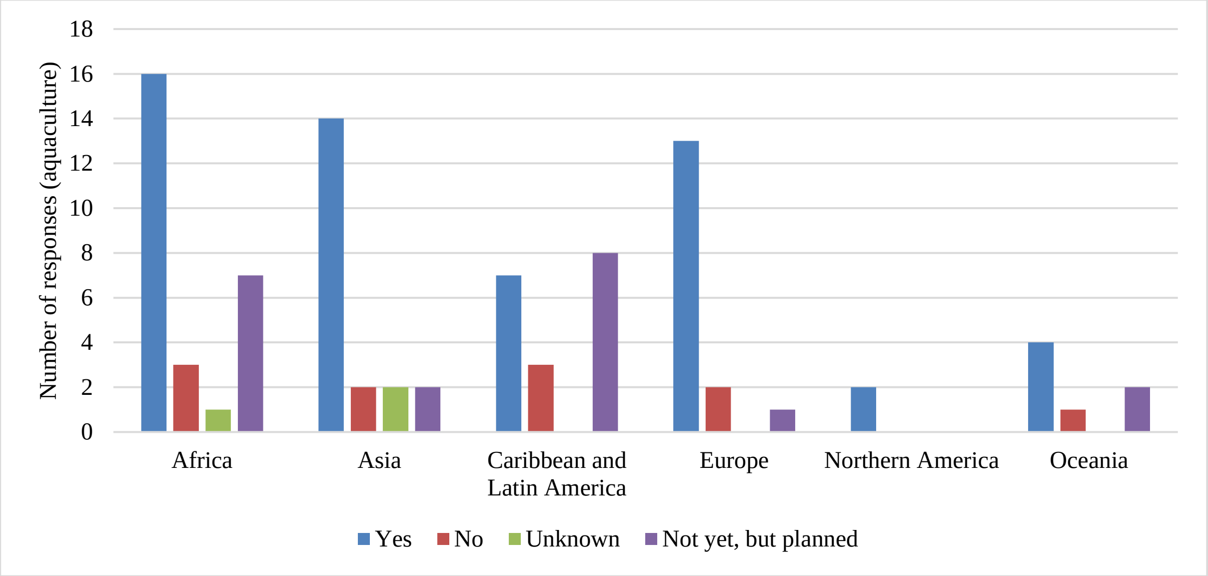
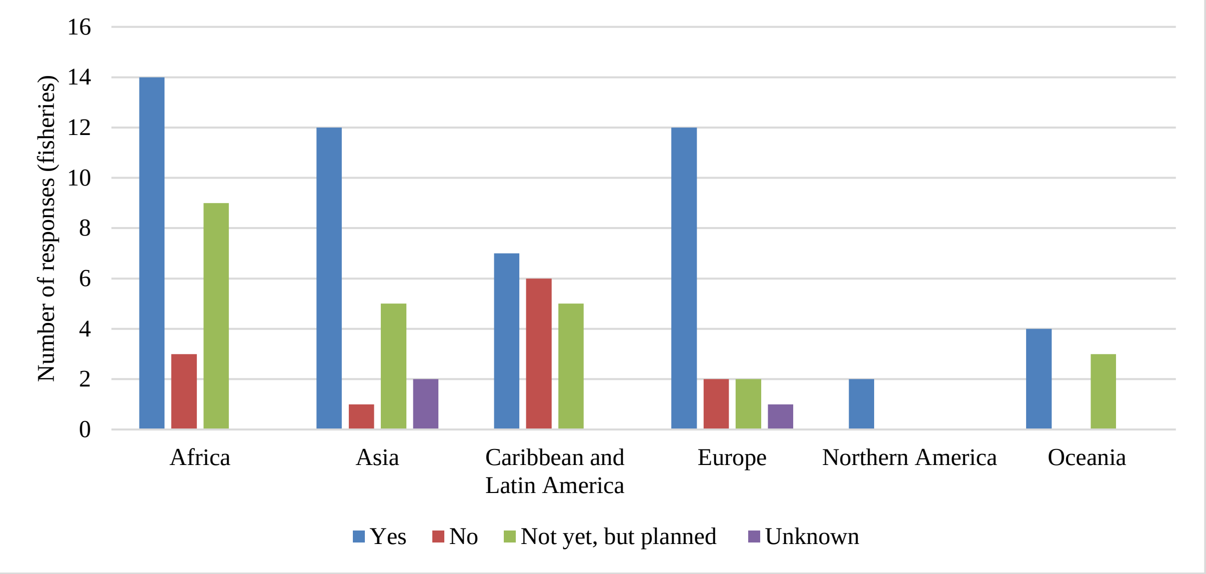
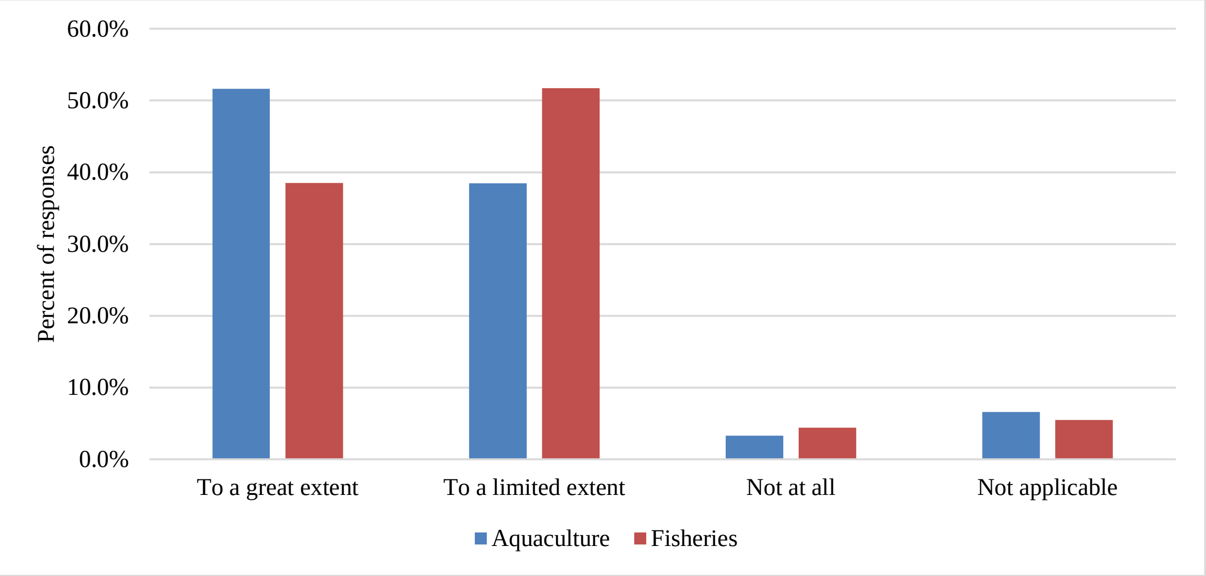


Figure 4.2c
Conservation as an objective of aquaculture and fisheries policies. Fisheries by region



Countries reported generally positive messages in regards to existing facilities, aquaculture and fisheries management in providing *in situ* conservation (Figure 4.3). This trend was present in the analysis of countries grouped by region, economic class and level of production (data not shown). It is noteworthy that both aquaculture and fisheries were seen as contributing to the conservation of AqGR to about the same extent.

Figure 4.3
Extent of effectiveness of fisheries and aquaculture providing *in situ* conservation of farmed aquatic species and their wild relatives



The collection of broodstock and early life history stages from the wild was also seen as providing *in situ* conservation and for maintaining habitats (Figure 4.4) at least to some extent in most areas.

The 'not applicable' reported in some areas primarily in regards to collection of AqGR from the wild could indicate a lack of awareness of the role fisheries and aquaculture can play in conservation of AqGR and aquatic habitats. (Figures 4.3 and 4.4). Thus, objectives of *in situ* conservation should be explicitly stated in aquaculture and fisheries management policies and operating plans and communicated to resource managers, fishers and aquaculturists.

Figure 4.4a
Contribution of collectors of wild broodstock and seed towards *in situ* conservation and maintenance of aquatic habitats by economic groupings

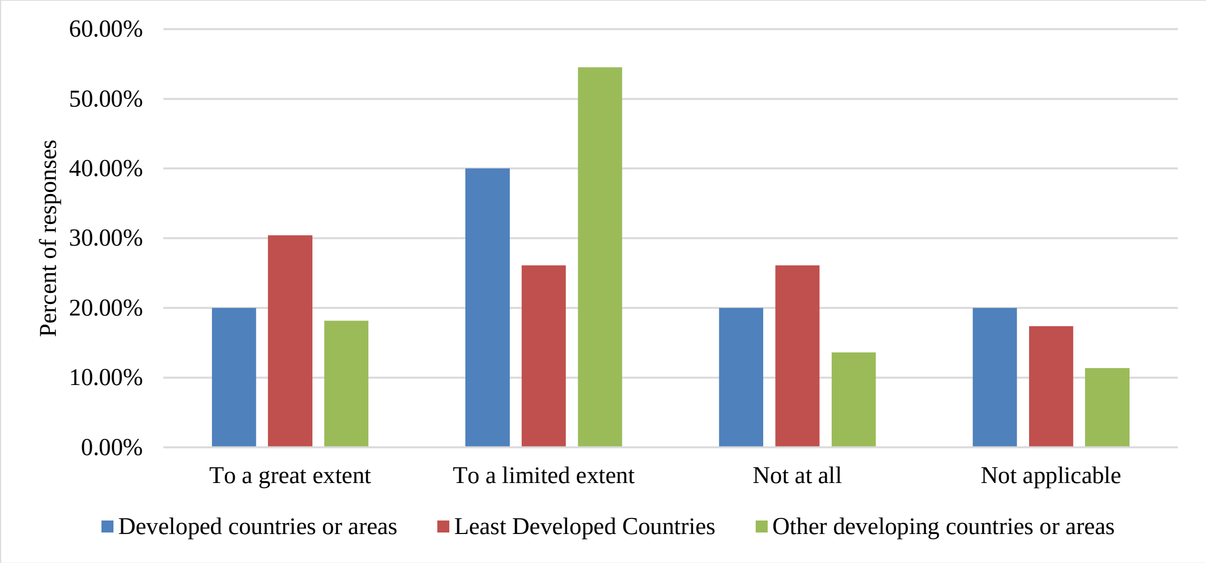
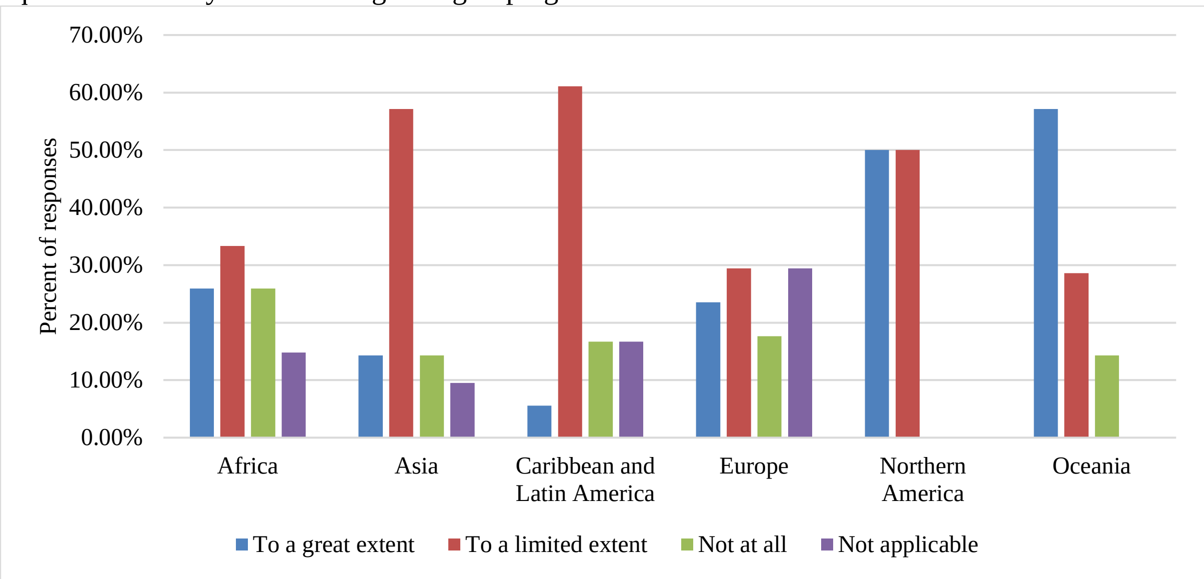


Figure 4.4b
Contribution of collectors of wild broodstock and seed towards *in situ* conservation and maintenance of aquatic habitats by economic regional groupings



MPAs have been promoted as a fishery management tool to maintain or rebuild capture fisheries. This provides a clear example of fishery management and conservation merging. This merge has not been without controversy however as the efficacy of MPAs as a tool for fishery management and increased fish production has been questioned (Adams *et al.*, 2004; Weigel *et al.*, 2014). There is often tension between those seeking more conservation from a protected area and those seeking more livelihood benefits.

Rice fields are an example of a modified ecosystem that can serve as *in situ* conservation of biological diversity if properly managed. Rice fields in Asia have been shown to contain over 200 species, including fish, insects, crustaceans, molluscs, amphibians and reptiles (Halwart and Bartley 2005). Integrated pest management (IPM) in rice fields is a traditional practice in much of Asia that eliminates or reduces the amount of pesticides used and relies on natural enemies of pests and on beneficial species to facilitate production of rice. Country Reports did not specifically mention rice fields as sources of *in situ* conservation, perhaps indicating a lack of appreciation of the role modified ecosystems can play in conservation.

4.3 *In situ* conservation of farmed aquatic species

In situ conservation of *farmed* aquatic species essentially means 'on farm' conservation. This type of *in situ* conservation is less common in aquaculture than in agriculture due to the relatively recent domestication of most farmed aquatic species in relation to terrestrial agriculture.

Living on-farm gene banks of some species do exist that would qualify as *in situ* on farm conservation. However on farm *in situ* and on farm *ex situ* conservation are often difficult to distinguish. For the former, it would be necessary for the farm to maintain:

- a production environment;
- the desired species; and
- no further genetic alteration or manipulation was deliberately used.

Thus the desired species would adapt to the production environment over time.

On farm *ex situ* conservation would require the farm to simply maintain the desired species where no selection or genetic change would take place. Thus the desired species would not change over time because it was not in a production environment.

Thus the distinction of *in situ* and *ex situ* conservation of farmed aquatic species is difficult to make. In fact, the Fish Culture Research Institute in Szarvas, Hungary maintains numerous breeds of common carp under farm-like conditions. Although this appears to be *in situ* conservation, the researchers at the institute call it *ex situ* conservation (Personal Communication, Z. Jeny, Director Fish Culture Research Institute, Szarvas – retired). Given the fact that aquaculture is rapidly growing and there will be strong motivation to increase productivity through continuously improving AqGR, it may be difficult to find actual cases of on farm i.e. *in situ*, conservation.

4.4 Key findings and conclusions

In situ conservation is the preferred method of conserving AqGR according to international agencies such as the Convention on Biological Diversity because it maintains the link between the resource and the environment regardless of whether that environment is in nature or on farm.
Preservation of aquatic genetic diversity and *Maintain good strains for aquaculture production* were the main priorities reported from *in situ* protected areas although there were slight regional differences.
To help adapt to impacts of climate change and *To Meet consumer and market demands* were reported to have the lowest priorities for aquatic protected areas.
Protected areas were reported to be effective at conserving AqGR. These results are heavily influence by several countries reporting very effective aquatic protected areas.
Policies exist that explicitly state conservation as an objective in about 50 percent of the responses for aquaculture facilities and fishery management.
Fisheries and aquaculture were seen to be effective mechanisms for *in situ* conservation in about 90 percent of the responses.
The collection of broodstock and early life history stages from the wild was also seen as providing *in situ* conservation and for maintaining habitats at least to some extent in between 50–100 percent of the responses from the regions.
In situ conservation on farms in aquaculture is rare and difficult to distinguish from *ex situ* conservation due to the relatively recent development of aquaculture and domestication of aquatic specie.

4.5 References and key documents

On line resources

- Convention on Biological Diversity: www.biodiv.org

References

Adams, W.M., Aveling, R., Brockington, D., Dickson, B., Elliott, J., Hutton, J., Roe, D., Vira, B., Wolmer. W. 2004. *Biodiversity conservation and the eradication of poverty*. Science 306. pp. 1146–1149.

FAO. 2003. *The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Rome, FAO. 112 pp.

Halwart, M. & Bartley, D.M., eds. 2005. *Aquatic Biodiversity in Rice-Based Ecosystems.* Studies and Reports from Cambodia, China, Lao People's Democratic Republic, Thailand and Vietnam [CD-RoM]. FAO, Rome, Italy.

Roni, P., Hanson, K., Beechie, T., Pess, G., Pollock, M. & Bartley, D.M. 2005. *Habitat rehabilitation for inland fisheries: global review of effectiveness and guidance for rehabilitation of freshwater ecosystems*. FAO Fisheries Technical Paper No. 484. Rome, Italy.

Weigel, J.Y., Mannle, K.O., Bennett, N.J., Carter, E., Westlund, L., Burgener, V., Hoffman, Z., da Silva, A.S., Kane E.A., Sanders, J., Piante, C., Wagiman, S. & Hellman A. 2014. *Marine protected areas and fisheries: bridging the divide*. Aquatic Conserv: Mar. Freshw. Ecosyst. 24 (Suppl. 2). pp 199–215.

CHAPTER 5
EX SITU CONSERVATION OF AQUATIC GENETIC RESOURCES OF FARMED AQUATIC SPECIES AND THEIR WILD RELATIVES WITHIN NATIONAL JURISDICTION

PURPOSE: The purpose of this chapter is to review the current status and future prospects for the *ex situ* conservation of aquatic genetic resources of farmed aquatic species and their wild relatives. Specifically, this chapter will review:

- existing *ex situ* conservation of aquatic genetic resources of farmed aquatic species and their wild relatives in aquaculture facilities, culture collections and gene banks, research facilities, zoos and aquaria (both *in vivo* and *in vitro* collections); and
- needs and priorities for the future development of *ex situ* conservation of aquatic genetic resources of farmed aquatic species and their wild relatives, including any that are threatened or endangered.

KEY MESSAGES:

- Approximately 75 percent of surveyed countries have current *ex situ in vivo* conservation programs for live breeding aquatic.
- Thirty-eight percent of surveyed countries have current *ex situ* "*in vitro*" conservation programs for aquatic organism.
- More than 690 cases of aquatic *in vivo ex situ* conservation programmes of approximately 290 different species were reported for live breeding organisms in various types of facilities among the 92 surveyed countries.
- The major producing countries reported more *in vivo ex situ* conservation programmes than the minor producers.
- There was a total of 197 examples of endangered aquatic species being conserved under *in vivo ex situ* conservation programs.
- The species more often reported being maintained *in vivo* were freshwater or brackishwater fin fish; about 909 percent of the AqGR conserved in *in vivo ex situ* collections were finfish and about 10 percent were microorganisms such as rotifers and algae.
- Uses of species in *in vivo ex situ* conservation collections were reported to be for direct human consumption, as live feed organisms, for future domestication or use in aquaculture; for conservation of aquatic biodiversity; as ornamental species; for pharmaceutical uses; for spat monitoring; for restocking and stock enhancement purposes; for recreational fisheries; and for research.
- Direct human consumption was the most often cited use for *in vivo ex situ* conservation. Nile tilapia was the species most conserved *in vivo* and its primary use was for direct human consumption, although it was also reported used as live feed.
- Other important uses were: conservation of aquatic diversity, restocking and stock enhancement, recreational fisheries, potential uses in aquaculture, ornamental use, and research.
- Two hundred ninety five cases of *in vitro ex situ* conservation collections were reported including more than 133 aquatic species in various types of facilities.
- Asia maintains the most *in vitro* collections whereas Latin America and the Caribbean reported the most *in vitro* collections per country.
- Common carp and rainbow trout were the two species most often conserved *in vitro*.
- Gametes were the type of AqGR most often conserved *in vitro* (almost exclusively male gametes).
- Research facilities were the type of facility most often used for *in vitro* conservation.
- The most important objective for *ex situ* conservation at the global level (both *in vivo* and *in vitro*) was the preservation of aquatic genetic diversity, followed by future strain improvement in aquaculture and for the maintenance of good strains for future aquaculture production.

- The least important objective for *ex situ* conservation programs was for adaptation to climate change.
- The rankings of the objectives were very similar when countries were grouped by region, economic level and level of production, i.e. preservation of AqGR was a high priority and adaptation to climate change a low priority.
- Approximately ninety percent of the aquatic genetic resources being conserved are finfish while only 10 percent are macro-invertebrates, and aquatic microorganisms such as small crustaceans, rotifers and microalgae.

5.1 Background

Because of the short history of domestication of aquatic organisms, breeding programs and related research for most farmed aquatic organisms, the free-living populations of their wild and feral relatives and of other potentially farmable aquatic species have high importance as genetic resources. Many of these free-living populations of AgGR, especially in freshwaters, are among the world's most seriously threatened biodiversity. For example, the wild genetic resources of farmed carps and tilapias (NSW Government, 2018; Carrizo *et al.*, 2013).

In order to help mitigate the threats and better inform development and conservation planning processes, knowledge is needed on where species occur, how important they are for human livelihoods and ecosystem functioning, and how threatened their status is.

Ex situ conservation programs are extremely relevant for certain threatened and endangered aquatic species, even more when natural habitats have disappeared or are also endangered.

Moreover in aquaculture, as in agriculture, most private sector seed producers and farmers keep only the most profitable farmed types and types, The use in aquaculture production and related research of alien species and of genetically altered farmed types (e.g. distinct strains, hybrids, polyploids, transgenes etc., whether developed from alien or indigenous species) is very important (see chapter 2).

These trends indicate an urgent need for better management – meaning fully integrated use and conservation – of aquatic genetic resources for aquaculture: *in situ*/*in vivo*, as free-living, wild and feral populations; *in situ*/*in vivo*, as captive populations on-farm; *ex situ*/*in vitro*, as collections of cryopreserved sperm, embryos and other tissues/DNA; and *ex situ/in vivo* as aquarium and research populations.

Establishing and maintaining *ex situ*, *in vivo* and/or *in vitro*, fish gene banks is also expensive and may require public and private sector investment and partnerships.

5.2 *In situ* versus *ex situ* conservation

Conservation techniques can be grouped into two basic, complementary strategies: *in situ* and *ex situ*.

The principal difference (and hence the reason for the complementarities) between the two lies in the fact that *ex situ* conservation implies the maintenance of genetic materials outside of their natural habitats i.e., where the species has evolved and aims to maintain the genetic integrity of the material at the time of collection. *In situ* conservation (maintenance of viable populations in their natural surroundings) is a dynamic system, which allows the biological resources to evolve and change over time through natural or human-driven selection processes.

According to the Convention on Biological Diversity (CBD), "The use of *ex situ* conservation is recommended if *in situ* conservation, the preferable conservation alternative, is not available or not functional for the near-term survival of a species. In-situ ("on site") conservation refers to conservation techniques implemented in the same area where the conservation target (species, ecosystem, population) is encountered. Although ex-situ and in-situ conservation were historically treated as distinct conservation strategies, both methods are implemented cooperatively within regional conservation plans in order to reach biodiversity conservation goals more effectively. In-situ measures are the primary conservation approach because they provide a more holistic strategy for conservation, by allowing easier conservation of a greater number of ecological and evolutionary processes."[26]

5.2.1 Ex situ conservation

Ex situ conservation is a technique of conserving AqGR outside its natural habitats, targeting all levels of biodiversity such as genetic, species, and ecosystems. In general, *ex situ* conservation is applied as an additional measure to supplement *in situ* conservation, which refers to conservation of biological diversity in its natural habitats.

In some cases, *ex situ* conservation will be central to a conservation strategy and in others it will be of secondary importance. Broadly, *ex situ* conservation includes a variety of activities, from managing captive populations, education and raising awareness, supporting research initiatives and collaborating with *in situ* efforts.

This means that they are not under the same selection pressures as wild populations, and they may undergo artificial selection if maintained *ex situ* for multiple generations (Engels *et al.*, 2001).

Captive populations under *ex situ* conditions are subject to problems such as inbreeding depression, loss of genetic diversity and adaptations to captivity. It is important to manage captive populations in a way that minimizes these issues so that the individuals that are being conserved will resemble the original species, stock, strain or farmed type as closely as possible, which will increase the chances of successful later use (Kleiman, Katerina and Baer, 2010).

How many individuals are needed for *ex situ* conservation? The target population size is the number of individuals that are required to maintain appropriate levels of genetic diversity, which is generally considered to by 90 percent of the current genetic diversity for a period of 100 years (Frankham, Ballou and Briscoe, 2011).

The number of individuals required to meet this goal varies based on potential growth rate, effective size, current genetic diversity, and generation time (Kleiman, Katerina and Baer, 2010). Once the target population size is reached, the focus shifts to maintaining the population and avoiding genetic issues within the captive population.

Some of the objectives of the management of *ex situ* conservation programs are:

- avoiding loss of genetic diversity;
- avoiding adaptation to captivity;
- correcting genetic disorders such as loss of diversity or loss of genes; and
- minimizing inbreeding.

5.2.2 Mechanisms for ex situ conservation

Aquaria and Zoos	Aquaria, zoos, zoological gardens or zoological parks in which animals are confined within enclosures or semi-natural and open areas, often displayed to the public, and in which they may also breed. They are considered to be important means of conserving biodiversity.
Captive breeding	Captive breeding is an integral part of the overall conservation action plan for a species that helps to prevent extinction of species, subspecies, or population. It is an intensive management practice for threatened individuals, populations, and species by anthropogenic and natural factors. In small and fragmented populations, even if the human caused threats could be reversed, the species would still have a high probability of extinction by random demographic and genetic events, environmental variations, and catastrophes.

[26] http://biodiversitya-z.org/content/ex-situ-conservation

Gene banks	Different types of gene banks have been established for the storage of AqGR, depending on the type of materials conserved. These include seed banks, gene banks, *in vitro* gene banks, chromosome, DNA sperm banks, embryos and tissues, that are held in short term or long term laboratory storage; usually cryopreserved or freeze-dried.
Botanical gardens	Botanical gardens are often run by universities or other scientific research organizations, and often have associated herbaria and research programs in plant taxonomy or some other aspect of botanical science. In principle, their role is to maintain documented collections of living plants for the purposes of scientific research, conservation, display, and education.
In vitro	*In vitro* means 'in glass' and is generally used synonymously with gene banking.

5.2.3 Advantages of ex situ conservation

The CBD states that it is preferred to conserve species *in situ,* because evolutionary processes will remain dynamic in natural habitats. T ranslocation, introduction, reintroduction, and assisted migrations are conservation strategies that are attracting increasing attention in regards to *in situ* conservation, especially in the face of climate change.

The major advantage of "*in vitro ex situ*" conservation is the relative low-cost methods used to cryogenically freeze genetic materials of animals. Collecting, cryogenically freezing and storing specimens does not take a lot of space, and staff maintenance is minimal. In addition, samples do not suffer from genetic drift while frozen. However, eggs and embryos of most aquatic species are difficult to re-animate after freezing. Therefore this technique has limited application for AqGR except for DNA, tissues and sperm.

Another advantage for "*in vitro ex situ*" conservation lies in research. Frozen genetic material can be easily exchanged, transferred or purchased by laboratories and scientists for experimentation. Fish breeders may also want access the material. Very large samples can be stored in small spaces, so there are ample supplies for researchers.

5.2.4 Disadvantages of ex situ conservation

Living organisms populations kept in captivity can deteriorate because of many reasons, for example: loss of genetic diversity, inbreeding depression, genetic adaptations to captivity, and accumulation of deleterious genes. These factors could seriously put at risk the success of *in vivo ex situ* conservation programs. Furthermore, it is recognized that *ex situ* conservation has many constraints in terms of personnel, costs, and reliance on electric power sources (especially in many developing countries where electricity power can be unreliable) for gene banks. It requires facilities and financial investments. It cannot also conserve all of the thousands of plant and animal species that make up complex ecosystems. Furthermore, capture of individuals from the wild for captive breeding or translocation sometimes can have detrimental effects on the survival prospects of the species as a whole through mining of viable organisms from the wild.

Ex situ conservation removes the species from its natural ecological contexts, preserving it under semi-isolated conditions whereby natural evolution and adaptation processes are either temporarily halted or altered by introducing the specimen to an unnatural habitat.

Seedbanks or genbanks are ineffective for certain genera with recalcitrant seeds that do not remain fertile for long periods of time.

5.2.5 Challenges of ex situ conservation programs

Ex situ conservation requires different kinds and levels of intensity of management, and a multi-- stakeholder approach like the input from experts on aquarium husbandry, *ex situ* breeding, gene-banking, reintroduction, and habitat restoration. Other expert input may include taxonomy, ecology and conservation, ethnography, and sociology. For outreach programs, there is a need to liaise with local communities, national government fisheries, and wildlife departments with international (nongovernmental and intergovernmental) conservation bodies.

The most important challenges of applying *ex situ* conservation are:

- identifying the precise role of the conservation efforts within the overall conservation action plan;
- setting realistic targets in terms of required time span, population size, founder numbers, resources, insurance of sound management and cooperation;
- management of small samples to avoid inbreeding and other changes in genetic structure;
- ownership rights, and access and benefit sharing protocols; and
- the development of new technical methods and tools.

5.3 Existing and planned collections of live breeding *(in vivo)* individuals of aquatic genetic resources of farmed aquatic species and their wild relatives

Countries were asked to provide a detailed list of their country's existing collections of live breeding aquatic organisms that can be considered as contributing to the *ex situ* conservation of aquatic genetic resources, including not only collections of aquatic species farmed directly for human use, but also collections of aquatic live feed organisms and collections of aquatic organisms devoted to other uses. The term *in vivo* has been used to signify *ex situ* conservation of live organisms.

5.3.1 Existing and planned collections: general overview

Regarding existing collection of live breeding organisms of aquatic genetic resources, a total of 69 countries (out of 92 surveyed countries 75 percent) have current *ex situ* conservation activities and programs being implemented at national level.

The precise number of species maintained *in vivo* is difficult to determine. In the case of Australia, live collection are held by various private stakeholders (fish breeders and fish farmers), but they have not been registered or recorded to a certain level of detail by the Government or States; therefore, the detailed information is unknown.

In the case of Brazil, the Government estimates around 55 species (marine and freshwater) being maintained in “real” *ex situ* conservation programs, although the information is incomplete at this stage, because of many private stakeholders (fish breeders) maintaining their own *ex situ* conservation facilities.

Peru mentioned a similar problem, with most actions being developed by the IMARPE (the Peruvian Institute of the Sea), but with detailed information not available, (it is mentioned in the report that more than 24 aquatic finfish species are being conserved as well as more than 159 strains of microalgae).

Although the questionnaire did not specifically ask who was funding *ex situ* conservation, Sweden stated that that most *ex situ* conservation actions of live aquatic organisms are being conducted by private fish farmers and fish breeders, as well as by private fishing (recreational fisheries) associations. Therefore the government does not have accurate information about these efforts.

There are a total of 690 cases of aquatic species are being conserved in *ex situ* conservation programs in 69 countries (Table 5.1). The countries with the largest number of *ex situ* conservation cases were Colombia, Peru, China, Bangladesh, Viet Nam and Mexico.

Table 5.1
Countries reporting *in vivo ex situ* conservation programmes

Country	Number of programs	Country	Number of programs	Country	Number of programs
Colombia	78	Norway	9	Cameroon	3
Peru	64	Senegal	9	Ghana	3
China	51	Turkey	9	Niger	3
Bangladesh	43	United States of America	9	Palau	3
Viet Nam	26	Germany	8	Chad	2
Mexico	23	Croatia	7	Czechia	2
Romania	23	Estonia	7	Dominican Republic	2
Argentina	22	Finland	7	Fiji	2
Japan	22	Ukraine	7	Guatemala	2
Philippines	20	Thailand	6	Republic of Korea	2
Sweden	20	Tunisia	6	Madagascar	2
Bulgaria	16	Benin	5	Sierra Leone	2
Algeria	15	Georgia	5	Togo	2
India	15	Indonesia	5	Venezuela (Bolivarian Republic of)	2
Sri Lanka	14	Malawi	5	Armenia	1
Uganda	14	Cambodia	4	Belize	1
Costa Rica	12	El Salvador	4	Bhutan	1
Malaysia	12	Nigeria	4	Canada	1
Egypt	10	Poland	4	Denmark	1
Iran (Islamic Republic of)	10	United Republic of Tanzania	4	Nicaragua	1
Zambia	10	Belgium	3	Vanuatu	1
Hungary	9	Burkina Faso	3	Australia	n.s.
Kenya	9	Burundi	3	Sweden	

Asia was the region reporting the most *in vivo ex situ* conservation programmes followed by Latin America and the Caribbean (Figure 5.1a). There are more *in vivo ex situ* conservation programmes in Other Developing Countries than in the other classifications and the major producing countries reported more *ex situ* conservation programmes per country than the minor producing countries (Figure 5.1b, c).

Figure 5.1a
Distribution of *in vivo ex situ* conservation programs by region

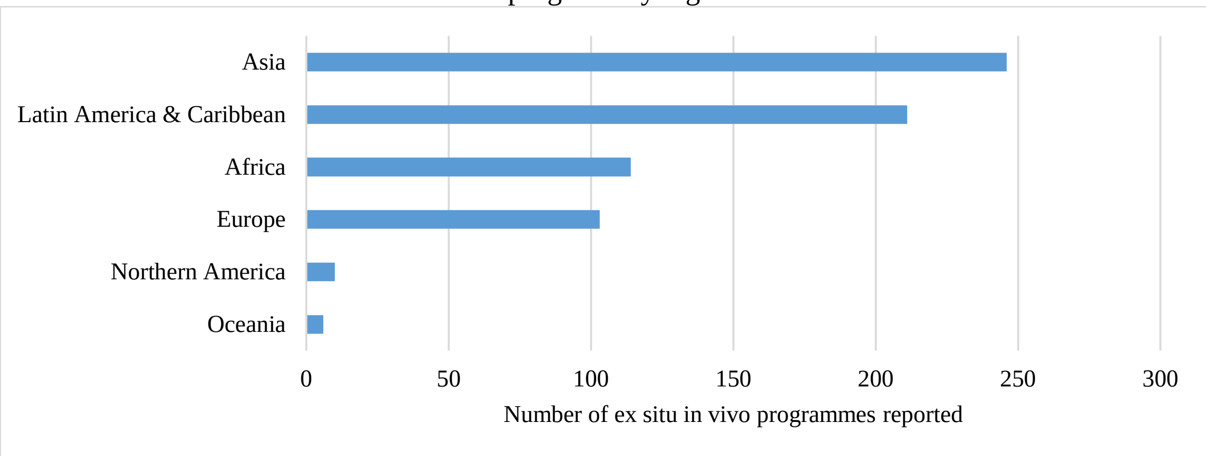


Figure 5.1b
Distribution of *in vivo ex situ* conservation programs by economic classification

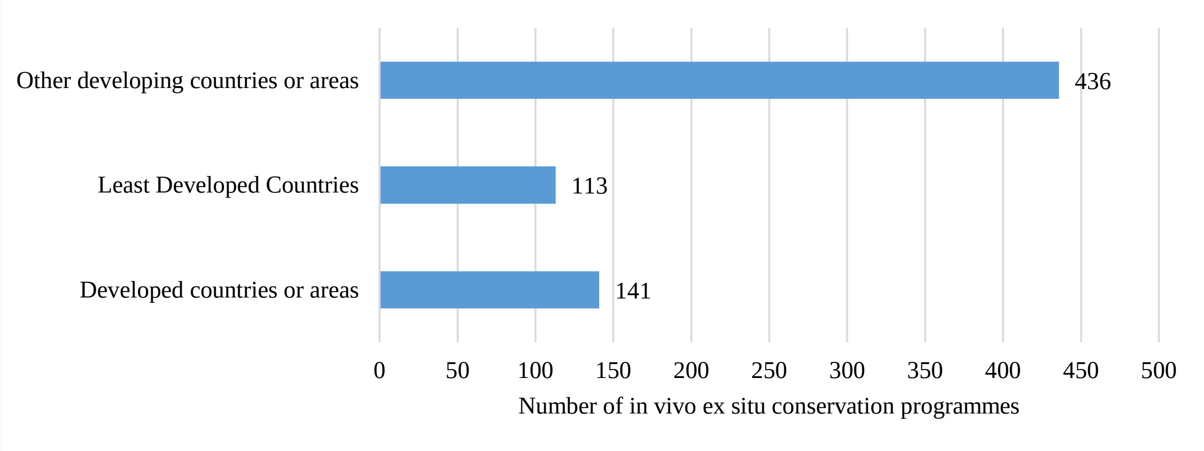
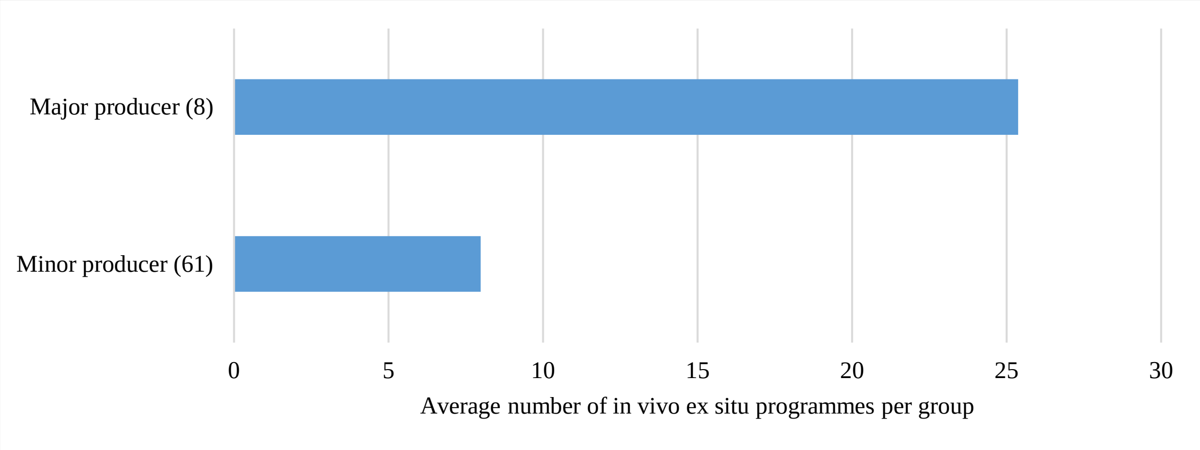


Figure 5.1c
Distribution of *in vivo ex situ* conservation programs by level of production



5.3.2 Endangered species

Countries were also asked to include whether the species being maintained in *ex situ* conservation facilities are threaten or considered as endangered at national and/or international levels. Thirty four countries (49 percent of the 69 countries reporting) indicated the maintenance of threatened/endangered aquatic genetic resources in their *ex situ* conservation.

There is a total of 197 examples of endangered aquatic species being conserved under *in vivo ex situ* conservation programs (Table 5.2). Columbia reported the highest absolute number of endangered species undergoing *in vivo ex situ* conservation while several countries reported that all of their *in vivo ex situ* conservation programmes targeted endangered species.

Table 5.2
Endangered aquatic species maintained in *in vivo ex situ* conservation programmes

Country	Number	Total	Percent
Colombia	49	78	63
Bangladesh	22	43	51
Viet Nam	15	26	58
India	10	15	67
Hungary	8	9	89
Romania	8	23	35
Philippines	7	20	35
Bulgaria	6	16	38
China	5	51	10
Finland	5	7	71
Georgia	5	5	100
Germany	5	8	63
Iran (Islamic Republic of)	5	10	50
Thailand	5	6	83
Turkey	5	9	56
Ukraine	5	7	71
Argentina	3	22	14
Burundi	3	3	100
Cambodia	3	4	75
Palau	3	3	100
Sri Lanka	3	14	21
Czechia	2	2	100
Guatemala	2	2	100
Japan	2	22	9
Norway	2	9	22
Armenia	1	1	100
Bhutan	1	1	100
Costa Rica	1	12	8
Croatia	1	7	14
Denmark	1	1	100
Malaysia	1	12	8
Mexico	1	23	4
Poland	1	4	25
Uganda	1	14	7

N= number of endangered species; Total = total number of species of *in vivo ex situ* programmes; Percent= percent endangered species out of total number of programmes in country.

Box 5.1

Sturgeon 2020 – A coordinated approach to conservation of endangered and critical genetic resources in the Danube River Basin

Sturgeon fisheries in the Danube river have long represented a major income source for communities along the river, particularly in the Middle and Lower Danube and the Delta. Sturgeons are part of the natural heritage of the Danube River Basin (DRB). However, populations have declined rapidly and drastically in recent decades. Of the six species of Sturgeon native to the Danube one has already gone extinct in the DRB, a further four are classed as critically endangered, with one of these on the verge of extinction. Even the most common species, the Sterlet (Acipenser ruthenus), is classed as vulnerable. The decline of these populations is due to multiple factors including overfishing, illegal fishing, anthropogenic disruptions to spawning migration and habitat loss due to river engineering. As a flagship species, conservation of Sturgeon has been recognized by the Danube countries and the European Commission as a basin wide issue of great importance.

The European Union adopted a Strategy for the Danube Region (EUSDR) in June 2011 with the objective of harmonizing sectoral policies under an integrated approach providing a framework for balancing environmental protection with regional social and economic requirements. As a result of the EUSDR, scientists, governmental and non-governmental organizations came together to form the Danube Sturgeon Task Force (DSTF) in January 2012 to support the target of the EUSDR "to ensure viable populations of sturgeon and other indigenous fish species by 2020". The Sturgeon 2020 program (Sandu, Reinartz and Bloesch, 2013) was conceived as a living structure dependent on the long term commitment of the Danube and Black sea countries requiring cooperation between various stakeholders including governments, policy makers, local communities, scientists, and NGOs. The various measures proposed were grouped under six key topics:

- acquiring political support for sturgeon conservation;
- capacity building and law enforcement;
- *in situ* sturgeon conservation;
- *ex situ* sturgeon conservation;
- socio-economic measures to support sturgeon conservation; and
- raising public awareness.

Of specific interest in the context of this SoW report was the integrated approach to *in situ* and *ex situ* conservation.

The focus of *in situ* conservation is the characterization of Sturgeon populations, including genetic characterization using modern molecular tools, and the identification of sturgeon life cycles. This will inform the development of applied *in situ* conservation measures including monitoring of the sturgeon life cycles, the conservation and restoration of life cycle requirements, harmonization of the respective measures, methods and fishing regulations within the DRB and research on the possibility to develop and introduce sturgeon friendly fishing techniques. The plan has also identified and prioritized species and region specific requirements.

The focus of *ex situ* conservation is the establishment of captive broodstock of all species within a joint regional network and preferably in non-commercial facilities. *Ex situ* hatcheries will develop breeding and release protocols in line with WSCS-FAO guidelines(Chebanov et al., 2011) to support targeted stocking and reintroduction programs which will follow IUCN guidelines (IUCN, 1998).

Neither *in situ* (see Chapter 4) or *ex situ* conservation methods are intended to stand alone but will be integrated to support and best ensure the viability of the natural life cycle, including in the implementation of species and region specific requirements. Research on the characterization of sturgeon populations and life cycles will under pin the coordinated strategies for both *in situ* and *ex situ* conservation. Active monitoring programs will be applied to both *in situ* and *ex situ* conservation and the impacts of restocking will be fully evaluated.

Sturgeon 2020 represents a holistic approach to conservation of flagship aquatic genetic resources, involving strong international cooperation and incorporating strong integration of both *ex situ* and in situ conservation.

5.3.3 Main species being conserved

The ten species most often reported as being maintained in *in vivo ex situ* conservation programmes were primarily freshwater or brackishwater fin fish, but also included microorganisms (Table 5.3). Approximately ninety percent of the aquatic genetic resources conserved are finfish species and ten percent are aquatic microorganisms, such as rotifers and microalgae.

Table 5.3
The most common species and species items in *in vivo ex situ* conservation programmes

Species	N	Species	N
Oreochromis niloticus	16	*Microalga*	4
Oncorhynchus mykiss	10	*Tilapia*	4
Brachionus plicatilis	9	*Probarbus jullieni*	3
Clarias gariepinus	9	*Salmo Trutta*	3
Cyprinus carpio	9	*Skeletonema costatum*	3
Isochrysis galbana	9	*Spirulina sp.*	3
Acipenser gueldenstaedtii	7	*Tor putitora*	3
Huso huso	7	*Undaria pinnatifida*	3
Acipenser stellatus	6	*Artemia salina*	3
Chlorella sp.	6	*Brachionus rotundiformis*	3
Salmo salar	6	*Copepoda sp.*	3
Sander lucioperca	6	*Crassostrea Gigas*	3
Acipenser ruthenus	5	*Dicentrarchus labrax*	3
Nannochloropsis oculata	5	*Esox lucius*	3
Tetraselmis sp.	5	*Hypophthalmichthys molitrix*	3
Acipenser baerii	4	*Lutjanus guttatus*	3
Artemia sp.	4	*Macrobrachium rosenbergii*	3
Chaetoceros sp.	4	*Moina sp.*	3
Penaeus monodon	4	*Nannochloropsis sp.*	3
Penaeus vannamei	4	*Microcyclops sp.*	1
Brachionus sp.	4	*Rotifers*	3

N= number of countries reporting three or more examples.

5.3.4 Main uses of conserved species

Countries were asked to provide the main destination/use of each conserved aquatic species in *ex situ* conservation programs or actions, including: used as live feed, used for direct human consumption and other uses. Finfishes are maintained both for direct human consumption and as live feed for aquaculture, while the microorganisms are used as live feed for aquaculture in most cases.

From the 690 reports of *in vivo ex situ* conservation programs, 398 cases including 290 species were reported to be for direct human consumption; 127 species are conserved for use as live feed in aquaculture or other primary industries; and 212 aquatic species are conserved for “other uses”, such as: future domestication or potential use in aquaculture; conservation of aquatic biodiversity; potential use as ornamental species; pharmaceutical uses; spat monitoring; restocking and stock enhancement purposes; recreational fisheries; research, among many other uses (Table 5.4).

Certain species are used to several uses. For example, Nile tilapia, is being used for direct human consumption but also, as live feed for aquaculture in certain countries where carnivorous species are fed with Nile tilapia juveniles. Rotifers were the most important group of AqGR used for live feed (Table 5.4).

Figure 5.2
Uses of *ex situ* conserved aquatic species (Percent)

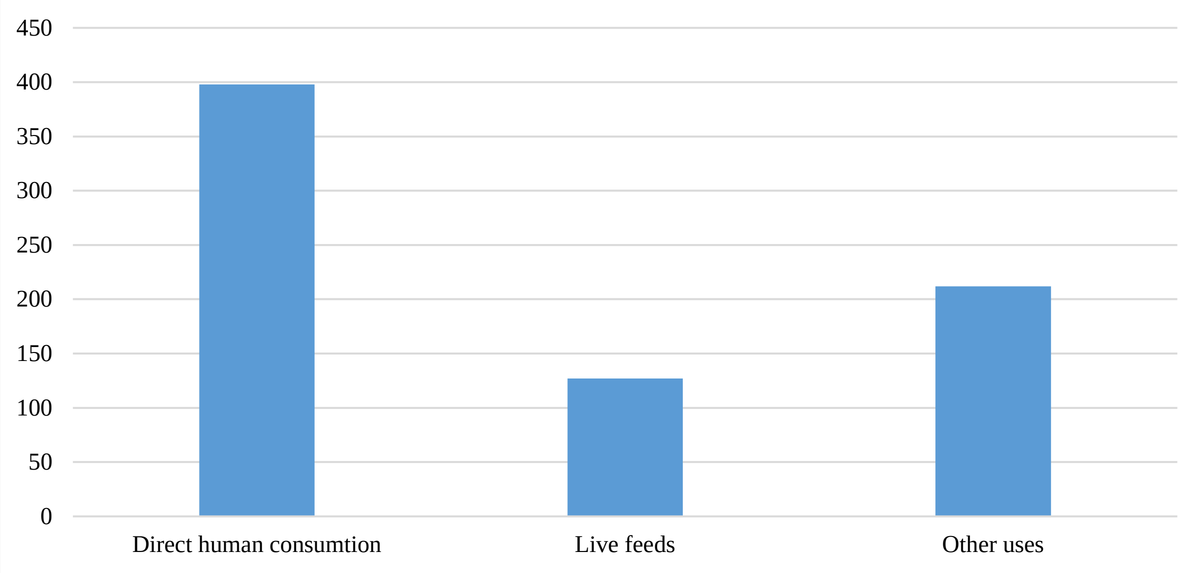


Table 5.4
Most important species or species items reported in *in vivo ex situ* conservation and their uses

Species	Number of countries reporting	Type of use	Species	Number of countries reporting	Type of use
Oreochromis niloticus	16	DHU	*Macrobrachium rosenbergii*	3	DHU
Clarias gariepinus	9	DHU	*Probarbus jullieni*	3	DHU
Cyprinus carpio	9	DHU	*Salmo Trutta*	3	DHU
Oncorhynchus mykiss	9	DHU	*Tilapia*	3	DHU
Huso huso	6	DHU	*Brachionus plicatilis*	8	LF
Acipenser gueldenstaedtii	5	DHU	*Isochrysis galbana*	8	LF
Acipenser ruthenus	5	DHU	*Chlorella* sp.	5	LF
Acipenser stellatus	5	DHU	*Artemia* sp.	4	LF
Acipenser baerii	4	DHU	*Brachionus* sp.	4	LF
Penaeus monodon	4	DHU	*Chaetoceros* sp.	4	LF
Penaeus vannamei	4	DHU	*Microalga*	4	LF
Sander lucioperca	4	DHU	*Nannochloropsis oculata*	4	LF
Crassostrea Gigas	3	DHU	*Rotifers*	3	LF
Lutjanus guttatus	3	DHU	*Spirulina* sp.	3	LF

N= number of countries reporting; DHU= direct human use; LF= live feed organism.

Table 5.5
Main aquatic species used as live feed organisms for aquaculture activities and number of reported programmes

Rotifers	*Brachionus plicatilis*	8
	Brachionus rotundiformis	3
	Rotifers (Brachyionus plicatilis)	3
	Brachionus sp	4
Artemia	*Artemia franciscana*	1
	Artemia salina	4
	Artemia urmiana	1
	Isochrysis galbana	8
Copepods	Copepodes (*Thermocyclops* sp.)	1
Cladocerans	Cladocerans	1
	Daphnia moina	1

	Daphnia pulex	1
Microalgae	*Tetraselmis tetrahele* *Dunaliela tertiolecta* *Nannocloropsis occulata* *Chaetoceros gracilis* *Skeletonema costatum* *Nitzschia alba* *Chlorella vulgaris*	6
	Chaetoceros lorenziano	1
	Chaetoceros compressus	1
	Chaetoceros debilis	1
	Chaetoceros socialis	1
	Chlorella sp.	5
	Dendrocephalus affinis	1
	Diaphanosoma	1
Cyanobacterium	*Spirulina* sp.	3
Live fish	*Clarias anguillaris*	1
	Clarias gariepinus	1
	Oreochromis niloticus	2

5.4 *In vitro* collection

5.4.1 Introduction

This section provides a global review of existing *ex situ* conservation activities of aquatic genetic resources of farmed aquatic species and their wild relatives *in vitro*. *In vitro* has been defined for the purpose of this study as specimens maintained in a tissue culture laboratory rather than as living organisms; specimens are propagated clonally, therefore the strain genetics remain constant even when small populations are maintained. This is very different from sexual propagation of conserved material, where genetic drift and small population size is a constant consideration in maintaining each variety's genetic diversity.
n vitro conservation is conducted using components of an organism that have been isolated from their usual biological surroundings, such as freezing of microorganisms, cells, DNA, gametes or molecules. For example, microorganisms or cells can be studied in artificial culture media, and proteins can be examined in solutions.

Following are some of the advantages of "*in vitro*" conservation programs and studies:

- Simplicity: living organisms are extremely complex functional systems that are made up of, at a minimum, many tens of thousands of genes, protein molecules, RNA molecules, small organic compounds, inorganic ions, and complexes in an environment that is spatially organized by membranes, and in the case of multicellular organisms, organ systems (Albert *et al.*, 2008). These myriad components interact with each other and with their environment in a way that processes food, removes waste, moves components to the correct location, and is responsive to signaling molecules, other organisms, light, sound, heat, taste, touch, and balance.
- This complexity makes it difficult to identify the interactions between individual components and to explore their basic biological functions. *In vitro* work simplifies the system under study, so the investigator can focus on a small number of components (Price and Nairn, 2009; Vignais and Vignais, 2010).
- Species specificity: another advantage of *in vitro* methods is that cells can be studied without "extrapolation" from an experimental animal's cellular response.
- Convenience, automation: *In vitro* methods can be miniaturized and automated, yielding high-throughput screening methods for testing molecules in pharmacology or toxicology.

By contrast, the primary disadvantage of *in vitro* conservation is that it may be challenging to extrapolate from the results of *in vitro* work back to the biology of the intact organism. Investigators doing *in vitro* work must be careful to avoid over-interpretation of their results, which can lead to erroneous conclusions about organismal and systems biology (Rothman, 2002).

5.4.2 Existing and planned in vitro collections: general overview

Countries were asked to provide a detailed list of *in vitro* collections and gene banks of gametes, embryos, tissues, spores and other quiescent forms of farmed aquatic species and their wild relatives, using cryopreservation or other methods of long-term storage.

Countries were also requested to describe major examples, identifying the facilities in which the collections are held, and including examples of any such genetic material from the country that is being kept in *in vitro* collections outside the country, on behalf of beneficiaries in country.

A total of 35 countries reported *in vitro* collections of aquatic genetic resources of both farmed and wild relatives. Countries reported 295 cases of aquatic species involving about 133 separate species being maintained in *in vitro* collections (Table 5.6).

This is probably an underestimate as is not possible to determine the exact number of *in vitro* collections from the answers given by surveyed countries; several institutions and agencies are involved in maintaining these collections without specific monitoring from the Government. The number and complexity of the *in vitro* conservation programs often makes it difficult to list all the species being conserved. For example in Norway there are more than 1 000 isolates of marine bacteria being conserved *in vitro* in various institutes. The diversity of freshwater conservation program can also be high to list all conserved species in the report but Malaysia reported 73 aquatic species being conserved for future aquaculture uses, biodiversity conservation, and other uses.

The country with the largest number of species being maintained *in vitro* collections is Malaysia, followed by India and Mexico.

Table 5.6
Countries and number of species maintained in *in vitro* collections

Country	Species	Country	Species
Malaysia	73	Bangladesh	4
India	34	Thailand	3
Mexico	30	Tunisia	3
Finland	29	Indonesia	2
Germany	14	Kiribati	2
United States of America	13	Republic of Korea	2
Uganda	11	Philippines	2
Argentina	10	Poland	2
Czechia	9	Tonga	2
Colombia	8	Ukraine	2
Turkey	7	Armenia	1
Egypt	6	Hungary	1
Senegal	6	Iran (Islamic Republic of)	1
Sri Lanka	6	Kenya	1
Netherlands	5	Nigeria	1
Palau	5		

Table 5.7 and Table 5.8 provide the absolute number and average numbers of species maintained per country by region and by economic class. Differences are observed between regions with Asia maintaining the most *in vitro* collections and Latin America and the Caribbean maintaining the highest number of collections per country. Least developed countries had the lowest average number of *in vitro* collections, but the differences among the economic groupings were not large (Table 5.8). There were only small difference found in average number of *in vitro* collections when countries were analyzed by level of production (data not shown).

Table 5.7
In vitro collections by region – Total number of species maintained and average number of species maintained per country

Region	Species	Number of countries	Average species
Africa	28	6	4.7
Asia	135	10	13.5
Latin America and the Caribbean	56	3	18.7
Europe	63	7	9.0
North America	13	1	13.0
Oceania	10	4	2.5

Table 5.8
In vitro collections by economic class – Total number of species maintained and average number of species maintained per country

Economic class	Species	Country	Average species/country
Developed countries or areas	78	10	7.8
Least Developed Countries	23	4	5.75
Other developing countries or areas	131	17	7.7

5.4.3 Main species being conserved in vitro

Table 5.9 provides a summary of the 133 species being conserved *in vitro* conservation programs. Common carp, *C. carpio*, and rainbow trout, *O. mykiss*, were reported to be the species most often conserved *in vitro*. The assessment of these species shows that their principle use is for direct human consumption (data not shown).
Detailed information on the main objectives of the *ex situ* conservation programs at global, sub-regional and by economic class levels is provided below in Section 5.5 of this chapter.

Table 5.9
Summary of conserved in *in vitro* collections

Species name	N	Species name	N	Species name	N
Cyprinus carpio	6	*Claresse catfish*	1	*Ompok malabaricus*	
Oncorhynchus mykiss	5	*Clarias batrachus*	1	*Ompok pabda*	
Artemia sp.	4	*Clarias gariepinus*	1	*Oncorhynchus* sp.	
Isochrysis galbana	4	*Colossoma macropomum*	1	*Oncorhynchus tshawytscha*	
Anguilla anguilla	3	*Coregonus lavaretus*	1	*Oreochromis niloticus souche Niayes*	
Brachionus plicatilis	3	*Coregonus maraena*	1	*Oreochromis niloticu souche fleuve Sénégal*	1
Catla catla	3	*Coregonus peled*	1	*Oreochromis* sp.	1
Chaetoceros muelleri	3	*Crassostrea gasar*	1	*Pagrus pagrus*	1
Labeo rohita	3	*Crassostrea virginica*	1	*Pangasianodon gigas*	1
Oreochromis niloticus	3	*Ctenopharyngodon idellus*	1	*Paralichthys californicus*	1
Salmo salar	3	*Dicentrarchus labrax*	1	*Penaeus monodon*	1
Acipenseridae	2	*E. cottonii*	1	*Penaeus vannamei*	1
Artemia salina	2	*E. striatus*	1	*Perca flavescens*	1
Cirrhinus mrigala	2	*Epinephelus coioides*	1	*Piaractus brachypomus*	1
Crassostrea gigas	2	*Epinephelus malabaricus*	1	*Piaractus mesopotamicus*	1
Gadus morhua	2	*Etroplus suratensis*	1	*Pleuronectes platessa*	1
Huso huso	2	*Garra surendranathanii*	1	*Polyprion americanus*	1

Pangasius pangasius	2	*Haliotis rufescens*	1	*Porphyra tenera*	1
Psetta maxima	2	*Heteropneustes fossilis*	1	*Prochilodus lineatus*	1
Rachycentron canadum	2	*Horabagrus brachysoma*	1	*Prochilodus* sp.	1
Salmo Trutta	2	*Hypophthalmichthys molitrix*	1	*Pseudoplatystoma corruscans*	1
Silurus glanis	2	*Hypophthalmichthys nobilis*	1	*Pseudoplatystoma* sp.	1
Acipenser baerii	1	*Hypselobarbus curmuca*	1	*Rhamdia quelen*	1
Acipenser fulvescens	1	*Ictalurus furcatus*	1	*Rhinomugil corsula*	1
Acipenser gueldenstaedtii	1	*Ictalurus punctatus*	1	*Sahyadria chalakkudiensis*	1
Acipenser oxyrhynchus	1	*Kappaphycus alvarezii*	1	*Salminus brasiliensis*	1
Acipenser ruthenus	1	*Labeo calbasu*	1	*Salmo ischchan*	1
Acipenser sturio	1	*Labeo dero*	1	*Sarotherodon melanotheron*	1
Acipenser stellatus	1	*Labeo dussumieri*	1	*Schizothorax richardsonii*	1
Anabas testudineus	1	*Labeo dyocheilus*	1	*Sciaenops ocellatus*	1
Anoplopoma fimbria	1	*Labeo fimbriatus*	1	*Seriola lalandi*	1
Bagrus docmak	1	*Labeo victorianus*	1	*Silonia silondia*	1
Barbodes carnaticus	1	*Lates calcarifer*	1	*Sorubim cuspicaudus*	1
Barbus altianalis	1	*Lates niloticus*	1	*Spirulina*	1
Brachionus	1	*Leiarius marmoratus*	1	*Tenualosa ilisha*	1
Brycon moorei	1	*Leporinus obtusidens*	1	*Tetraselmis*	1
Brycon sp.	1	*Microalga*	1	*Tilapia guineensis*	1
Channa marulius	1	*Moina belli*	1	*Tilapia* sp.	1
Channa striata	1	*Morone chrysops*	1	*Tinca tinca*	1
Chelidonichthys cuculus	1	*Morone saxatilis*	1	*Tor khudree*	1
Chirostoma humboldtianum	1	*Mugil cephalus*	1	*Tor putitora*	1
Chitala chitala	1	*Mytilus edulis*	1	*Totoaba Macdonaldi*	1
Chlorella sp.	1	*Nannochloropsis sp.*	1	*Undaria pinnatifida*	1
Chlorella vulgaris	1	*Odontesthes bonariensis*	1	*Wallago attu*	1
Cirrhinus cirrhosus	1				

N= number of countries maintaining *in vitro* collections

5.4.4 In vitro conservation mechanisms

Countries were asked to provide information on the *in vitro* conservation mechanisms and strategies used for each species. Options given in the report for “type of *ex situ* conservation collection *in vitro*” were:

- *in vitro* collection of gametes
- *in vitro* collection of embryos
- *in vitro* collection of tissues
- spores
- others.

As a result of this assessment, it was observed that:

- gametes (almost exclusively male gametes) were the type most often conserved *in vitro* with about 46 percent of species are maintained in the form of gametes (mostly in the case of finfish species – marine, freshwater and brackishwater finfish aquatic species);
- twenty-four percent of the species are conserved as tissues (mostly freshwater finfish species);
- twenty-five percent of the species are conserved as embryos (with a wide range of genus and species, including finfish, molluscs and crustaceans, such as *Artemia*, oysters and mullets);
- only four percent are conserved in the form of spores (this methodology is mostly being applied in the case of microalgae used as live feed for aquaculture or conserved for research purposes); and
- in addition, 15 percent of the aquatic species are conserved in other ways.

Table 5.10
Summary of the number of species being maintained by each mechanism (N), including the percentage out of 248 total collections reported

Mechanism	N	Percentage
In vitro collection of gametes	115	46
In vitro collection of embryos	25	10
In vitro collection of tissues	60	24
Others	37	15
Spores	11	4

5.4.5 Facilities for in vitro conservation

Countries were also asked to identify the type of facilities where AqGR are being conserved in *in vitro* conservation programs.

The options given in the report to surveyed countries were:

- aquaculture facilities
- research facilities
- universities and Academia
- zoos and aquaria
- others

Among the 133 aquatic species being conserved in 269 cases of *in vitro* conservation programs, 56 of them are being conserved in aquaculture facilities, 146 of them are being conserved in research facilities; 59 of them are being conserved in Zoos and aquaria, and six of them are being conserved in other type of facilities (Table 5.11).

Table 5.11
Summary of the number of species being maintained by each type of facility (N), including the percentage out of 269 total collections reported by countries

Type of facility	N	Percentage
Aquaculture facilities	56	21
Research facilities	146	54
Universities and academia	59	22
Zoos and aquaria	2	1
Others	6	2

5.5 Global assessment of objectives of *ex situ* conservation programs

Countries were requested to assess the level of importance of the following objectives of *ex situ* conservation programs (both *in vivo* and *in vitro)* in their respective countries:

- preservation of aquatic genetic diversity
- maintain good strains for aquaculture production
- meet consumer and market demands
- to help adapt to impacts of climate change
- future breed improvement in aquaculture.

Objectives were ranked from one to ten with one being a very important objective of the overall national *ex situ* conservation programs, and ten the less important objective. The most important objective for *ex situ* conservation at the global level was the preservation of aquatic genetic diversity (Figure 5.3) followed by the use of these resources for future breed improvement in aquaculture and for the maintenance of good strains for future aquaculture production. The less important objective of national *ex situ* conservation programs at global level was the need to maintain these resources for adaptation to climate change.

Analysis by region Figure 5.3a) revealed similar results with five of the six regions citing preservation of AqGR as the highest priority and four of the six citing adaptation to climate change as the least important objective. Meeting consumer demands was also listed as a relatively less important objective of *ex situ* conservation. Analysis by economic and production level (Figure 5.3b,c) revealed similar results.

It is somewhat surprising that "Meeting consumer and market demands" was reported to have a lower priority in countries that have the highest level of production (Figure 5.3c). However, this is a very similar result to that reported for the priority objectives for *in situ* conservation (See Chapter 4). The low ranking of adapting to impacts of climate change was also seen in the rankings of objectives for *in situ* conservation.

Table 5.12: Ranking of objectives of *ex situ* conservation programs

	1	2	3	4	5	6	7	8	9	10	Average Rank
Preservation of aquatic genetic diversity	51	10	10	5	8				1	2	2.18
Maintain good strains for aquaculture production	45	10	12	6	4	1		1	4	4	2.70
Future breed improvement in aquaculture	33	19	13	7	5	2		4	2	2	2.82
To help adapt to impacts of climate change	20	10	9	9	15	5	4	4	7	4	4.26
Meet consumer and market demands	13	11	16	11	12	6	5	7	1	5	4.29
Other											2.33

Column numbers are ranks with 1= highest priority and 10 the lowest.

Figure 5.3a: Priority rankings of objectives for *ex situ* conservation of AqGR by region (see text for full explanation of objectives)

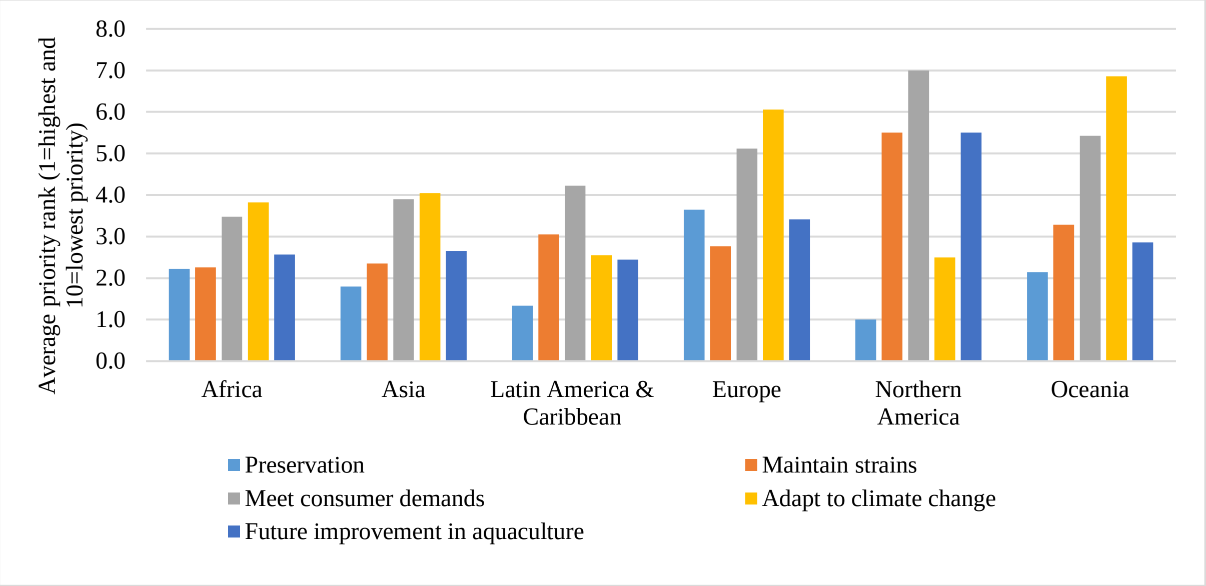


Figure 5.3b: Priority rankings of objectives for *ex situ* conservation of AqGR by economic classification (see text for full explanation of objectives)

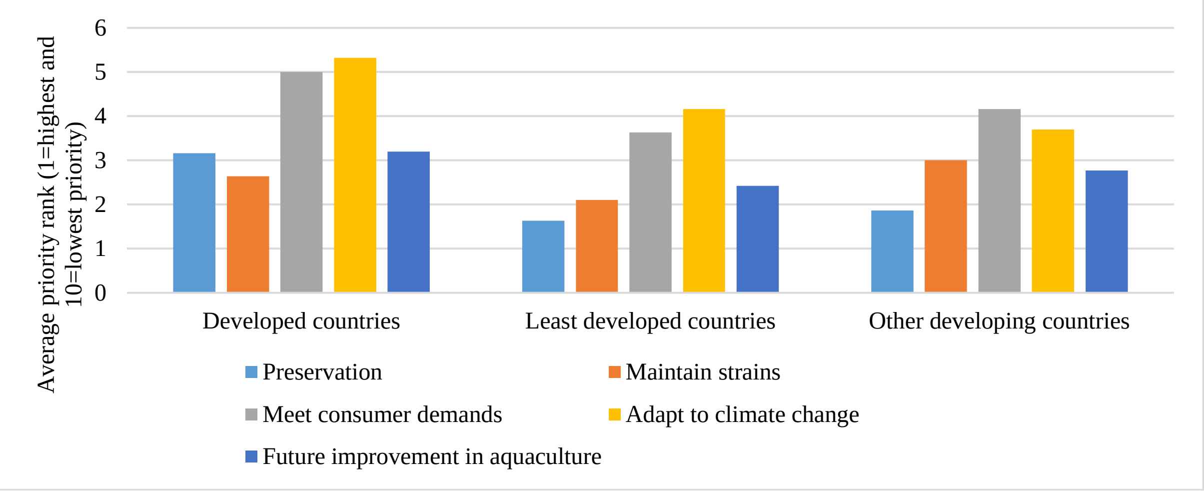
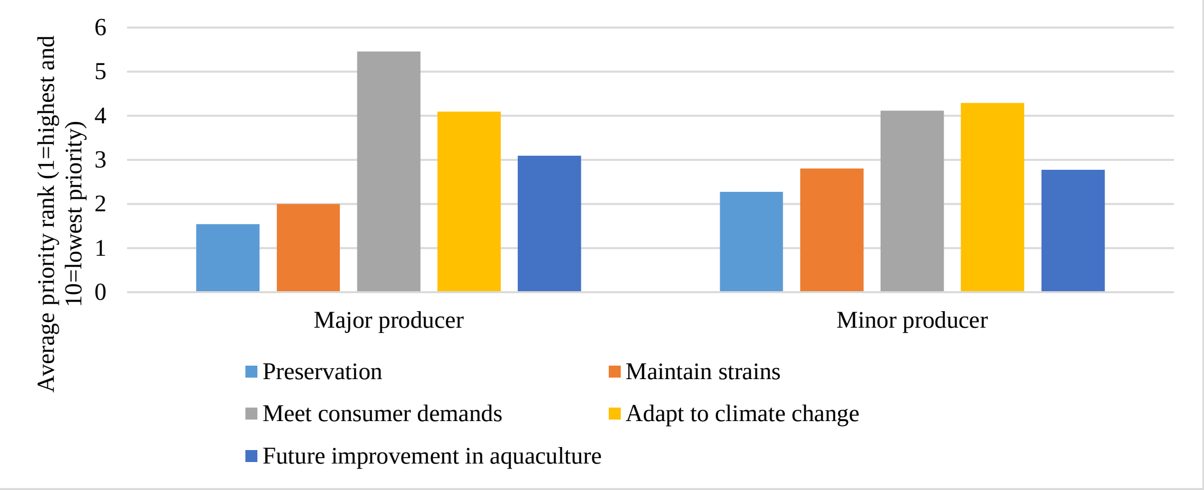


Figure 5.3c: Priority rankings of objectives for *ex situ* conservation of AqGR by level of production (see text for full explanation of objectives)



5.6 Key findings and conclusion

Ex situ collections, both *in vivo* and *in vitro*, are a common mechanism for the conservation of AqGR	Most countries have *ex situ* vivo collections of AqGR conserving about 290 different aquatic species. Almost 200 endangered aquatic species are being maintained in *ex situ in vivo* collections.
	Two hundred ninety five cases of *In vitro ex situ* conservation collections were reported including more than 133 aquatic species in various types of facilities.
	The most important objective for *ex situ* conservation at the global level (both *in vivo* and *in vitro*) was the preservation of aquatic genetic diversity, followed by future strain improvement in aquaculture and for the maintenance of good strains for future aquaculture production.
	The rankings of the objectives were very similar when countries were grouped by region, economic level and level of production, i.e. preservation of AqGR was a high priority and adaptation to climate change a low priority.
AqGR is often conserved so that it can be used as well	Direct human consumption was the most often cited use for *in vivo ex situ* conservation; an important objective of *ex situ* conservation was for future aquaculture strain improvement.
Finfish are the group most often conserved in *ex situ* collection	Approximately ninety percent of the aquatic genetic resources being conserved are finfish) while only ten percent are macro-invertebrates, and aquatic microorganisms such as small crustaceans, rotifers and microalgae.

5.7 References and key documents

Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K.& Walter, P. 2008. *Molecular biology of the cell*. New York: Garland Science. ISBN 0-8153-4105-9.

Carrizo, S.F., Smith, K.G. & Darwall, W.R.T. 2013. *Progress towards a global assessment of the status of freshwater fishes (Pisces) for the IUCN Red List: application to conservation programmes in zoos and aquariums*. International Zoo Yearbook, vol. 47. pp. 46–64.

Chebanov, M., Rosenthal, H., Gessner, J.. Van Anrooy, R., Doukakis, P., Pourkazemi, M. & Williot, P. 2011. *Sturgeon hatchery practices and management for release-Guidelines*. FAO Fisheries and Aquaculture Technical Paper No 570. Ankara, FAO.110 pp. Also available at: www.fao.org/docrep/015/i2428e/i2428e.pdf

Engels J.M.M, Rao, V.R., Brown, A. H. D. & Jackson, M.T. 2001. *Managing plant genetic diversity*. CABI. pp. 89.

Frankham R., Ballou, J.D. & Briscoe, A.D. 2011. *Introduction to Conservation Genetics*. United Kingdom: Cambridge University Press. ISBN 978-0-521-70271-3. pp. 430–471.

IUCN. 1998. *Guidelines for Re-introductions*. Prepared by the IUCN/ SSC Re-introduction Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. 10 pp.

Kleiman, D.G., Katerina, V.T. & Baer, C.K. 2010. *Wild Mammals in Captivity: Principles and Techniques for Zoo Management*. University of Chicago Press. 720 pp.

NSW Government. 2018. *Freshwater threatened species distribution maps*. Department of primary industries Australia, 2018. Also available at: www.dpi.nsw.gov.au/fishing/species-protection/threatened-species-distributions-in-nsw/freshwater-threatened-species-distribution-maps

Price, N. & Nairn J. 2009. *Exploring proteins: a student's guide to experimental skills and methods*. Oxford, Oxford University Press. ISBN 0-19-920570-1. 528 pp.

Rothman, S. S. 2002. *Lessons from the living cell: the culture of science and the limits of reductionism*. New York: McGraw-Hill. ISBN 0-07-137820-0. pp. 531–550.

Sandu, C., Reinartz, R. & Bloesch, J., Eds. 2013. *"Sturgeon 2020": A program for the protection and rehabilitation of Danube sturgeons*. Danube Sturgeon Task Force (DSTF) & EU Strategy for the Danube River (EUSDR) Priority Area (PA) 6 – Biodiversity. 24 pp. Also Available at: www.dstf.eu/assets/Uploads/documents/Sturgeon-2020edited_2.pdf

Vignais, P.M. & Vignais, P.V. 2010. *Discovering Life, Manufacturing Life*: How the experimental method shaped life sciences. Berlin: Springer. ISBN 90-481-3766-7.

CHAPTER 6
STAKEHOLDERS WITH INTERESTS IN AQUATIC GENETIC RESOURCES OF FARMED AQUATIC SPECIES AND THEIR WILD RELATIVES WITHIN NATIONAL JURISDICTIONS

PURPOSE: Chapter 6 provides an overview of the perspectives and needs of the principal stakeholders with interests in aquatic genetic resources of farmed aquatic species and their wild relatives for food and agriculture within national jurisdictions. Specific objectives are to:

- Identify the different principal stakeholder groups with interests in aquatic genetic resources of farmed aquatic species and their wild relatives;
- Identify the type(s) of aquatic genetic resources of farmed aquatic species and their wild relatives in which each stakeholder group has interests and why;
- Describe the roles of stakeholder groups and the actions they are taking for the conservation, sustainable use and development of the aquatic genetic resources in which they have interests; and
- Describe the actions that stakeholder groups would like to see taken for the conservation, sustainable use and development of aquatic genetic resources in which they have interest.

KEY FINDINGS

- Through participatory regional workshops twelve key stakeholder groups and ten categories of activity were identified.
- Some differences were observed among regions in terms of how they viewed stakeholder participation in the conservation, management and use of AqGR of farmed species and their wild relatives.
- Government Resource Managers, Fishing or Aquaculture Associations and Donors played the greatest roles in the conservation, management and use of AqGR, while Consumers, Marketing People and Fishers, played lesser roles.
- Activities related to conservation, production and advocacy were the most common roles played by the 12 stakeholder groups.
- Stakeholder interests in conservation, management and use of AqGR were consistently greatest at the species level, followed by strain (stock, breed or variety) and then at the genome (DNA) level.
- The importance of indigenous communities in conservation and protection of aquatic biodiversity and aquatic ecosystems of relevance for wild relatives of farmed aquatic genetic resources is recognized by nearly all countries.
- Women are important in the aquaculture sector in all countries, although the qualitative information provided suggests that they may play a wider range of roles in developed countries.
- Little information was provided on what stakeholder groups would like to see take place with respect to the conservation, management and use of aquatic genetic resources.

6.1 Background

Many stakeholders have interests in the conservation, management, use and development of aquatic genetic resources (AqGR) of farmed aquatic species and their wild relatives, either because it comes within the ambit of their jobs or for livelihood and income generating purposes. Yet we know little about where, specifically, these interests lie or what they entail. This section addresses the findings and knowledge gaps from analyses of a total of 91 national responses to the question ‘*Please indicate the principal stakeholder groups with interests in AqGR*’.

6.2 Identification of stakeholders

Stakeholder groups were identified on the basis of institutional knowledge as well as from sectoral and sub-sectoral consultations conducted during the country reporting process and, where necessary, from expert opinion. Gender issues pertaining to the conservation, management, use and development of aquatic genetic resources of farmed aquatic species and their wild relatives are considered, as well as the perspectives and needs of indigenous peoples and local communities.

Multi-stakeholder workshops or meetings were convened in some countries to assess the involvement of different stakeholder groups in key areas associated with aquatic genetic resources conservation, management, use and development. Most countries followed a participatory and inclusive strategy, involving a wide range of stakeholders with interests in aquatic genetic resources, either through a national consultative process such as workshops or seminars, or through the establishment of national committees or task forces composed of key players.

Some countries, such as Germany or Mexico, provided details on the consultative and participatory processes followed in the stakeholder assessment exercise, involving the aquaculture industry, hatchery managers, policy makers and research/academia, among others.

6.3 Global level analysis of stakeholder roles

6.3.1 Introduction

Through the process of national consultation, supported by regional capacity building workshops and advice, countries identified 12 stakeholder groups with interests in the conservation, management and use of aquatic genetic resources of farmed species and their wild relatives (Table 6.1).

Table 6.1. Brief description of stakeholders in conservation, management and use of AqGR, developed by the Secretariat from discussions at national consultations and at stakeholder workshops

Stakeholder	Description
Aquatic protected area managers	Persons responsible for controlling or administering protected areas of seas, oceans, rivers or lakes; these areas usually restrict human activity for a conservation purpose, typically to protect natural or cultural resources.
Consumers	A person who purchases goods and services (in this case related to aquatic genetic resources) for personal use
Donors	Any individuals, organizations, or institutions that make a gift
Fish farmers	Professionals involved in raising aquatic organisms commercially by controlling the entire or parts of the aquatic organism’s life cycle
Fish hatchery people	Professionals involved in running and/or management of a place for breeding aquatic organisms, hatching and rearing through the early life stages of these organisms, with special emphasis on finfish and shellfish in particular
Fishers	People who capture fish and other aquatic animals from a body of water
Fisheries and aquaculture associations	Professional societies of fish farmers, fishermen or both, which is registered and legally recognized at national, regional or international levels
Government resource managers	Managers working in the public sector, responsible for management of natural resources
IGOs	Intergovernmental organizations or international governmental organizations (IGOs) are composed primarily of sovereign states (referred to as member states) or other intergovernmental organizations
NGOs	Non-governmental organizations (NGOs) include any non-profit, voluntary citizens’ groups that are organized at local, national or international levels
People involved in marketing	Professionals involved in the action or business of promoting and selling products or services related to aquatic genetic resources, including market research and advertising
Policy makers	People responsible for formulating policies and other types of regulatory frameworks and instruments

For the purposes of the present exercise ten roles (including ‘others’) associated with the conservation, management, and use of AqGR were also identified through the process of national consultation, supported by regional capacity building workshops and advice (Table 6.2).

Table 6.2. Brief description of roles in conservation, management, and use of AqGR, developed by the Secretariat from discussions at national consultations and stakeholder workshops

Role	Definition
Advocacy	Individual or group activity that aims to influence decisions within political, economic and social systems and institutions
Breeding	Mating and reproduction of offspring by animals
Conservation	Preserving, guarding or protecting wise use
Feed manufacture	The production of aquaculture feeds from plant and animal-based feedstuffs
Marketing	The management process responsible for identifying, anticipating and satisfying customer requirements profitably[1]
Outreach/extension	The application of scientific research and new knowledge to aquaculture practices through farmer extension
Processing	The processes associated with aquatic animals and aquatic animal products between when they are caught or harvested and the time the final product is delivered to customers
Production	The elaboration of aquatic animal biomass in aquaculture systems, through maintenance of good growing conditions and the provision of food
Research	The systematic investigation of scientific theories and hypotheses
Others	None of the above; largely undefined by countries in their responses

[1]Definition from the Chartered Institute of Marketing
Source: www.CIM.co.uk

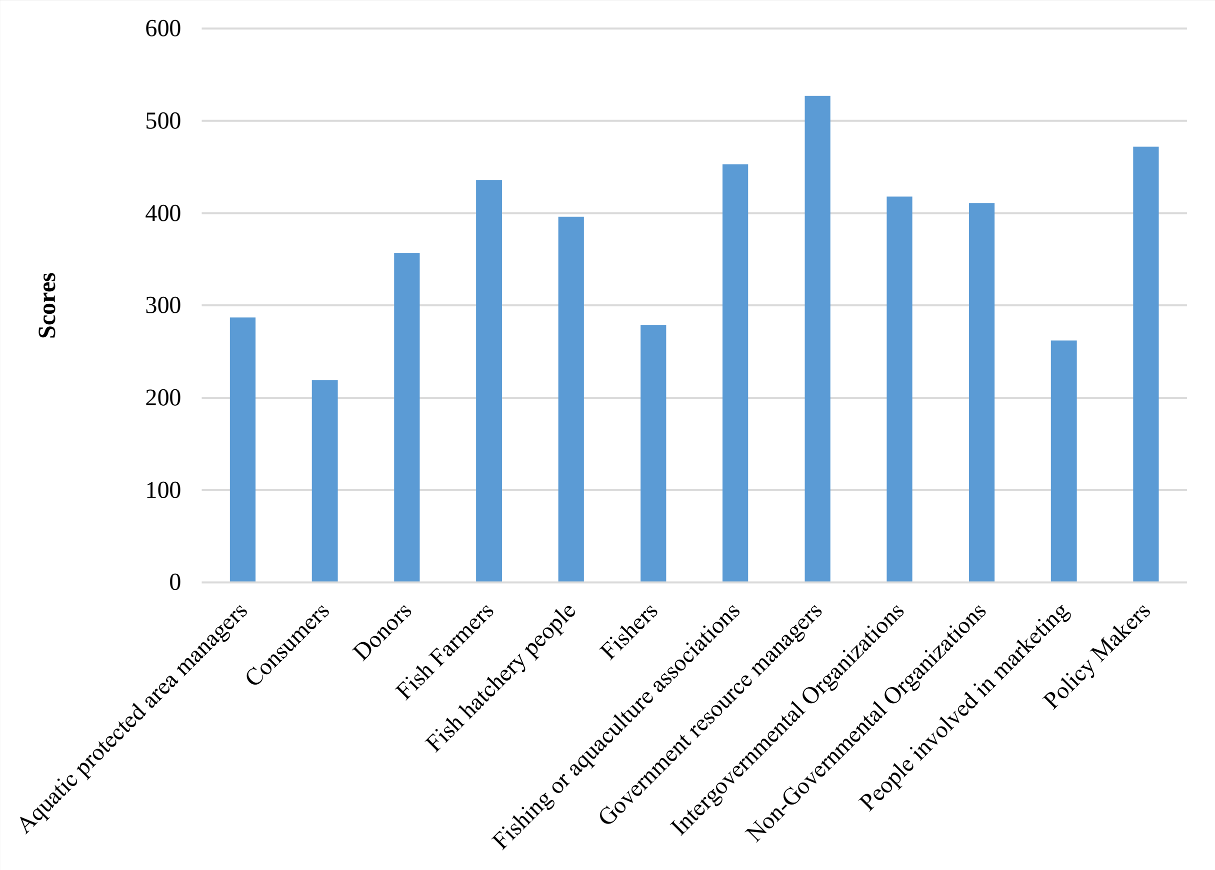
6.3.2 Role of different stakeholder groups in the conservation, management, and use of AqGR

In order to provide a simple global-level indicator of stakeholder activity in the conservation, management, and use of AqGR, data on the number of countries that found various stakeholder groups to be involved in each of the ten categories were summed. Out of a possible maximum score of 1 092 (i.e. all 91 responding countries reported that all 12 stakeholder types are involved in a particular category of AqGR conservation, management or use), highest scores were found for Conservation (681, equivalent to 62 percent of the maximum score), Production (653, or 60 percent) and Marketing (537, or 49 percent), while lowest scores were found for Processing (355, or 33 percent Feed Manufacturing (262, or 24 percent and Other (65, or 6 percent (Table 6.3).

An overview of the importance of the roles of each stakeholder group was developed by summing all scores submitted by all reporting countries for each of the ten categories associated with the conservation, management and use of AqGR. The highest score that any stakeholder group could thus obtain results if all countries (91) agreed that a particular stakeholder group was involved in all ten roles associated with the conservation, management and use of aquatic genetic resources conservation i.e. 91 x 10 = 910. The results show that Government Resource Managers (527), Fishing or Aquaculture Associations (453) and Fish Farmers (436) played the greatest roles, while Consumers (219), Marketing People (262) and Fishers (279), with around half the average scores of those that topped the rankings, came bottom (see Figure 6.1 and Table 6.3).

In terms of the categories in which the majority (i.e. >50 percent) of countries agreed the stakeholder played a role, the highest score, at six out of ten categories, was accorded to Fisheries/Aquaculture Organizations and Government Resource Managers. There followed a cluster of three stakeholder groups (IGOs, NGOs, Policy Makers) whom the majority of countries reported played a role in half (i.e. five out of ten) of the different categories of AqGR conservation, management and use. The lowest scoring groups of stakeholders was People Involved in Marketing and Consumers, who the majority of countries assessed as playing a role in only one of the categories (Table 6.3). Looking in more detail at the top and bottom scoring countries in Table 6.3, it is apparent that both Fisheries/Aquaculture Organizations and Government Resource Managers were regarded as active in very similar categories of AqGR; consumers, not surprisingly perhaps, were seen as only being active in marketing, as were Marketing People.

Figure 6.1. Total scores (numbers of responding countries x number of categories in the conservation, management and use of AqGR of farmed species and their wild relatives) for each identified stakeholder group (see text)



***Source*: Data derived from Table 6.3.**

When the results are ranked in terms of the top three stakeholders by category of AqGR conservation, management and use (Table 6.4), then Fish Farmers and Fisheries/Aquaculture Organizations were assessed as playing the greatest number of roles (five out of ten categories), followed by policy makers and marketing people (four out of ten categories). Only Consumers were not ranked in the top three of any category of AqGR conservation, management and use. Fishers too scored low (1).

Table 6.3. Roles of different stakeholder groups in the conservation, management and use of AqGR of farmed species and their wild relatives, as determined by the global numbers (percentage) of all respondent countries that agreed on the particular role of a stakeholder (see text)

	Roles									
	Advocacy	**Breeding**	**Conservation**	**Feed manufacturing**	**Marketing**	**Outreach/ extension**	**Processing**	**Production**	**Research**	**Other**
Aquatic protected area managers	64 (70)	16 (18)	87 (96)	2 (2)	4 (4)	46 (50)	1 (1)	12 (13)	52 (57)	3 (3)
Consumers	30 (33)	5 (5)	21 (23)	3 (3)	51 (56)	16 (18)	38 (42)	37 (41)	4 (4)	14 (15)
Donors	47 (52)	34 (37)	59 (65)	18 (20)	27 (30)	43 (47)	22 (24)	41 (45)	54 (59)	12 (13)
Fish farmers	21 (23)	76 (84)	37 (41)	42 (46)	72 (79)	27 (30)	47 (52)	87 (96)	25 (27)	2 (2)
Fish hatchery operators	22 (24)	85 (93)	53 (58)	23 (25)	43 (47)	35 (38)	7 (8)	77 (85)	49 (54)	2 (2)
Fishers	23 (25)	7 (8)	48 (53)	5 (5)	57 (63)	17 (19)	42 (46)	64 (70)	11 (12)	5 (5)
Fisheries/aquaculture organizations	49 (54)	48 (53)	49 (54)	43 (47)	61 (67)	53 (58)	43 (47)	76 (84)	27 (30)	4 (4)
Government resource managers	67 (74)	58 (64)	85 (93)	32 (35)	37 (41)	70 (77)	30 (33)	69 (76)	76 (84)	3 (3)
IGOs	57 (63)	35 (38)	72 (79)	17 (19)	33 (38)	55 (60)	23 (25)	53 (58)	67 (74)	6 (7)
NGOs	64 (70)	34 (37)	77 (85)	20 (22)	31 (34)	59 (65)	21 (23)	51 (56)	51 (56)	3 (3)
People involved in marketing	23 (25)	16 (18)	9 (10)	20 (22)	78 (86)	29 (32)	42 (46)	30 (33)	13 (14)	2 (2)
Policy makers	56 (62)	42 (46)	84 (92)	37 (41)	43 (47)	54 (59)	39 (43)	56 (62)	52 (57)	9 (10)
TOTALS	**523**	**456**	**681**	**262**	**537**	**504**	**355**	**653**	**481**	**65**

Table 6.4. The three stakeholder groups with the greatest involvement in each category of conservation, management and use of AqGR, as judged from Country Reports (number of countries in parenthesis)

Roles in AqGR conservation	Top three stakeholders[1] (number of countries reporting that the stakeholder plays a role)	Total scores[2]
Advocacy	Government resource managers (67) Aquatic protected area managers (64) NGOs (64)	523
Breeding	Fish hatchery operators (85) Fish farmers (76) Government resource managers (58)	456
Conservation	Aquatic protected area managers (87) Government resource managers (85) Policy makers (84)	681
Feed manufacturing	Fisheries/aquaculture organizations (43) Fish farmers (42) Policy makers (37)	262
Marketing of AqGR	People involved in marketing (78) Fish farmers (72) Fisheries/aquaculture organizations (61)	537
Outreach/extension	Government resource managers (70) NGOs (59) IGOs (55)	504
Processing	Fish farmers (47) Fisheries/aquaculture organizations (43) Fishers (42) People involved in marketing (42)	355
Production	Fish farmers (87) Fish hatchery operators (77) Fishing/aquaculture organizations (76)	653
Research	Government resource managers (76) IGOs (67) Donors (54)	481
Other	Consumers (14) Donors (12) Policy makers (9)	65

[1]Unless two categories of stakeholder have the same score.

[2]Sum of all countries that determined a stakeholder played a role in a particular aspect of AqGR conservation, management and use. Maximum score for each type of role = 91 (i.e. number of respondent countries) x 12 (number of stakeholder types)
= 1092 – see text and Table 6.3.

6.4 Analysis of stakeholder roles by geographic region, economic class and status as an aquaculture producing country

6.4.1 Introduction

Almost half of all countries in the world /196responded, with between 40 percent and 100 percent of countries answering on a regional basis. The top 11 aquaculture-producing countries, responsible for more than 90 percent of production responded and are included in the analysis, while the numbers of countries per economic class that responded (Table 6.6) was judged sufficient for present analysis.

Table 6.5. Number (percentage) of countries that responded per region, out of a total of 91

Region	Total number of countries in region	Number of countries responding (%)
Africa	54	27 (50)
Asia	47	20 (43)
Latin America and the Caribbean	33	18 (55)
Europe	43	17 (40)
North America	2	2 (100)
Oceania	17	7 (41)
TOTAL	**196**	**91 (46)**

Table 6.6. Number (percent) of responding countries in each economic class

Category	Total number of countries	Number of responding countries (%)
Developed countries or areas	58	25 (43)
Least Developed Countries	50	23 (46)
Other Developing Countries or Areas	88	43 (49)

6.4.2 Stakeholder interest in AqGR by geographic region

Few consistent inter-regional differences were found in terms of stakeholder interest in AqGR (Table 6.7). Interest in North America and Africa was somewhat higher than in the rest of the world.

Table 6.7. Interest of stakeholders (percent respondent countries that identified the category of stakeholder) in AqGR by geographic region

	Africa	Asia	Latin America and the Caribbean	Europe	North America	Oceania
Aquatic protected area managers	37	35	26	27	40	23
Consumers	32	22	24	22	10	9
Donors	45	34	44	23	25	63
Fish farmers	57	39	42	49	75	44
Fish hatchery operators	46	34	52	42	40	43
Fishers	39	24	23	30	45	36
Fisheries/aquaculture organizations	62	46	38	54	50	33
Government resource managers	63	53	60	56	75	47
IGOs	54	42	42	36	30	64
NGOs	53	43	39	45	30	43
People involved in marketing	33	26	31	24	75	16
Policy makers	60	47	35	70	75	29

6.4.3 Interest of stakeholders in types of AqGR by economic class and by whether or not they are a major aquaculture producer

Stakeholder interest in the conservation, management and use of AqGR of farmed and wild relatives was consistently high (69–88 percent of respondent countries) at the species level, interest being greatest among Fisheries/Aquaculture Associations (88 percent), closely followed by Aquatic Protected Area Managers, Fishers, Government Resource Managers and NGOs, all of whom attracted 87 percent of country responses (Table 6.8). At the strain level, respondent countries recorded lower and more variable interest among stakeholders (27–77 percent), greatest interest at this level being among Fish Hatchery Operators (77 percent), Fish Farmers (75) and Government Resource Managers (74 percent). Interest among stakeholders in AqGR at the genotype (DNA) level was lowest: 0–33 percent of respondent countries that acknowledged stakeholder interest, not surprisingly being lowest among consumers (1) and fishers (0) (Table 6.8).

In summary, interest in AqGR among stakeholders is greatest at the species level, lower at the level of the stock, breed or variety and lowest at the genotype (DNA) level.

Table 6.8 Summary of type of AqGR of interest to different stakeholders by number of respondent countries (max = 91) and percentage of total respondent countries (in parenthesis)

Stakeholder	Genetic resources of interest			
	Species	**Stock, breed, variety**	**DNA**	**Others**
Aquatic protected area managers	79 (87)	52 (57)	14 (15)	3 (3)
Consumers	76 (84)	25 (27)	1 (1)	4 (4)
Donors	63 (69)	45 (49)	19 (21)	12 (13)
Fish farmers	78 (86)	68 (75)	3 (3)	6 (7)
Fish hatchery operators	78 (86)	70 (77)	19 (21)	6 (7)
Fishers	79 (87)	35 (38)	0	1 (1)
Fisheries/aquaculture associations	80 (88)	55 (60)	6 (7)	5 (5)
Government resource managers	79 (87)	67 (74)	30 (33)	13 (14)
IGOs	72 (79)	52 (57)	19 (21)	7 (8)
NGOs	79 (87)	53 (58)	18 (20)	6 (7)
People involved in marketing	75 (82)	31 (34)	2 (2)	8 (9)
Policy makers	78 (86)	56 (62	25 (27)	10 (11)
TOTAL	**916**	**609**	**156**	**81**

The above pattern of interest in AqGR remained similar, irrespective of economic class of country (Table 6.9) or status as an aquaculture producing country (Table 6.10).

Table 6.9. Interest of different economic classes of country in AqGR, as determined across all stakeholder groups

Economic class of country	% countries that reported stakeholder interest	AqGR of interest
	85	Species
Developed countries or Areas	56	Stock, breed or variety
	17	DNA
	88	Species
Least Developed Countries	59	Stock, breed or variety
	17	DNA
	81	Species
Other Developing Countries or Areas	54	Stock, breed or variety
	12	DNA

Table 6.10. Interest of different types of producer country in AqGR, as determined across all stakeholder groups

Economic class of country	% countries that reported stakeholder interest	AqGR of interest
	89	Species
Major producing countries	71	Stock, breed or variety
	30	DNA
	83	Species
Minor producing countries	54	Stock, breed or variety
	12	DNA

6.5 Indigenous and local communities

Individuals from indigenous and local communities in many parts of the world are employed in aquaculture businesses – in hatcheries, on fish farms and as traders – as well as in the public sector and in NGOs engaged in aquaculture or conservation of AqGR. In countries such as Indonesia or the Philippines, for example, small-scale hatcheries and aquaculture production is common among indigenous and local communities. The Tanzania Country Report reported on the involvement of communities not only in fingerling production, but also in aquaculture producer associations, in the marketing of fingerlings and in the collection of wild relatives of farmed fish as broodstock.

With respect to the indigenous and local communities and their roles in the conservation, management and use of AqGR, of the 83 respondent countries, 70 provided details of their involvement. A number of countries reported that while indigenous and local communities were involved in the conservation, management and use of AqGR, their specific roles were unknown (e.g. Argentina). However, from those countries that provided details it is apparent that indigenous and local communities in many countries are involved in a wide range of conservation and management activities. Some countries, such as Cambodia, point to the importance of indigenous knowledge in the formulation of policies that protect AqGR. Others point to specific activities, such as helping enforce protection of marine protected areas and implementation of fishing regulations with respect to gears and fishing seasons (e.g. Sri Lanka). Other conservation and management activities include support of aquaculture-based fisheries (i.e. release into the wild of hatchery reared juveniles, in support of depleted fisheries e.g. South Africa). In countries such as the United States of America and Australia indigenous people have rights in law to the sustainable exploitation of AqGR.

No consistent differences in roles of communities between economic classes of country or geographic regions are readily apparent.

One example of the important role of indigenous communities in the conservation of genetic resources for food and agriculture at national level is Brazil, which reported that "… indigenous and local communities' knowledge usually make sustainable use of natural resources. The relationship between such people and environment pass *on through generations are an important source of information of the distinct uses of biodiversity. Fish and other aquatic organisms are not different. The fighting of the indigenous groups against power plant construction in Brazil is an example how the fish resources are important for them and indirectly for the whole population. Long term conservation of genetic resources rely mainly on aquatic environment preservation*".

6.6 Gender

Only 8 percent of reporting countries omitted to mention gender, which was unrelated to geography or country economic status (Table 6.11). While often pointing out that women make up a relatively small part of the agricultural labour force (e.g. Brazil 13 percent; Bulgaria 10 percent), the majority of the least developed and other developing countries mention the important role of women in the use of AqGR – in hatcheries, through harvesting, post-harvest, processing and marketing activities – directly related to the aquaculture and fisheries sectors. While many such countries omitted mention of the role of women in the conservation and management of aquatic genetic resources, some do (e.g. Bangladesh, Benin, Bhutan, the Philippines).

By contrast, the majority of developed countries indicated that women, as in other economic activities, are fully integrated in the aquaculture sector and play a crucial role at all levels and in all stages of the production chain, including broodstock management, seed production, grow-out, harvest, processing, research, academia and policy making action. Specific mention was sometimes made of gender equality in law.

Some respondent countries pointed to their lack of knowledge of the role of women in conservation, management and use of AqGR. The Philippines, for example, has noted that *"the participation of women before and after fish harvest in the aquaculture industry has been given little importance, leading to the near invisibility of women as contributors to this sector. However, these pre- and post-production activities are significant in terms of their economic and social value. These include: net mending, sorting fish upon landing, fish vending, trading and market retailing, (handling the small scale marketing that involves inexpensive fish varieties), processing and preservation (salting or drying) which are considered tasks for women"*.

Table 6. 11. Reports of the roles of women in the conservation, management and use of AqGR. Note that the stakeholder roles identified differ somewhat from those used elsewhere in the text

Role	Country
No information provided	Algeria, Burkina Faso, Canada, Japan, Palau, Togo, Ukraine
All categories that men are involved in	Argentina, Australia[1], Bulgaria[3], Chile, China, Croatia, Cuba, Czechia, Dominican Republic, Ecuador, Estonia, Finland, Germany[4], Guatemala, Kiribati, Republic of Korea, Latvia, Norway[3], Philippines, Romania[3], Samoa, Slovenia, South Africa, Tonga, United States of America
Little (no other details)	Belize, Vanuatu[6]
Finance	Niger
Breeding and hatchery work	Armenia, Bangladesh, Chad, Georgia, Hungary, Indonesia, Senegal, Sri Lanka, United Republic of Tanzania
Farming	Bangladesh, Bhutan, El Salvador, India, Iran (Islamic Republic of), Kenya, Madagascar[5], Mozambique, Paraguay, Senegal, Sri Lanka, United Republic of Tanzania
Post-harvest processing	Brazil[3], Burundi, Cabo Verde, Cameroon, Democratic Republic of the Congo, Costa Rica, Cyprus, El Salvador, Georgia, Hungary, India, Kenya, Lao People's Democratic Republic, Malawi, Mexico, Morocco, Niger, Paraguay, Sierra Leone, Sri Lanka, Sudan, Uganda
Trading and Marketing	Benin[2], Bhutan, Burundi, Cabo Verde, Cameroon, Democratic Republic of the Congo, Cyprus, Egypt, El Salvador, Fiji, Georgia, Ghana, Honduras, Hungary, India, Indonesia, Kenya, Lao People's Democratic Republic, Malawi, Mexico, Morocco, Nicaragua, Niger, Paraguay, Peru, Sierra Leone, Sri Lanka, United Republic of Tanzania, Thailand, Uganda, Venezuela (Bolivarian Republic of), Zambia
Food preparation and consumption	Bangladesh, Cambodia
Gleaning	Benin[2], Morocco, Tunisia
Fishing	Cabo Verde
Fisheries management	Cabo Verde
Consultancy	Netherlands[3]
Professional Organizations	Dominican Republic, Georgia, Morocco
Conservation	Burundi, Cabo Verde, Cameroon, Fiji, Honduras, Peru
Advocacy	Bhutan, Fiji
NGOs	Georgia, Netherlands[3], Panama
Education and extension	Honduras, Indonesia, Peru, Viet Nam
Policy making	Honduras, Hungary, Mexico, Netherlands[3], Panama, Peru
Research	Armenia, Fiji, Georgia, Honduras, Iran (Islamic Republic of), Malaysia, Mexico, Mozambique, Netherlands[3], Panama, Peru, Venezuela (Bolivarian Republic of)

[1] especially in marketing, research; [2] dominate trading and marketing; [3] women play only a minor role in the sector; [4] but play a minor role in production; [5] especially seaweed and sea cucumbers; [6] to be improved.

6.7 Discussion and Conclusions

6.7.1 Introduction

Analyses of the Country Reports has identified some puzzling responses and difficult to explain inter-country and regional differences. This warrants a closer consideration of the process of producing the first State of the World Report on Aquatic Genetic Resources for Food and Agriculture, e.g. the design of the questionnaire, the terminology used and the overall process. It is thus worth reviewing what was done and how in collecting the data.

6.7.2 Terminology

The list of stakeholders assembled for the purposes of the present study is not exhaustive but nonetheless is fairly comprehensive. Prior to implementation of the study, a regional stakeholder consultation workshop was held in Thailand, at which it was decided to merge some stakeholder types and to discard others. Arguably, the final list should have included scientists, regional fisheries management bodies and aquaculture networks – and indeed future consideration may wish to be given to the list of stakeholders used – although the question remains as to whether their roles are important or would change the overall picture very much.

Twelve stakeholder types were ultimately chosen. Some are relatively unambiguous; others, however, may be open to a degree of interpretation. For example, the regional stakeholder workshop in Thailand initially found it difficult to distinguish between the role of a 'government resource manager' and how it differed from that of a 'policy maker'. Similarly, the various possible roles of stakeholders in the conservation, management and use of AqGR of farmed species and their wild relatives are open to interpretation. *Post-hoc* definitions are provided in Tables 6.1 and 6.2; future studies may wish to include clear definitions of stakeholders.

All individuals consulted or directly involved in completing a country questionnaire belonged to at least two stakeholder groups. Everyone, for example, is a consumer; some fish farmers also own and operate their own hatcheries or processing facilities, while some fishers may also be aquaculturists. This should have helped foster an understanding of stakeholder roles and types of conservation, management and use of AqGR among respondents.

Excluding 'others,' nine types of AqGR conservation, management and use were distinguished for the purpose of this first attempt to capture stakeholder roles. Most are self-obvious – e.g. advocacy, breeding, conservation, marketing, outreach/extension, production, research – but two are not: feed manufacture and processing. In the absence of any other guidance, it is concluded here that the former refers to the use of wild fish in the form of fishmeal and fish oil, the fisheries that form the basis of these products are not always being sustainably managed. Similarly, processors of farmed aquatic species by definition use AqGR. Nevertheless, these two categories recorded the lowest scores, suggesting a degree of uncertainty among respondents.

The category 'other', which was included both for AqGR conservation, management and use and for AqGR of interest to stakeholders, being something of a catch-all, is of limited value, other than to signal that stakeholders had roles and interests in areas other than those included in the study.

Little attention was, however, paid to defining roles beyond the categories developed for the purposes of the present questionnaire, leaving exactly what stakeholders did in fulfillment of these roles being very much open to interpretation. Take the issue of conservation of AqGR, for example. Almost 90 percent of responding countries believed policy makers were involved in conservation of AqGR, although, as elsewhere, no supporting evidence is provided. It may simply have been assumed that policy makers develop policies that conserve AqGR; but is this true, and are the assumptions supported by evidence? Are the conservation policies being implemented, are they effective? The responses in Chapter 7 on national policies indicate that policies exist for AqGR at the species level, however there are significant challenges in implementing and enforcing them. Several populations of wild relatives of farmed aquatic species are decreasing indicating that in fact conservation policies are not working in many instances (see Chapter 2).

Fish farmers often also claim to be managing *ex-situ* AqGR. But are they sufficiently knowledgeable to manage these in such a way that creates more productive farmed strains while effectively avoiding inbreeding? Various studies point to mismanagement of *ex-situ* AqGR for aquaculture purposes as being the norm. Brummett *et al.* (2004), for example, demonstrated that the growth performance of African catfish (*Clarias gariepinus*) sourced from commercial hatcheries, where they had been derived from 3rd or 4th generation fish taken from the wild, was inferior to that of fry obtained directly from wild broodstock, indicating poor hatchery management of broodstock. Chapters 4 and 5 point out some of the problems with on farm conservation of AqGR. In fact, farmers' main goal is to produce a profitable farmed type; very few farmers' objective is to 'conserve' AqGR.

6.7.3 Country and regional responses

Ideally, all countries in all regions would have completed the questionnaire for this first analysis. However, more than 40 percent of countries in all regions responded (Table 6.5), the response rate ranging from 41 percent (Oceania) to 100 percent (North America). Moreover, the proportions of countries within economic class – developed, developing, etc. (Table 6.6) – at around 45 percent, was reasonable and balanced. The top 11 aquaculture producing countries, accounting for more than 90 percent of production, also responded.

6.7.4 The roles of stakeholders in AqGR conservation, management and use

At a global level the results from the questionnaire show clear differences among stakeholders in terms of their roles – actual and perceived – in conservation, management and use of AqGR of farmed aquatic species and their wild relatives. According to the roles accorded by the responding countries, then one third of all stakeholders are seen as being involved in all of the roles associated with AqGR conservation, management and use.

The majority of responding countries concurred that fish farmers play roles in conservation, research, production, advocacy and extension. This result was also reported in Chapter 5 on *in situ* conservation. Leaving aside the issue of how exactly they implement these roles and whether or not they are effective, the results are not surprising. Some critics of aquaculture, for example in countries with wild stocks of Atlantic salmon, might point to the conflicting roles of salmon farmers in both developing *ex-situ* genetically improved strains and, through the inadvertent introduction of feral farmed fish to the environment, increasing the risk of introgression of alien aquatic genetic material, with consequent effects on fitness (McGinnity *et al*., 2003). Similar points have been made elsewhere (Youngson *et al*., 2001, Lind *et al*., 2012, Lorenzen *et al*., 2012).

While some results are unsurprising, others are puzzling. Why, for example, did 70 percent of responding countries believe that fishers play a role in conservation of AqGR and how?

Such discrepancies and less than obvious allocation of stakeholder roles among different types of conservation, management and use of AqGR of farmed species and their wild relatives – and there are many, as is readily apparent in Table 6.1 – may be due to inter-country differences in their aquaculture sectors but are also likely due to differences in understanding and/or interpretation of stakeholder roles.

6.7.5 Genetic resources of interest

The results here posed fewer surprises than with regard to the role of stakeholders in different types of conservation, management and use of AqGR of farmed species and their wild relatives. The most striking result is that interest among stakeholders still resides primarily at the species level. And yet the results from the questionnaires also provide some interesting insights. Fish farmers and hatchery operators, for example, are seen as being especially interested in AqGR at the strain level. However, only a few aquaculture sub-sectors – most notably Atlantic salmon and tilapia farmers – currently have access to such varieties (Olesen *et al.*, 2009); understanding among fish farmers of the impact of genetically improved strains on production, growth and profitability remains limited. Similarly, few stakeholders are yet interested in AqGR at the DNA level. As the importance of marker-assisted selection and of the importance of conserving genetic diversity of AqGR at the population level in the wild becomes more apparent then interest at this level can be expected to increase.

6.7.6 Indigenous and local communities and gender

The reports from respondent countries indicated that there was some confusion as to what information was being sought in the questionnaire. Others may have thought this section of the questionnaire irrelevant, as they had no indigenous communities (e.g. five of the developed European countries), failing to notice that information on local communities was also sought. Some respondents limited details to the employment of individuals from such communities in hatcheries and fish farms. Answers were also often vague, explicitly or implicitly indicating that while the respondent was sure that indigenous and local communities played a role in the conservation, management and use of AQGR, they weren't entirely sure what that role was (e.g. the communities ' ... conserved genetic resources in bodies of water adjacent to [their] community;' or were engaged in 'conservation activities'). Nevertheless, it was also apparent that indigenous and local communities were actively engaged in enforcing regulations on destructive fishing gears and maintenance of marine protected areas.

Women seem to have been comprehensively engaged in all activities related to the conservation, management and use of AqGR. The Developed Countries mentioned a wider range of activities than Developing and Other Developing Countries or Areas may reflect the real situation or may not have been fully addressed.

Key findings and conclusions

- Numerous groups are considered as stakeholders in the conservation, management, use and development of aquatic genetic resources (AqGR).
- Through regional workshops the following stakeholders were identified: Aquatic protected area managers, Consumers, Donors, Fish farmers, Fish hatchery people, Fishers, Fisheries and aquaculture associations, Government resource managers, IGOs, NGOs, People involved in marketing, and Policy makers.
- Government Resource Managers, Fishing or Aquaculture Associations and Donors played the greatest roles in the conservation, management and use of AqGR, while Consumers, Marketing People and Fishers, played lesser roles.
- Activities related to conservation, production and advocacy were the most common roles played by the 12 stakeholder groups.
- Stakeholder interests in conservation, management and use of AqGR were consistently greatest at the species level, followed by strain (stock, breed or variety) and then at the genome (DNA) level.
- Indigenous communities play important roles in the conservation, management, use and development of aquatic genetic resources (AqGR) and this role was recognized by nearly all countries.
- Women are important in the aquaculture sector in all countries, although the qualitative information provided suggests that they may play a wider range of roles in developed countries.
- Respondents provided little information on what stakeholder groups would like to see take place with respect to the conservation, management and use of aquatic genetic resources.
- It will be important to continue work to further clarify the identification and roles of the many stakeholders in the conservation, management and use of aquatic genetic resources.

6.8 References

Brummett, R.E., Agnoni, D.E. & Pouomogne, V. 2004. *On-farm and on-station comparison of wild and domesticated Cameroonian populations of Oreochromis niloticus*. Aquaculture 242, 157–164.

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. pp. 125–141.

Lorenzen, K., Beveridge, M.C.M. & Mangel, M. 2012. *Cultured fish: Integrative biology and management of domestication and interactions with wild fish*. Biological Reviews 87. pp. 639–660.

McGinnity, P., Prodöhl, P., Ferguson, A., Hynes, R., Ó Maoiléidigh, N., Baker, N., Cotter, D.,

O'Hea, B., Cooke, D., Rogan, G., Taggart, J. & Cross, T. 2003. *Fitness reduction and potential extinction of wild populations of Atlantic salmon Salmo salar, as a result of interactions with escaped farm salmon*. Proceedings of the Royal Society of London Series B 270. pp 2443–2450.

Olesen, I., Rosendal, G.K., Bentsen, H.B., Tvedt M.W. & Bryde, M. 2007. *Access to and protection of aquaculture genetic resources – Strategies and regulations*. Aquaculture 272. Pp 47–61.

Youngson, A.F., Dosdat, A., Saroglia, M. & Jordan, W.C. 2001. *Genetic interactions between marine finfish species in European aquaculture*. Journal of Applied Ichthyology 17. pp 153–162.

CHAPTER 7
NATIONAL POLICIES AND LEGISLATION FOR AQUATIC GENETIC RESOURCES OF FARMED AQUATIC SPECIES AND THEIR WILD RELATIVES WITHIN NATIONAL JURISDICTION

PURPOSE: The purpose of Chapter 7 is to review the status and adequacy of national policies and legislation, including access and benefit sharing, concerning aquatic genetic resources of farmed aquatic species and their wild relatives. The specific objectives are:

- to describe the existing national policy and legal framework for the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives;
- to review current national policies and instruments for access to aquatic genetic resources of farmed aquatic species and their wild relatives and the fair and equitable sharing of benefits arising from their utilization; and
- to identify any significant gaps in policies and legislation concerning aquatic genetic resources of farmed aquatic species and their wild relatives.

KEY MESSAGES:

- The range of the policies relevant to the management of AqGR for food and agriculture is extremely large because it encompasses farming, fishing and conserving aquatic species.
- Lack of awareness of national policies, lack of technical capacity and insufficient resources were identified as key gaps in effective policy implementation; other gaps in policy concerned transboundary water courses, import and export of AgGR, long term aquaculture development, breeding and genetic manipulation, climate change, objective evaluation of policy efficacy, financial subsidies to implement policies, ownership and harmonization of policies.
- Numerous national policies exist, but there are gaps in national policies at the genetic level, because most policies address AqGR at the species level.
- Policies also include fisheries management, fishing closures and restrictions on import/export of a variety of types of AqGR.
- Monitoring and enforcement of national policies is often constrained by lack of human and financial resources.
- Access and benefit sharing regimes will be different for AqGR than for GR of crops and livestock.
- Genetic improvement of farmed aquatic species is often done by large companies or international institutions with modern breeding facilities, and in areas outside of the center of origin for many species. Thus farmer rights' and breeders' rights are not relevant in many cases and not included in national policies.
- Countries have taken steps to facilitate access to AqGR that address primarily access to living specimens.
- Countries have encountered obstacles in accessing or importing AqGR that are primarily a result of their own restrictive national legislation.

7.1 Introduction

The FAO Code of Conduct for Responsible Fisheries (Code) lays out a series of guiding principles and recommendations on which national legislation and policy could be based (FAO, 1995). The Code was adopted by the FAO Council in 1995 and includes sections on fishery management, fishing operations, coastal area management, aquaculture development, post-harvest and trade, international cooperation and research; there are articles on the special needs of developing countries. Whereas each biennium countries report to the FAO Committee on Fisheries (COFI) on their progress on implementation of the Code, very rarely have countries specifically reported on AqGR at the level below the species.

The 31st Session of COFI established the Advisory Working Group on Aquatic Genetic Resources and Technologies (Working Group) in order to advise the organization and increase international cooperation on AqGR. The Working Group (FAO, 2016) developed a framework to assist countries in managing their aquatic genetic resources and noted that often it is the lack of specific national policies that constrain effective use and conservation of AqGR (Box 7.1).

Box 7.1

Framework of minimum requirements for sustainable management, development, conservation and use of aquatic genetic resources[27]

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.

The information and databases component calls for:

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

The governance, policy and planning component calls for:

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

[27] The Framework was developed by FAO and 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, in Lusaka, Zambia, and finally by the COFI Advisory Working Group on Aquatic Genetic Resources and Technologies 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, and A. Stankus. The Government of Germany support for the development of the Framework is greatly appreciated.

x. effective and transparent engagement between government departments, private industry and other stakeholders, for among other things, exchange of policy and technical information.

The infrastructure and equipment component call for:

i. a plan for the development, use and maintenance of all infrastructure, taking into account partnerships and economies of scale;
ii. access to broodstock development and management facilities; [28]
iii. access to bio-secure facility(ies) for genetic management and/or genetic improvement of aquacultured species, including effective marking/tagging/identification;
iv. access to multiplication and dissemination centres for genetically improved strains;
v. access to genetic characterization and diagnostic laboratories;
vi. quarantine and veterinary facilities; and
vii. research, extension and training centres.

The component on enabling the private sector call for:

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

Capacity building is needed on all of the above components and would be facilitated by effective extension services.

The range of the policies relevant to the management of AqGR for food and agriculture is extremely large because it encompasses farming, fishing and conserving aquatic species. National legislation governing aquatic genetic resources are generally lacking, at the genetic level, in most parts of the world (Pullin, Bartley and Kooiman, 1999). Policies are better developed at the species level in capture fisheries and aquaculture, for example for setting catch limits and seasons for capture fisheries (FAO, 2003), or for allowing the import/export of certain species considered to be invasive (Bartley and Halwart, 2006).

Often ministries and policies promoting fishery and aquaculture development, i.e. the use and exchange of AqGR, are in conflict with those promoting conservation (see chapter 3); the use of non-native species is one example. The terrestrial agriculture sector is largely based on non-native species that were domesticated thousands of years ago and moved around the world with little regard for environmental risks. The relatively recent development of aquaculture and the domestication of aquatic species are occurring within a background of environmental awareness and an existing food production sector (Bartley *et al.*, 2007).

Therefore a much more restrictive policy environment exists today for AqGR than did for terrestrial genetic resources millennia ago.

The precautionary approach (FAO, 1996), environmental impact assessment and risk analysis provide a means to balance the risk/benefit of proposed development actions (Arthur *et al.*, 2009). These approaches are sometimes incorporated into national policy and allow the development of aquaculture and AqGR with due regard for the environment and biodiversity.
Recommendations have been made stating that policies and legislation should be decentralized to the extent possible to take into consideration the needs and capacities of local communities. However, local practices may often be inconsistent with international treaties or instruments (Chapter 8; Barlow, 2016).

[28] 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.

For example local trade of species listed on the CITES[29] appendices would be legal within a country, but would require special permits if the species were to be traded internationally.

This chapter reviews the status and adequacy of nation policies and legislation on aquatic genetic resources. Access to and the sharing of benefits derived from the use of AqGR is also presented.

7.2 Overview of national policies and legislation

The majority of Country Reports were submitted by signatories to the Convention on Biological Diversity (CBD). Under that convention countries are required to develop National Biodiversity Strategic Action Plans (NBSAP)[30] that set policies for the sustainable use and conservation of biological diversity and the fair and equitable sharing of benefits. The emphasis of the NBSAP is primarily on the species level for aquatic organisms. Other national legislation has opportunities for protection of genetically distinct segments of a species that are of special evolutionary importance (Box 7.2).

Box 7. 2
Conservation of AqGR below the species level

Whereas national legislation on conservation is usually directed at the species, the US Endangered Species Act recognized genetically important stocks of Pacific salmon as a ‘species’ and therefore eligible for protection under the act.
Under the Federal Endangered Species Act (ESA) in the United States of America, a species, subspecies, or a distinct population segment (DPS) may be listed as threatened or endangered. Numerous stocks of Pacific salmon and steelhead (*Oncorhynchus* sp.) on the west coast of North America have substantially declined and are at a fraction of their historical abundance. Reasons for these declines include excess fishing effort, loss of critical habitat, hydropower facilities, ocean conditions and fish hatchery practices. As a result, the National Marine Fisheries Service (NMFS) listed 28 salmon and steelhead stocks in California, Idaho, Oregon, and Washington as ‘endangered species’ under the Federal Endangered Species Act (ESA).

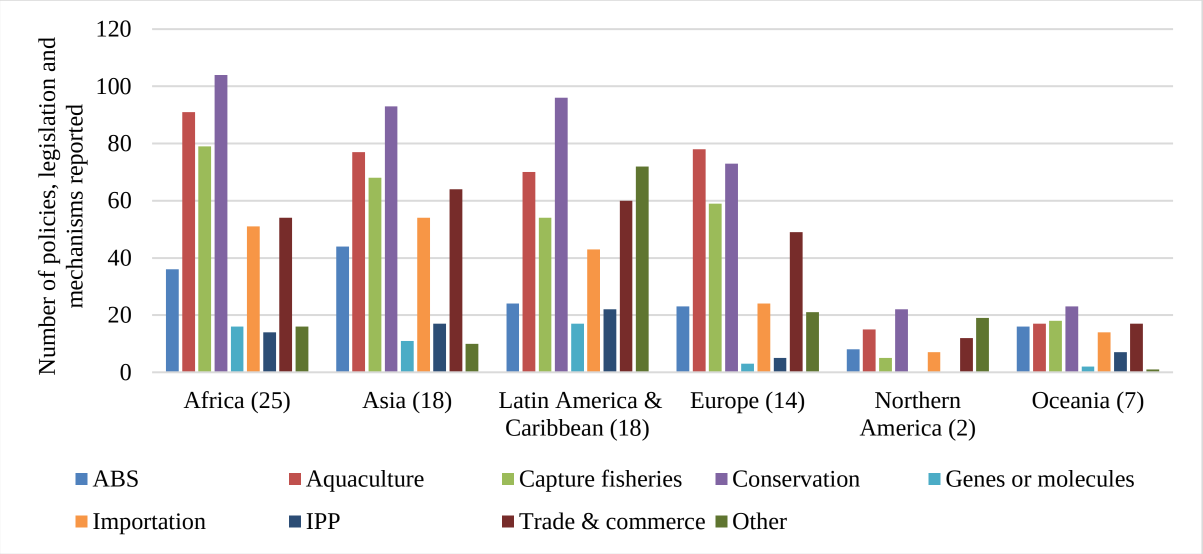
According US Federal policy guidance, “populations of salmon substantially reproductively isolated from other con-specific populations and representing an important component in the evolutionary legacy of the biological species are considered to be an [evolutionarily significant unit] ESU.” In the United States of America listing determinations for Pacific salmon under the ESA, the United States of America treated an ESU as constituting a DPS, and hence a “species.”

Source: www.nmfs.noaa.gov/pr/pdfs/species/sacramentoriver_winterrunchinook_5yearreview.pdf

The range of the policies relevant to the management of AqGR for food and agriculture is extremely large because it encompasses farming, fishing and conserving aquatic species. Countries reported about 619 policies and legislation that address aquatic genetic resources for food and agriculture (Figure 7.1). Many countries have fishery management plans that regulate the time and quantity of fishing activities. The Philippines for example lists several national policies regulating the use of amphibians, fish and shellfish. Most policies are primarily aimed at the species level (see Box 7.2).

[29] Convention on International Trade of Threatened and Endangered Species of Fauna and Flora www.cites.org
[30] National Biodiversity Strategic Action Plans: www.biodiv.org

Figure 7.1
Scope of national policies (number of countries in region). ABS = Access and benefit sharing; IPP= Intellectual property protection



Several countries reported that lack of awareness of national policies, lack of technical capacity and insufficient resources as key gaps in effective policy implementation. A fundamental challenge is that often the majority of legislation does not specifically refer to aquatic genetic resources, but rather on biodiversity at the habitat and species level. Conservation of aquatic resources per se is implied in legislation and its implementation, but is rarely explicit, even in legislation and conservation and marine protected areas. As a result there is little if any monitoring of AqGR below the species level other than on specific research and development projects (Australia and Morocco).

Other policy gaps identified concerned transboundary water courses (Bangladesh, Thailand), policies on import and export of AqGR (Uganda), lack of long term aquaculture development policies (Colombia); lack of policies on breeding and genetic manipulation (Bulgaria); out of date policies that don't address modern genetics (Mozambique, Panama, Venezuela (Bolivarian Republic of)), lack of policies dealing with climate change (Egypt), lack of objective evaluation mechanisms of the institutional programs implemented (Mexico), lack of financial subsidies to help develop sector (Romania); unclear ownership of genetic resources (Senegal), and lack of mechanism to harmonize legislation (Zambia).

Additionally, countries reported that significant problems in monitoring and enforcing national polices arose from lack of human resources and finances. In countries with extensive wetlands and coastal areas, e.g. Brazil and Indonesia, 'monitoring of environmental laws to protect genetic resources is a difficult task.' (Brazil).

7.3 Access and benefit sharing policies

The international community has established the Nygoya Protocols,[31] a 2010 supplementary agreement to the 1992 Convention on Biological Diversity (CBD). The protocols' objective is the fair and equitable sharing of the benefits arising from the utilization of genetic resources, and thereby contributing to the conservation and sustainable use of biodiversity. Access to AqGR and the sharing of benefits derived from that use present special considerations in aquaculture and fisheries. Unlike terrestrial agriculture where domestication and stewardship of improved breeds and varieties was often the result of farmers using and improving genetic resources over millennia, the domestication and genetic improvement of many commercial aquatic species did not take place in centers of origin, or as the result of the efforts of

[31] www.cbd.int/abs/

local aquaculturists (Bartley *et al.*, 2009). Often genetic improvement of aquatic genetic resources was the result of large-scale private industry with advanced breeding programmes.

For example the establishment of the strain of Specific Pathogen Resistant shrimp took place in a bio-secure part of the Hawaiian Islands; some improvements in the Pacific oyster, native to Japan, took place in North America; the genetic improvement of farmed tilapia native to Africa, the GIFT fish, took place in the Philippines (Bartley *et al.*, 2009). Thus, some principles such as farmers' rights and breeders' rights (Andersen and Winge, 2003) are less relevant to aquaculture than to agriculture.

7.3.1 Principles guiding access to AqGR

Principles have been established in some areas to guide access to native genetic resources. Key principles regarding access include prior informed consent and clearly defined benefit arrangements. A famous example of a bilateral ABS agreement concerns Costa Rica and the international pharmaceutical company Merck. Guiding principles to promote access to native biodiversity in Costa Rica included:

- genetic Resources Access permits
- registration of interested parties
- access request
- formulation and management of their prior informed consent agreement between providers and stakeholders (Coughlin, 1993).

The arrangement between Costa Rica and Merck may not be reproducible in many areas; it relies on a very strong financial partner (Merck). Many groups wishing to access AqGR are not as wealthy and Merck.

Material Transfer Agreements (MTA) have also been established on a case by case basis that outline the general conditions and obligations associated with accessing genetic resources. The World Fish Center of the Consultative Group on International Agriculture Research requires MTAs before distributing their genetically improved farmed tilapia (GIFT) (Table 7.1). These principles and obligations have been promoted by FAO (Bartley *et al.*, 2008) and would apply regardless of whether the entity seeking the genetic resource was national or foreign.

Table 7.1: Indicative elements of Material Transfer Agreements for accessing aquatic genetic resources

A country planning to import new or exotic species has to sign a Material Transfer Agreement which states that the recipient agrees to:
Abide by the provisions of the Convention on Biological Diversity and the FAO Code of Conduct for Responsible Fisheries
Preclude further distribution of germplasm to locations at which it could have adverse environmental impact
Not claim ownership over the material received, nor seek intellectual property rights over the germplasm or related information
Ensure that any subsequent person or institution to whom they make samples of germplasm available is bound by the same provision
Comply with the country's biosafety and import regulations and any of the recipient country's rules governing the release of genetic materials
Follow quarantine protocols
Abide by international guidelines in case germplasm is transferred beyond the boundaries of the country[32] (see chapter 8)

Source: WorldFish Center: www.worldfish.org and Bartley *et al.*, 2008

7.3.2 Facilitating and restricting access to AqGR

Countries have sovereign rights to restrict access to AqGR. At the DNA, stock/strain and species levels

[32] www.fao.org/nr/cgrfa/cgrfa-global/cgrfa-codes/en/

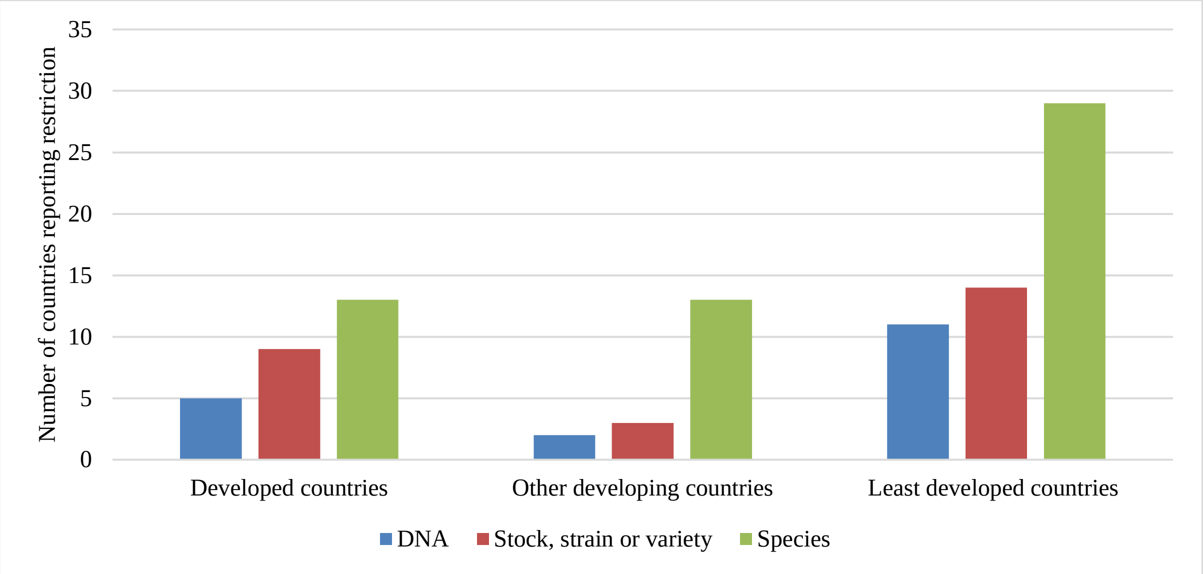
there was a complete range in level of restrictions reported from no restriction to severe restriction. For example in Germany, there is no legislation restricting access to genetic resources in line with CBD Article 15 or the Nagoya Protocol.[33] Whereas for Malawi there is highly restricted access unless national approval is obtained.

Certain countries identified individual species where access was restricted, e.g. Thailand restricts access to *Botia sidthimunkii*, *Probarbus jullieni*, *Catlodaio siamensis*, *Scleropages formosus*, *Pangasianodon gigas*, and *Datnioides microlepis* (several of these species are on CITES Appendix 1 and international trade would be restricted as well).

Species was the most often cited level of AqGR for which restrictions were put in place (Figure 7.2). This trend was also seen when countries were grouped by region and by level of production. There was no important difference seen among country groupings, e.g. major producers did not restrict access any more than minor producing countries.

Figure 7.2

Types of aquatic genetic resources for which countries have restricted access

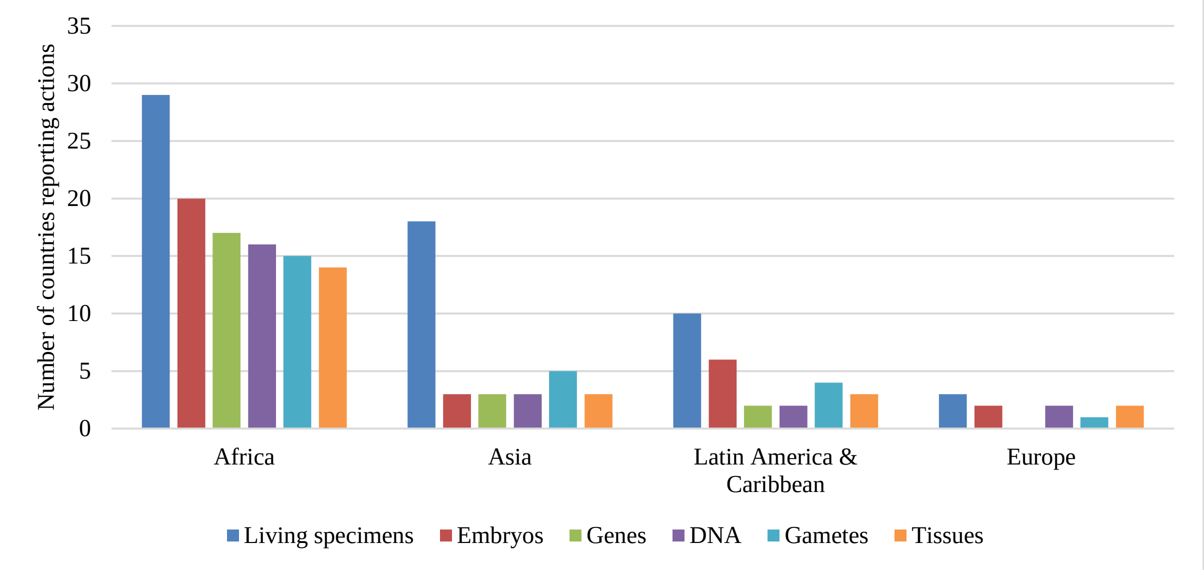


Whereas countries do restrict access to AqGR, countries have also been proactive in facilitating access to genetic resources outside their national border (Figure 7.3). Overall, living specimens were the group of organisms reported where access was most often facilitated. This trend was similar when countries were grouped by region, economic class and level of production (data not shown). However in Asia there was more facilitation of access to embryos (Figure 7.3).

---

[33] Nagoya Protocol: www.cbd.int/abs/

Figure 7.3
Number of actions taken to facilitate access to aquatic genetic resources



7.3.3 Obstacles to accessing AqGR

Countries seeking to access AqGR have also encountered obstacles. The most widely reported obstacle was national legislation in the receiving country, however legislation in exporting country was also seen as an obstacle (Figure 7.4a). Lack of knowledge, was also identified as another overall important obstacle. Analysis by regional groups revealed a similar patter except that Asia reported that donor country laws and expense were the major obstacles to accessing AqGR (Figure 7.4b).

Figure 7.4a: Types of obstacles encountered in accessing aquatic genetic resources; global assessment

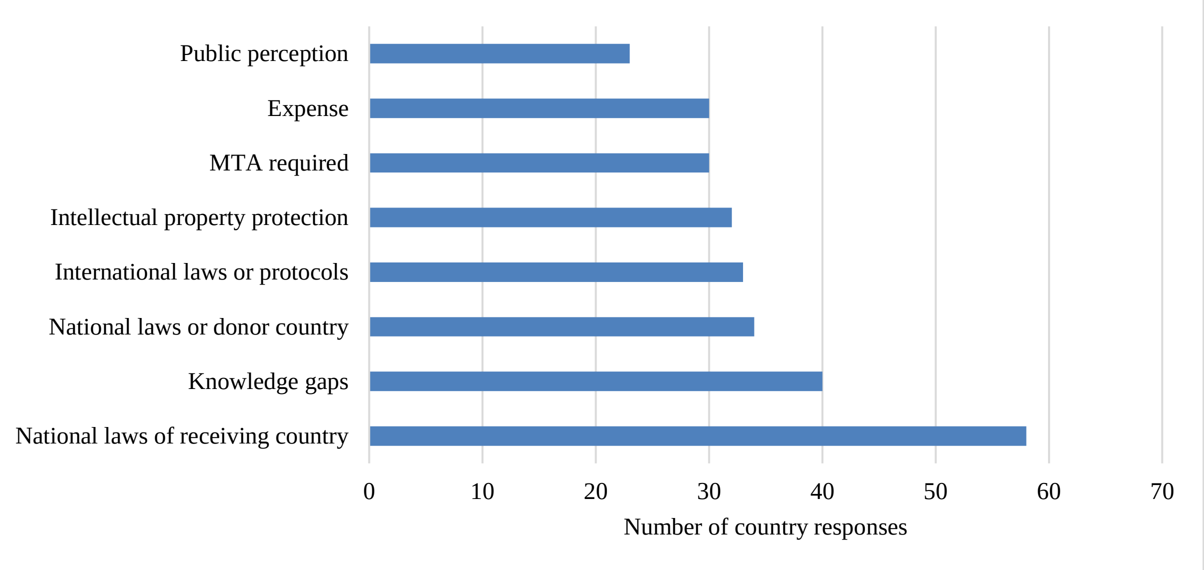
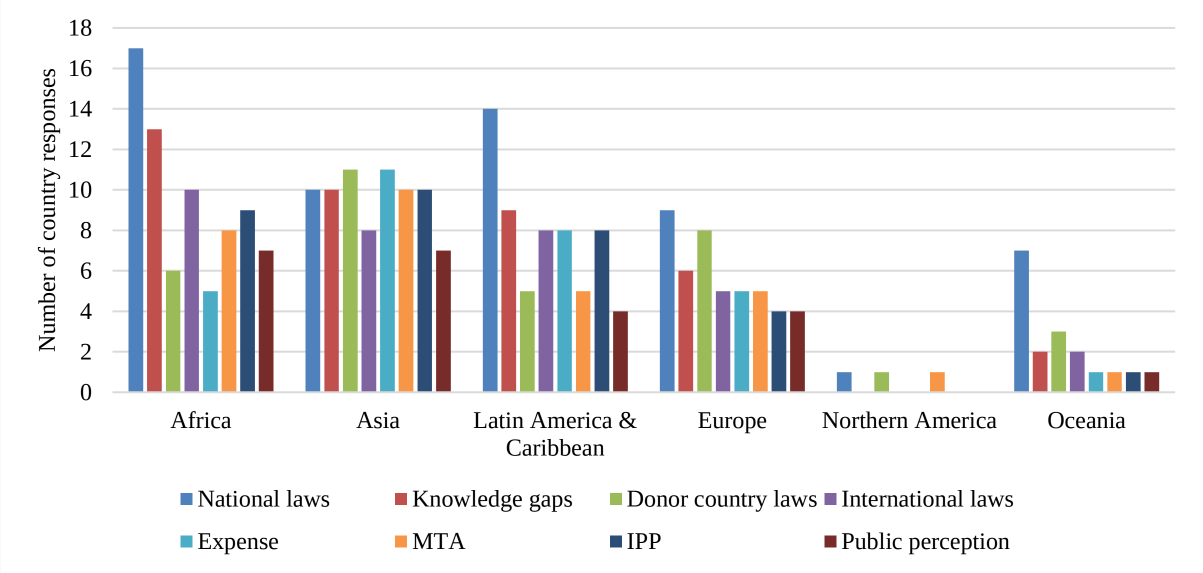
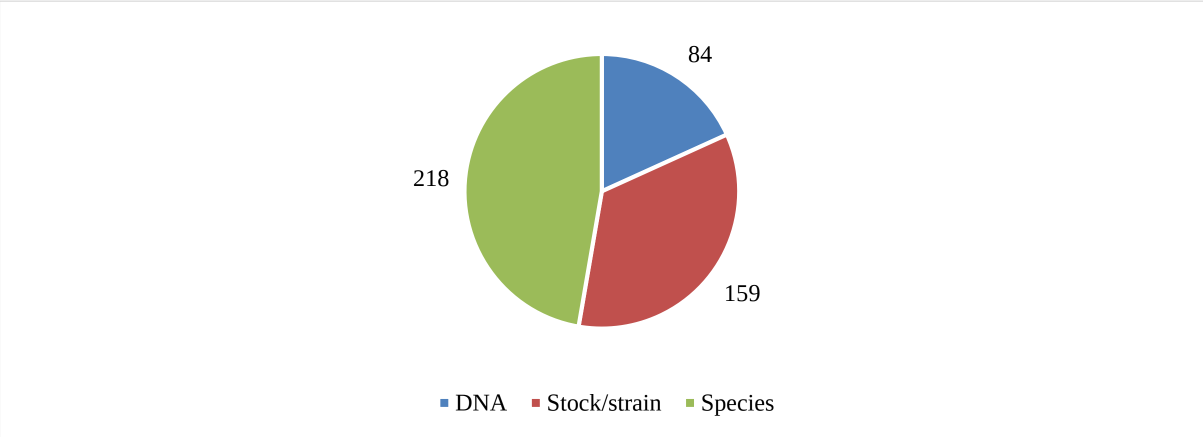


Figure 7.4b
Types of obstacles encountered in accessing aquatic genetic resources; regional assessment



Species was the type of AqGR where most (47 percent) obstacles to access were encountered (Figure 7.5), but obstacles in accessing breeds and strains were also encountered in about 1/3 of the responses and countries reported having problems accessing DNA in 18 percent of the responses.

Figure 7.5
Types of aquatic genetic resources where obstacles to access were encountered (number of responses)



7.4 Key findings and conclusions

Policy	The range of the policies relevant to the management of AqGR for food and agriculture is extremely large because it encompasses farming, fishing and conserving aquatic species.
	Lack of awareness of national policies, lack of technical capacity and insufficient resources were identified as key gaps in effective policy implementation; other gaps in policy concerned transboundary water courses, import and export of AgGR, long term aquaculture development, breeding and genetic manipulation, climate change, objective evaluation of policy efficacy, financial subsidies to implement policies, ownership and harmonization of policies.
	Numerous national policies exist, but there are gaps in national policies at the genetic level, because most policies address AqGR at the species level.
	Fisheries management, fishing closures and restrictions on import/export of a variety of types of AqGR are also included in policies on AqGR.
	Monitoring and enforcement of national policies is often constrained by lack of human and financial resources.
Access and	Access and benefit sharing regimes will be different for AqGR than for GR of crops and livestock.

benefit sharing	Genetic improvement of farmed aquatic species is often done by large companies or international institutions with modern breeding facilities, and in areas outside of the center of origin for many species. Thus farmer rights' and breeders' rights are not relevant in many cases and not included in national policies.
	Countries have taken steps to facilitate access to AqGR that address primarily access to living specimens.
	Countries have encountered obstacles in accessing or importing AqGR that are primarily a result of their own restrictive national legislation.

7.5 References and key documents

Andersen, R. &Winge, T. 2003. *Realising Farmers' Rights to Crop Genetic Resources: Success Stories and Best Practices*. EarthScan from Routledge.

Arthur, J.R., Bondad-Reantaso, M.G., Campbell, M.L., Hewitt, C.L., Phillips, M.J. & Subasinghe, R.P. 2009. *Understanding and applying risk analysis in aquaculture: a manual for decision-makers*. FAO Fisheries and Aquaculture Technical Paper. No. 519/1. Rome, FAO. 113 pp.

Barlow, C. 2016. *Conflicting Agendas in the Mekong River: Mainstream Hydropower Development and Sustainable Fisheries*. pp 281–288. In Taylor, W.W., Bartley, D.M. Goddard, C.I., Leonard, N.J. & Welcomme, R., eds. Freshwater, fish, and the future: proceedings of the global cross-sectoral conference. FAO, MSU and the American Fisheries Society, Bethesda, Maryland.

Bartley, D.M., Brugère, C., Soto, D., Gerber, P. & Harvey, B. eds. 2007. *Comparative assessment of the environmental costs of aquaculture and other food production sectors: methods for meaningful comparisons*. FAO Fisheries Proceedings. No. 10. Rome, FAO. 241 pp.

Bartley, D.M., Brummett, R., Moehl, J., Ólafsson, E., Ponzoni, R. & Pullin, R.S.V. eds. 2008. *Pioneering fish genetic resource management and seed dissemination programmes for Africa: adapting principles of selective breeding to the improvement of aquaculture in the Volta Basin and surrounding areas (trilingual)*. CIFAA Occasional Paper No. 29.

Bartley, D.M. & M. Halwart, eds & comps. 2006. *Alien species in fisheries and aquaculture: information for responsible use* [CD RoM]. Rome, FAO. Also available at: www.fao.org/fi/oldsite/eims_search/1_dett.asp?calling=simple_s_result&lang=en&pub_id=224467

Bartley, D.M., Nguyen, T.T., Halwart, M. & De Silva, S.S. 2009. *Use and exchange of aquatic genetic resources in aquaculture: information relevant to access and benefit sharing*. Reviews in Aquaculture (2009) 1. pp 157–162.

Coughlin, T.R., Jr. 1993. *Using the Merck-INBio agreement to clarify the Convention on Biological Diversity*. Columbia Journal of Transnational Law 31 (2): 337-75.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. FAO, Rome.

FAO. 1996. *The precautionary approach to fisheries management and species introduction*. FAO Technical Guidelines for Responsible Fisheries No. 2. FAO, Rome.

FAO. 2003. *The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Rome, FAO. 112 pp.

FAO. 2016. *Report of the first session of the COFI Advisory Working Group on Aquatic Genetic Resources and Technologies, Brasilia, Brazil, 1–2 October 2015*. FAO Fisheries and Aquaculture Report No. R1139. Rome, Italy. Also available at: www.fao.org/3/a-i5553e.pdf

Pullin, R.S.V., Bartley, D.M. & Kooiman, J. eds. 1999. *Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources*. ICLARM Conference Proceedings, 59. Manila, the Philippines.

CHAPTER 8
RESEARCH, EDUCATION, TRAINING AND EXTENSION ON AQUATIC GENETIC RESOURCES WITHIN NATIONAL JURISDICTION: COORDINATION, NETWORKING AND INFORMATION

PURPOSE: The purpose of Chapter 8 is to review the status and adequacy of national research, education, training and extension, coordination and networking arrangements and information systems that support the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives for food and agriculture. Specifically to:

- describe the current status, future plans, gaps, needs and priorities for research, training, extension and education on the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives;
- describe existing or planned national networks for the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives; and
- describe existing or planned information systems for the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives.

KEY MESSAGES:

- Ninety-seven percent of countries have at least one research institution dealing with use, conservation and management of AqGR.
- Eight percent of countries noted that research on AqGR (conservation, use and/or management) is covered under their national research programs with Mexico, China, the Philippines and India each reporting more than 20 cases where AqGR is covered in national research programmes.
- Basic knowledge on aquatic genetic resources was the most often reported research topic.
- Regarding capacity needs, improve capacities for characterization and monitoring of AqGR was identified as the most important priority, followed very closely by the improvement of capacities for genetic improvement.
- Four hundred eighty-three research centres were identified by 89 countries. Seventy-nine percent of these centres are focused on basic knowledge on aquatic genetic resources; 33 percent of the research centres were focused on economic valuation as one of their research areas.
- Globally the most important capacity need identified by countries regarding research is *to improve characterization and monitoring of aquatic genetic resources*, whereas on a regional level to *improve capacities for genetic improvement* and *improve capacities for characterization and monitoring of aquatic genetic resources* were often very highly ranked research needs.
- Three hundred ninety-eight training and education centres dealing with use, conservation and/or management of AqGR were identified by 83 countries. The main areas of training at global level are genetic resource management and characterization and monitoring of AqGR. The least covered area was economic valuation of AqGR.
- Around 30 percent of the training courses were at the PhD level.
- One hundred ninety-nine inter-sectoral collaboration mechanisms were listed by 67 countries. Asia reported the highest average number of mechanisms per country.
- *Increase technical capacities of institutes* was reported to be the most important capacity need to strengthen inter-sectoral collaboration, followed very closely by *improve awareness* and *improve information sharing*.
- Two hundred fifty-three national networks were listed by 67 countries (73 percent of the total); the most important objective of these networks at the global level was to *improve communication on aquatic genetic resources*, however on a per country basis *to improve capacities for characterization and monitoring of aquatic genetic resources* was the main objective.

- The region with the highest number of national networks per country was Asia, and the region with the least national networks was Oceania.
- One hundred seventy-one information systems on AqGR were listed by 64 countries.
- The region with the highest number of information systems per country was Latin America and the Caribbean.
- Main users of national information systems on AqGR are universities and academia, and government resource managers.
- Major producing countries reported higher number of information systems per country than did the minor producing coutries.
- The type of information stored in these information systems was mostly (1) species names; (2) distribution; and (3) production data on AqGR. Very few information systems are focused on DNA sequences, genes and genomics and strains, breeds and stocks of aquatic genetic resources.

8.1 Introduction

Appropriate capacities, knowledge and skills on aquatic genetic resources use, conservation, management and development at country, sub-region or regional levels are keys to better characterize, use and develop genetic resources of importance for food and agriculture, and therefore, for livelihoods and national economies.

Appropriate knowledge and skills are also key to ensure sustainable use and development of these resources for future generations.

This chapter aims to examine the education and training situation regarding aquatic genetic resources, and to report on actions that can enhance knowledge on the use and conservation of AqGR. It is generally accepted that if we do not know what we have, what we culture, or what we intend to culture in the near future, we will hardly be able to use it in an efficient, effective and sustainable manner.

Applied scientific research in aquaculture is key for long-term sustainable development of the sector, and should aim to boost the value, competitiveness and sustainability of global aquaculture industry. Research could improve and increase food production from aquaculture species through integrated studies of genetics, physiology, health, aqua feeds, environments and food science.

Furthermore, education, training and capacity building is a cross cutting theme which are major elements for sustainable development in the aquaculture sector. Training and extension material, guidelines and participatory approaches could be developed, promoted and applied around the world, since the aquaculture sector is still in its infancy in most countries and regions.

The present chapter aims to better understand existing research, education, training and networking programs on aquaculture, with special emphasis on aquatic genetic resources developed and implemented by surveyed countries.

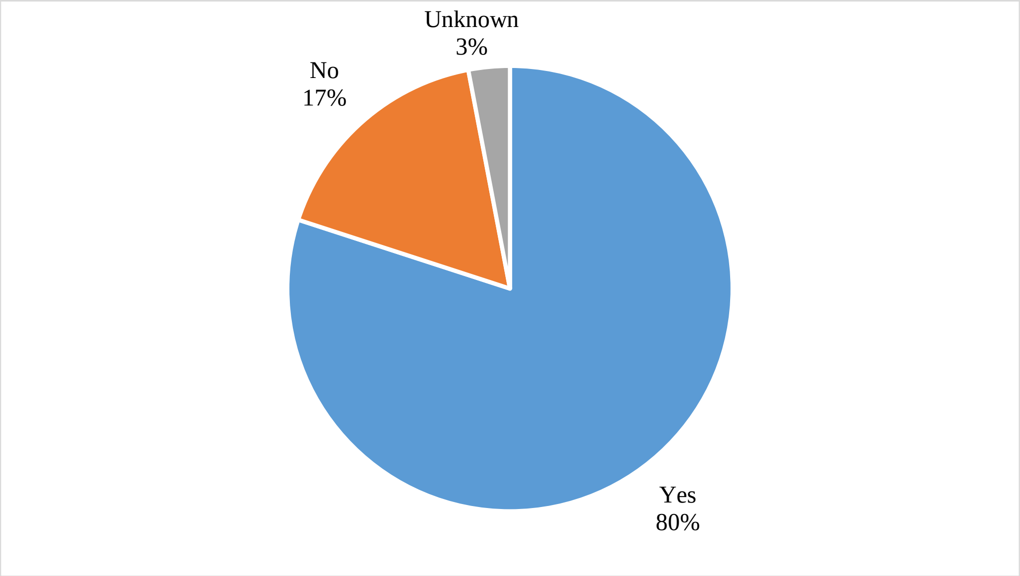
Moreover, specific and clear needs, gaps, limitations and constraints have been identified by surveyed countries, and this information is extremely relevant for FAO and other development partners in order to identify suitable and feasible entry points in regard to education, research and training, for aquaculture improvement.

8.2 Research on AqGR

Countries were asked whether their current national research programs support the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives or not.
For the total of 92 surveyed countries, most reported that AqGR were included in national

research programmes (Figure 8.1).

Figure 8.1
Is aquatic genetic resources included in national research programs?



Regarding geographical distribution of answers, the various countries within regions reported good coverage of AqGR within their research national programs (Table 8.1).

Analysis of countries based on economic level did not reveal substantial differences among the levels (Table 8.2). Mexico was the country that reported the most research facilities covering AqGR followed by China and the Philippines (Table 8.3).

This question also has a section devoted to additional information from surveyed countries regarding existing and/or planned research programs on aquatic genetic resources. Many countries inserted detailed information regarding existing and/or planned programs and actions, mostly being implemented by public institutions and in close collaboration with the University and Academia.

Developed countries noted that the participation of the private sector in research is certainly increasing, mostly applied to characterization of potential farmable species, breeding and economic evaluation of aquatic genetic resources, while public institutions are more focused on conservation and characterization of aquatic genetic resources that provide ecosystem services (data not shown).

Least developed countries and developing countries mentioned that there are no private initiatives in research on aquatic genetic resources, and that public institutions, universities and academia, funded by external projects and foreign donors, and for a short duration of time, are implementing most of the actions.

This matter makes it difficult to maintain the sustainability of the research actions at national level in many developing and least developed countries, which affects not only the long-term sustainability of the aquaculture sector, but also, the survival of the national researchers and trainers.

Table 8.1
Regional coverage regarding national research programs supporting use, conservation and management of aquatic genetic resources

Region	Yes	No	Unknown
Africa	19	7	1
Asia	18	1	1
Latin America and the Caribbean	13	5	
Europe	13	2	1
North America	2		
Oceania	7		

Yes= number of countries with aquatic genetic resources research programs; No= number of countries without aquatic genetic resources research programs

Table 8.2
Economic coverage of national research programs supporting use, conservation and management of aquatic genetic resources

Economic class	Yes	No	Unknown
Developed countries or areas	20	2	2
Least developed countries	16	6	1
Other developing countries or areas	36	7	

Yes= number of countries with aquatic genetic resources research programs; No= number of countries without aquatic genetic resources research programs

Table 8.3
The countries with 10 or more research facilities covering aquatic genetic resources and number of facilities (N)

Country	N
Mexico	32
China	23
Philippines	21
India	20
Iran (Islamic Republic of)	15
Argentina	12
Nigeria	11
Australia	10
Bangladesh	10
Romania	10
Zambia	10

8.2.1 Research institutions

Countries were asked to list main institutions, organizations, corporations and other entities in their respective countries that are engaged in various types of field and/or laboratory research related to the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives. Eighty-nine countries out of 9290 countries mentioned that there are institutions focused on research on AqGR conservation, use, development, management, etc. present in their respective countries.

A total of 483institutions were identified by these 89 countries as main research centres at the national level, (~5.4 institutions per country).
The two regions with the higher number of institutions per country are North America and Asia (Table 8.4).

Table 8.4
Regional distribution of research centres on aquatic genetic resources

Region	Institution	Country	Ratio
Africa	101	25	4.04
Asia	141	20	7.05
Latin America and the Caribbean	109	18	6.06
Europe	86	17	5.06
North America	17	2	8.50
Oceania	29	7	4.14
Grand Total	483	89	5.43

Other developing countries was the economic class with the highest number of research centres per country, while the least developed countries had the lowest number (Table 8.5).

Table 8.5
Distribution of research centres on aquatic genetic resources by economic level

Economic class	Number of institutions	Number of country	Ratio
Developed countries or areas	124	25	4.96
Least developed countries	82	21	3.90
Other developing countries or areas	277	43	6.44
Grand Total	483	89	5.43

8.2.2 Major areas of research

Main areas of research of the 483 listed research centres were provided by countries. Most institutions (79 percent) were focused on "Basic knowledge on aquatic genetic resources" while the rest of the areas of research are not as well covered by research centres (Table 8.6).

The least covered area of research was reported to be the "Economic valuation of aquatic genetic resources." "Basic knowledge on aquatic genetic resources" was the most often reported focus of research in all classifications, without regional or economic distinctions (Table 8.7).

Certain differences are observed in Table 8.7, for example "Conservation of AqGR" is as important as "Basic knowledge on AqGR" in developed countries, while it is not so relevant for least developed and other developing countries, where "Characterization of AqGR", "Management of AqGR" and Communication on AqGR" are better covered research areas.

Table 8.6
Main areas of research of institutions focused on aquatic genetic resources

Area of research institutions	Number of institutions devoted to each area of research (total= 483)	Percent
Genetic resource management	236	49
Basic knowledge on aquatic genetic resources	381	79
Characterization and monitoring of aquatic genetic resources	292	60
Genetic improvement	226	47
Economic valuation of aquatic genetic resources	158	33
Conservation of aquatic genetic resources	295	61
Communication on aquatic genetic resources	267	55
Access and distribution of aquatic genetic resources	193	40

Table 8.7
Main areas of research by economic class

Description	Response count	Area of Research	Average priority ranking
Developed countries or areas	103	Basic knowledge on aquatic genetic resources	4.3
	90	Conservation of aquatic genetic resources	4.3
	94	Characterization and monitoring of aquatic genetic resources	3.5
	79	Genetic resource management	3.4
	73	Communication on aquatic genetic resources	3.3
	53	Access and distribution of aquatic genetic resources	2.8
	56	Genetic improvement	2.8
	51	Economic valuation of aquatic genetic resources	3.1
Least Developed Countries	67	Basic knowledge on aquatic genetic resources	4.1
	54	Communication on aquatic genetic resources	3.9
	52	Conservation of aquatic genetic resources	3.7
	44	Characterization and monitoring of aquatic genetic resources	3.4
	42	Genetic resource management	2.8
	33	Access and distribution of aquatic genetic resources	2.1
	36	Genetic improvement	2.6
	25	Economic valuation of aquatic genetic resources	2.5
Other developing countries or areas	211	Basic knowledge on aquatic genetic resources	5.1
	154	Characterization and monitoring of aquatic genetic resources	4.5
	153	Conservation of aquatic genetic resources	4.1
	115	Genetic resource management	3.5
	140	Communication on aquatic genetic resources	4.5
	107	Access and distribution of aquatic genetic resources	3.3
	134	Genetic improvement	3.8
	82	Economic valuation of aquatic genetic resources	2.9

Table 8.8a
Geographical and economic distribution of institutions focused on various aspects of research on aquatic genetic resources. Management of genetic resources

Geographic region	Number of institutions	Number of countries	Average
Africa	47	17	2.76
Asia	68	17	4.00
Latin America and the Caribbean	38	13	2.92
Europe	51	16	3.19
North America	13	2	6.50
Oceania	19	6	3.17
Grand Total	236	71	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	79	23	3.43
Least developed countries	42	15	2.80
Other developing countries or areas	115	33	3.48
Grand Total	236	71	

Table 8.8b
Geographical and economic distribution of institutions focused on basic knowledge of aquatic genetic resources

Geographic region	Number of institutions	Number of countries	Average
Africa	81	22	3.68
Asia	101	19	5.32
Latin America and the Caribbean	90	17	5.29
Europe	70	16	4.38
North America	17	2	8.50
Oceania	22	7	3.14
Grand Total	381	83	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	103	24	4.29
Least developed countries	67	17	3.94
Other developing countries or areas	211	42	5.02
Grand Total	381	83	

Table 8.8c
Geographical and economic distribution of institutions focused on characterization and monitoring of aquatic genetic resources

Geographic Region	Number of institutions	Number of countries	Average
Africa	57	22	2.59
Asia	95	17	5.59
Latin America and the Caribbean	41	10	4.10
Europe	62	16	3.88
North America	15	2	7.50
Oceania	22	7	3.14
Grand Total	292	74	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	94	27	3.48
Least developed countries	44	13	3.38
Other developing countries or areas	154	34	4.53
Grand Total	292	74	

Table 8.8d
Geographical and economic distribution of institutions focused on genetic improvement of aquatic genetic resources

Geographic region	Number of institutions	Number of countries	Average
Africa	46	20	2.30
Asia	88	14	6.29
Latin America and the Caribbean	34	13	2.62
Europe	36	14	2.57
North America	8	2	4.00
Oceania	14	6	2.33
Grand Total	226	69	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	56	20	2.80
Least developed countries	36	14	2.57
Other developing countries or areas	134	35	3.83
Grand Total	226	69	

Table 8.8e
Geographical and economic distribution of institutions focused on economic valuation of aquatic genetic resources

Geographic region	Number of institutions	Number of countries	Average
Africa	35	11	3.18
Asia	49	14	3.50
Latin America and the Caribbean	19	10	1.90
Europe	37	12	3.08
North America	5	2	2.50
Oceania	13	6	2.17
Grand Total	158	55	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	51	17	3.00
Least developed countries	25	10	2.50
Other developing countries or areas	82	28	2.93
Grand Total	158	55	

Table 8.8f
Geographical and economic distribution of institutions focused on conservation of aquatic genetic resources

Geographic region	Number of institutions	Number of countries	Average
Africa	54	17	3.18
Asia	91	15	6.07
Latin America and the Caribbean	46	16	2.88
Europe	65	16	4.06
North America	13	2	6.50
Oceania	26	7	3.71
Grand Total	295	73	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	90	21	4.29
Least developed countries	52	14	3.71
Other developing countries or areas	153	38	4.03
Grand Total	295	73	

Table 8.8g
Geographical and economic distribution of institutions focused on communication on aquatic genetic resources

Geographic region	Number of institutions	Number of countries	Average
Africa	64	18	3.56
Asia	89	14	6.36
Latin America and the Caribbean	38	11	3.45
Europe	52	16	3.25
North America	9	2	4.50
Oceania	15	6	2.50
Grand Total	267	67	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	73	22	3.32
Least developed countries	54	14	3.86
Other developing countries or areas	140	31	4.52
Grand Total	267	67	

Table 8.8h
Geographical and economic distribution of institutions focused on access and distribution of aquatic genetic resources

Geographic region	Number of institutions	Number of countries	Average
Africa	43	18	2.39
Asia	68	16	4.25
Latin America and the Caribbean	29	11	2.64
Europe	34	14	2.43
North America	9	2	4.50
Oceania	10	6	1.67
Grand Total	193	67	
Economic class	**Number of institutions**	**Number of countries**	**Average**
Developed countries or areas	53	19	2.79
Least developed countries	33	16	2.06
Other developing countries or areas	107	32	3.34
Grand Total	193	67	

8.2.3 Capacity needs

Countries were requested to identify main capacity strengthening needs, in order to improve national research in support of the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives.

The following capacities were assessed by countries, ranking them from very important (1) to not important at all (10):

- improve capacities for basic knowledge on aquatic genetic resources
- improve capacities for characterization and monitoring of aquatic genetic resources
- improve capacities for genetic improvement
- improve capacities for genetic resource management
- improve capacities for economic valuation of aquatic genetic resources
- improve capacities for conservation of aquatic genetic resources
- improve communication on aquatic genetic resources
- improve access to and distribution of aquatic genetic resources.

Table 8.9
Global ranking of capacity needs on research applied to aquatic genetic resources at global level

Capacity need	Ranking
Improve basic knowledge on aquatic genetic resources	2.14
Improve capacities for characterization and monitoring of aquatic genetic resources	1.90
Improve capacities for genetic improvement	1.96
Improve capacities for genetic resource management	2.43
Improve capacities for economic valuation of aquatic genetic resources	3.12
Improve capacities for conservation of aquatic genetic resources	2.39
Improve communication on aquatic genetic resources	3.36
Improve access to and distribution of aquatic genetic resources	3.54

Highest priority=1 and lowest=10.

At the global level, the capacities ranked the highest were: (1) improve characterization and monitoring of aquatic genetic resources; and (2) improve national capacities for genetic improvement (Table 8.9). The capacity needs ranked the lowest were: (1) access and distribution of aquatic genetic resources; and (2) communication on aquatic genetic resources.

On a regional level, to *improve capacities for genetic improvement* and *improve capacities for characterization and monitoring of aquatic genetic resources* were often the highest ranked research needs (Table 8.10).

Table 8.10
Top two research capacity needs identified by regions

Region	Highest ranked research capacity need	Second highest ranked research capacity need
Africa	Improve capacities for genetic improvement	Improve capacities for characterization and monitoring of aquatic genetic resources
Asia	Improve capacities for basic knowledge on aquatic genetic resource	Improve capacities for characterization and monitoring of aquatic genetic resources
Latin America and the Caribbean	Improve capacities for basic knowledge on aquatic genetic resource	Improve capacities for characterization and monitoring of aquatic genetic resources
Europe	Improve capacities for genetic improvement	Improve capacities for characterization and monitoring of aquatic genetic resources
North America	Improve capacities for characterization and monitoring of aquatic genetic resources	Improve capacities for genetic resource management
Oceania	Improve capacities for characterization and monitoring of aquatic genetic resources	Improve capacities for genetic improvement

8.3 Education, training and extension on AqGR

8.3.1 Institutions, areas of work and type of courses

Countries were requested to indicate the extent that education, training and extension in their respective countries covers the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives, listing the main institutions involved and the types of courses offered by these institutions.

A total of 83 countries, from the countries in total (90 percent of the total surveyed countries) indicated that there are specific institutions involved in education, training and/or extension on aquatic genetic resources. A total of 398 training institutions were identified by the 83 countries, giving an average of around 4.8 training centres per country.

Table 8.11 provides a summary of training centres on AqGR per region, including the number of training centres per country for each region. The regions with the higher number of education and training centres on aquatic genetic resources per country are Asia, followed by Europe.

Table 8.11
Total Number and average number per country of training centres on aquatic genetic resources by geographical region

Geographical region	Number of institutions	Number of countries	Average
Africa	120	26	4.62
Asia	109	16	6.81
Latin America and the Caribbean	67	16	4.19
Europe	80	16	5.00
North America	9	2	4.50
Oceania	13	7	1.86
Grand Total	398	83	4.80

Table 8.12 provides a summary of training centres on AqGR by economic class, including the number of training centres per country for each economic class. It can be assessed that the average number of training centres per country is similar in the three economic classes.

Table 8.12
Number of training centres on aquatic genetic resources by economic class and average number of training centres per country

Economic class	Number of institutions	Number of countries	Average
Developed countries or areas	103	22	4.68
Least Developed Countries	110	22	5.00
Other developing countries or areas	185	39	4.74
Grand Total	398	83	4.80

Table 8.13
Total number of training institutions for countries reporting 10 or more training institutions

Country	N	Country	N
Germany	22	Mexico	13
Bangladesh	18	Senegal	12
India	18	Benin	11
Madagascar	14	Niger	11
Turkey	14	Thailand	10

N= number of countries

The lowest number of training centres are devoted to extension, in general, and specifically in the areas of characterization and monitoring of aquatic genetic resources and economic valuation of aquatic genetic resources (Table 8.14). Training areas such as genetic resources management and conservation of aquatic genetic resources are well covered in all types of training methodologies.

Courses were classified by countries as (1) training; (2) undergraduate; (3) post-graduate; and (4) extension. A common trend for all regions and sub-regions, without distinction by economic classes, is the limited availability of "Extension courses" and "Graduate" courses available for all thematic areas.

Table 8.14
Ratio of number of types of courses per country for each thematic area related to aquatic genetic resources

Thematic area	Average number of type of course per country			
	Undergraduate	Graduate	Training	Extension
Genetic resource management	7	3.3	3.1	2.9
Characterization and monitoring of AqGR	2.9	3.4	3.2	2.5
Genetic improvement	2.8	3.3	3.2	3.0
Economic valuation of AqGR	2.5	2.7	3	2.4
Conservation of AqGR	2.9	3.3	3.3	2.9

There are more courses available for *Genetic resource management* than the other thematic areas and less courses available for *Economic valuation of AqGR* (Table 8.15). Between 25 and 33 percent of the courses were at the PhD level.

Table 8.15
Courses available for each subject area and including at the PhD level

Topic of the course	No. of courses	Percent of total training courses	No. of PhD courses	Percent PhD courses out of total number of courses
Genetic resource management	175	23	45	**26**
Characterization and monitoring of AqGR	162	22	53	**33**
Genetic improvement	150	20	48	**32**
Economic valuation of AqGR	107	14	31	**29**
Conservation of AqGR	**159**	**21**	**45**	**28**

The areas of characterization and monitoring of aquatic genetic resources, conservation of aquatic genetic resources and genetic resource management can be considered the areas better covered, while the economic valuation of aquatic genetic resources, followed by the training area of genetic improvement are the less covered areas in training courses at global level.

8.4 Coordination and networking on AqGR

8.4.1 Networking mechanisms

Countries were requested to list any mechanisms within their respective countries that are responsible for coordinating the aquaculture, culture-based fisheries and capture fisheries subsectors with other sectors that use the same watersheds and coastal ecosystems, and that have impacts on aquatic genetic resources of wild relatives of farmed aquatic species (e.g. agriculture, forestry, mining, tourism, waste management and water resources).

A total of 199 different mechanisms of inter-sectoral and intra-sectoral coordination were identified by 67 countries (Table 8.16). Therefore, 70 percent of the surveyed countries (92 countries in total) have responded positively to the presence of coordination mechanisms between different sub-sectors, including the aquaculture and fisheries sectors. Countries that did not include the existence of any inter-sectoral coordinating mechanisms are Armenia, Belize, Burundi, Cabo Verde, Canada, Chad, China, the Democratic Republic of the Congo, Czechia, Finland, Georgia, Honduras, Iraq, Kazakhstan, Kenya, Kiribati, Latvia, Poland, Samoa, the Sudan, Togo, Tonga, Vanuatu, Viet Nam and Zambia.

Table 8.16
Total number of coordinating mechanisms (N) detailed by the 67 countries with positive answers

Country	N	Country	N
Algeria	2	Japan	3
Argentina	6	Republic of Korea	1
Australia	1	Lao People's Democratic Republic	2
Bangladesh	6	Madagascar	12
Belgium	6	Malawi	2
Benin	5	Malaysia	5
Bhutan	1	Mexico	6
Brazil	2	Morocco	2
Bulgaria	5	Mozambique	1
Burkina Faso	1	Netherlands	5
Cambodia	1	Nicaragua	1
Cameroon	2	Niger	1
Chile	1	Nigeria	4
Colombia	4	Norway	7
Costa Rica	1	Palau	1
Croatia	1	Panama	4
Cuba	1	Paraguay	1
Cyprus	2	Peru	2
Denmark	1	Philippines	20
Djibouti	1	Romania	1
Dominican Republic	2	Senegal	3
Ecuador	2	Sierra Leone	2
Egypt	1	Slovenia	1
El Salvador	2	South Africa	1
Estonia	1	Sri Lanka	6
Fiji	2	Sweden	5
Germany	5	United Republic of Tanzania	1

Ghana	1	Thailand	7
Guatemala	1	Tunisia	1
Hungary	1	Turkey	1
India	2	Uganda	5
Indonesia	3	Ukraine	1
Iran (Islamic Republic of)	3	United States of America	2
		Venezuela (Bolivarian Republic of)	6
		Grand Total	**199**

Table 8.17
Number of inter-sectoral coordination mechanisms on aquatic genetic resources by Region and the average number of mechanisms per country in that region

Geographical region	Number of mechanisms	Number of country	Average
Africa	48	19	2.53
Asia	63	15	4.20
Latin America and the Caribbean	42	16	2.63
Europe	40	13	3.08
North America	2	1	2.00
Oceania	4	3	1.33
Grand Total	199	67	2.97

The regions with the highest average number of inter-sectoral mechanisms per country are Asia and Europe. The regions with the lowest level of inter-sectoral mechanisms are Oceania, followed by North America (Table 8.17).

Other developing countries, followed by least developed countries are the economic classes with the highest number of inter-sectoral mechanisms per country (Table 8.18).

Table 8.18
Number and average number per country of inter-sectoral coordination mechanisms on aquatic genetic resources by economic class

Economic class	Number of mechanisms	Number of countries	Average
Developed countries or areas	47	17	2.76
Least Developed Countries	44	15	2.93
Other developing countries or areas	108	35	3.09
Grand Total	199	67	2.97

8.4.2 Capacity needs

Countries were requested to rank how capacity strengthening could be improved in inter-sectoral coordination, in support of the conservation, sustainable use and development of aquatic genetic resources. Three different capacities were ranked from 1 (very important) to 10 (no importance) by countries.

The three different capacities ranked were:

1. Increase awareness in institutions.
2. Increase technical capacities of institutions.
3. Increase information sharing between institutions.

Increase technical capacities of institutes was identified by countries as the most important, followed very closely by *improve awareness* and *improve information sharing* (Table 8.19).

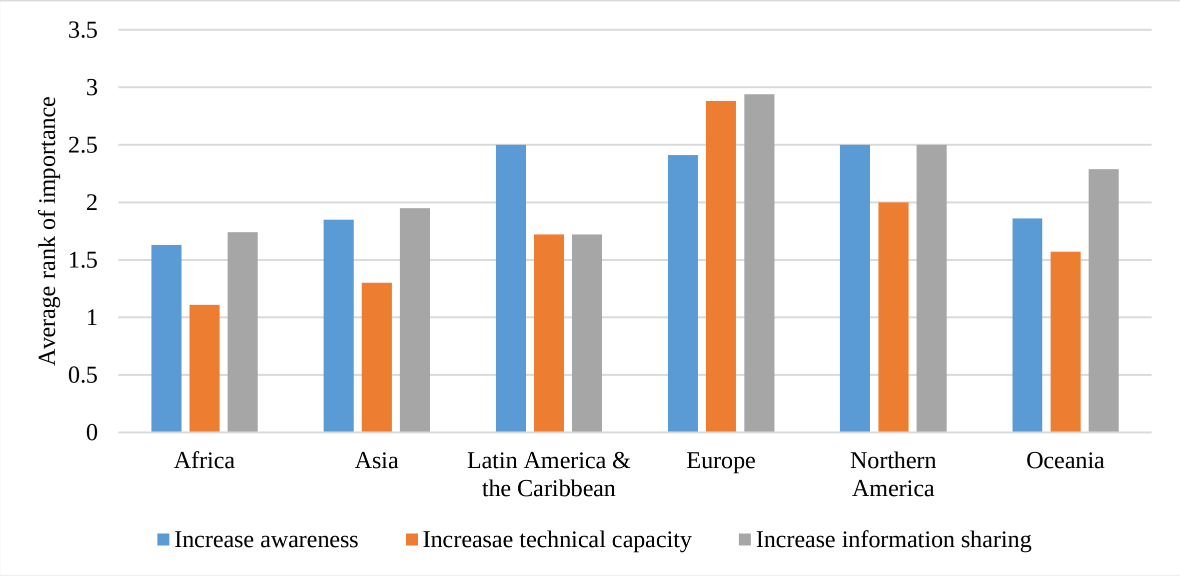
Table 8.19
Average rank of capacity strengthening to be improved in inter-sectoral coordination in support of conservation, use and management of aquatic genetic resources

Capacities to be improved	Average Rank
Improve awareness in institutions	2.03
Increase technical capacities of institutions	1.66
Increase information sharing between institutions	2.07

1: very important; 10: no importance.

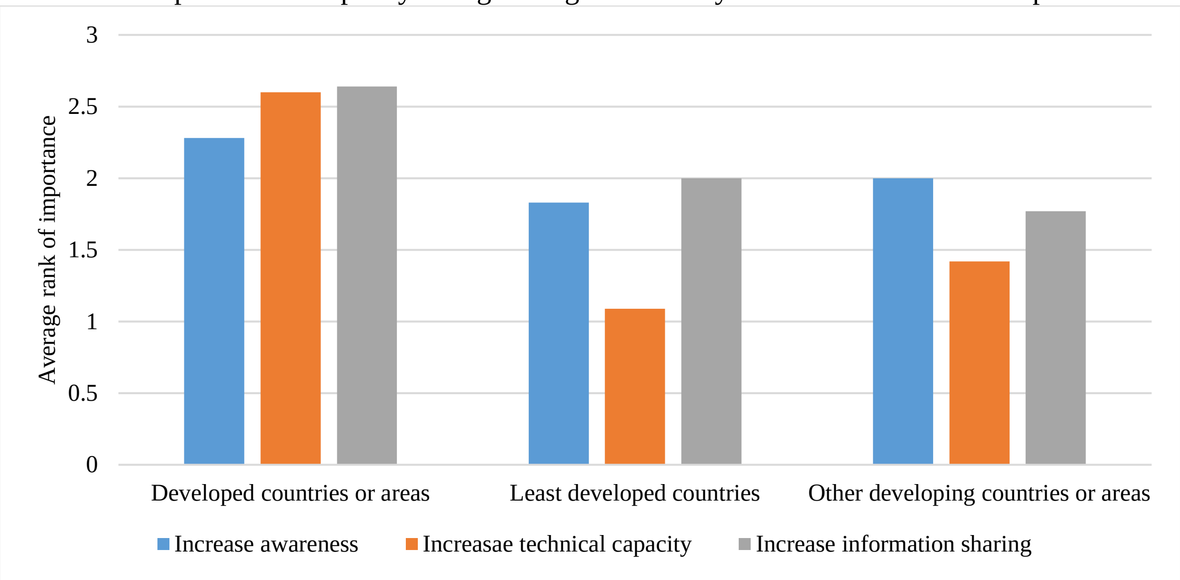
The three capacity strengthening activities were generally ranked similarly in level of importance, however *Increase technical capacity* ranked most important in five of the six region (Figure 8.2). *Increased technical capacity* was generally ranked more important when countries were grouped by level of economic development (Figure 8.3). However in developed countries *Increased awareness* was ranked most important.

Figure 8.2
Rank of the importance of capacity strengthening activities by region



1= very important and 10 = no importance.

Figure 8.3
Rank of the importance of capacity strengthening activities by level of economic development



1= very important and 10 = no importance.

8.4.3 National networking on AqGR

Countries were asked to list all national networks in their respective countries, as well as all international networks their countries belongs to that support the conservation, sustainable use and development of aquatic genetic resources.

Sixty-seven countries have national networks related to use, conservation and/or management of AqGR. A total of 253 national networks were identified by these 67 countries, which gives an average value of 3.8 networks per country. Peru was the country with the most national networks and several countries listed only one national network (Table 8.20).

Table 8.20: Number of national networks (N) related to aquatic genetic resources

Country	N	Country	N	Country	N
Peru	25	Indonesia	4	Sudan	2
Germany	11	Iran (Islamic Republic of)	4	United Republic of Tanzania	2
Bangladesh	10	Slovenia	4	Thailand	2
China	10	Argentina	3	Viet Nam	2
Philippines	10	Bulgaria	3	Zambia	2
Cambodia	9	Dominican Republic	3	Algeria	1
Uganda	8	Hungary	3	Belize	1
Canada	7	Republic of Korea	3	Benin	1
Romania	7	Norway	3	Burundi	1
El Salvador	6	Palau	3	Chad	1
Ghana	6	Tunisia	3	Colombia	1
India	6	Turkey	3	Costa Rica	1
Mexico	6	Belgium	2	Czechia	1
Nigeria	6	Brazil	2	Egypt	1
Senegal	6	Cabo Verde	2	Fiji	1
Croatia	5	Cuba	2	Mozambique	1
Malawi	5	Democratic Republic of the Congo	2	Niger	1
Malaysia	5	Guatemala	2	Panama	1
Netherlands	5	Japan	2	Paraguay	1
Sweden	5	Madagascar	2	Poland	1
Australia	4	Sierra Leone	2	Togo	1
Cameroon	4	Sri Lanka	2	Ukraine	1
				United States of America	1

The region with the highest number of national networks as well as the most networks per country is Asia (Table, 8.21).

The economic class with the highest number of national networks related to aquatic genetic resources is other developing countries, followed by developed countries and with least developed countries at the end of the ranking.

Table 8.21
Total number and average number of national networks related to aquatic genetic resources by region

Geographic region	Number of networks	Number of countries	Average
Africa	60	22	2.73
Asia	72	14	5.14
Latin America and the Caribbean	54	13	4.15
Europe	51	13	3.92
North America	8	2	4.00
Oceania	8	3	2.67
Grand Total	253	67	3.78

Table 8.22
Total number and average number of national networks related to AqGR by economic level of development

Economic class	Number of networks	Number of countries	Average
Developed countries or areas	65	17	3.82
Least Developed Countries	56	17	3.29
Other developing countries or areas	132	33	4.00
Grand Total	253	67	3.78

The objectives of the national networks on aquatic genetic resources were to:

- improve basic knowledge on aquatic genetic resources
- improve capacities for characterization and monitoring of aquatic genetic resources
- improve capacities for genetic improvement
- improve capacities for economic valuation of aquatic genetic resources
- improve capacities for conservation of aquatic genetic resources
- improve communication on aquatic genetic resources
- improve access to and distribution of aquatic genetic resources.

On a global level the main objective of most national networks was to *improve communication on aquatic genetic resources*, however on a per country basis to *Improve capacities for characterization and monitoring of aquatic genetic resources* was the main objective (Table 8.23). There are several networks with various objectives in most countries.

However, analysis by regional and level of economic development revealed a diversity of number of networks for the various objectives (Figure 8.24a,b). The major producer countries consistently had more networks for a given objective than the lesser producing countries (Figure 8.24.c).

Table 8.23
Total number of network for each the objectives listed above, and the average number of networks per countries

Objectives of the network	Number of networks	Networks/countries
Improve basic knowledge on aquatic genetic resources	175	3.43
Improve capacities for characterization and monitoring of aquatic genetic resources	157	3.57
Improve capacities for genetic improvement	112	2.80
Improve capacities for economic valuation of aquatic genetic resources	119	3.05
Improve capacities for conservation of aquatic genetic resources	181	3.48
Improve communication on aquatic genetic resources	188	3.51
Improve access to and distribution of aquatic genetic resources	115	2.88

Figure 8.4

Average number of networks per country with a given objective by region

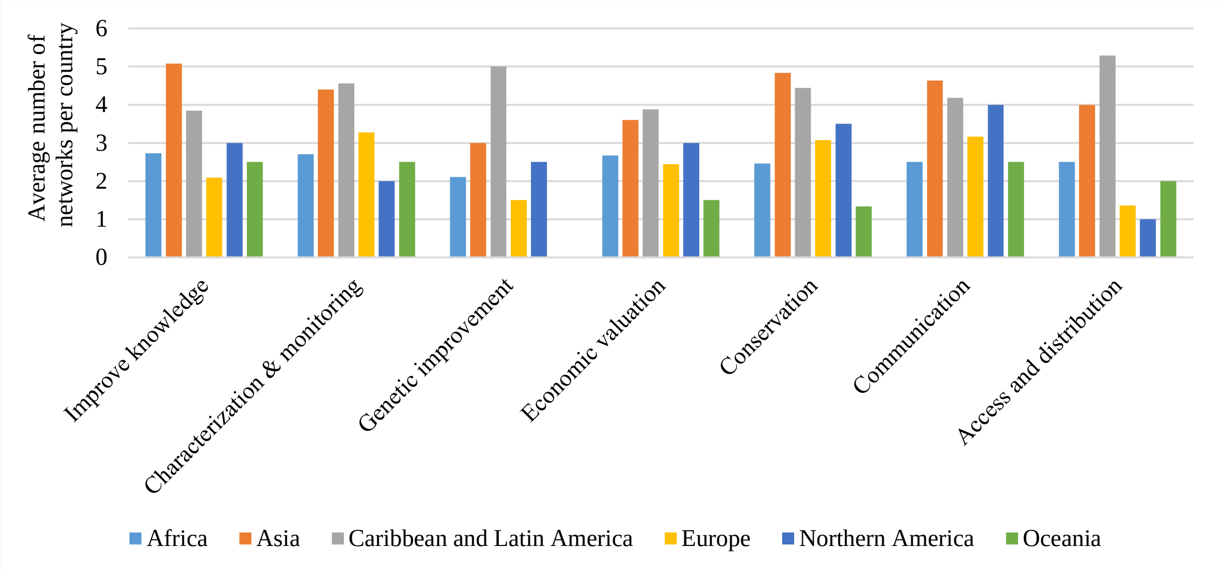


Figure 8.4a

Average number of networks per country with a given objective by economic level

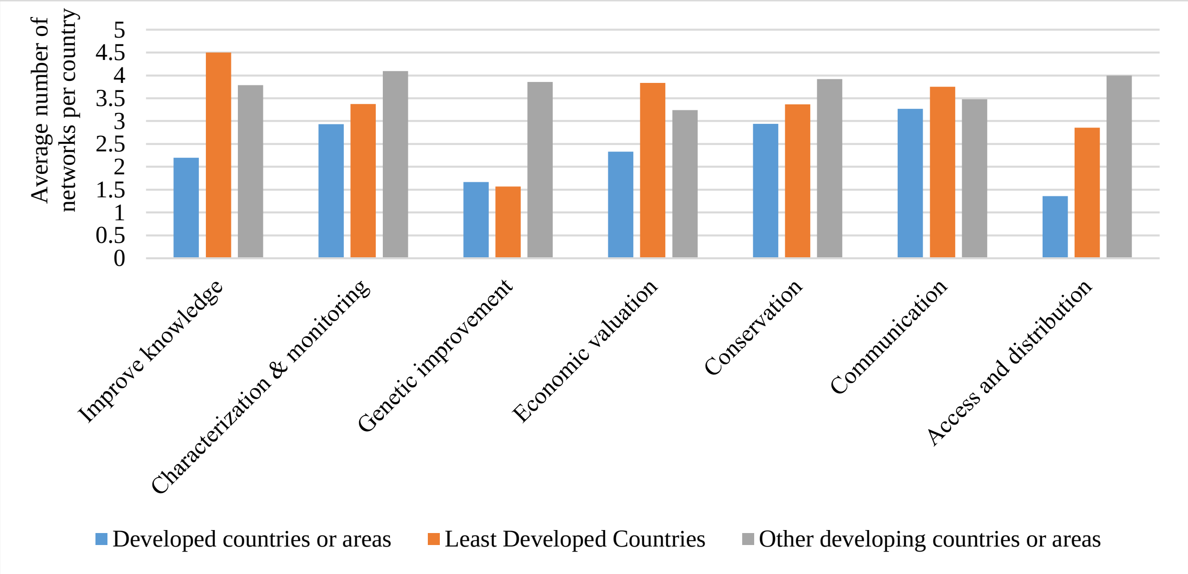
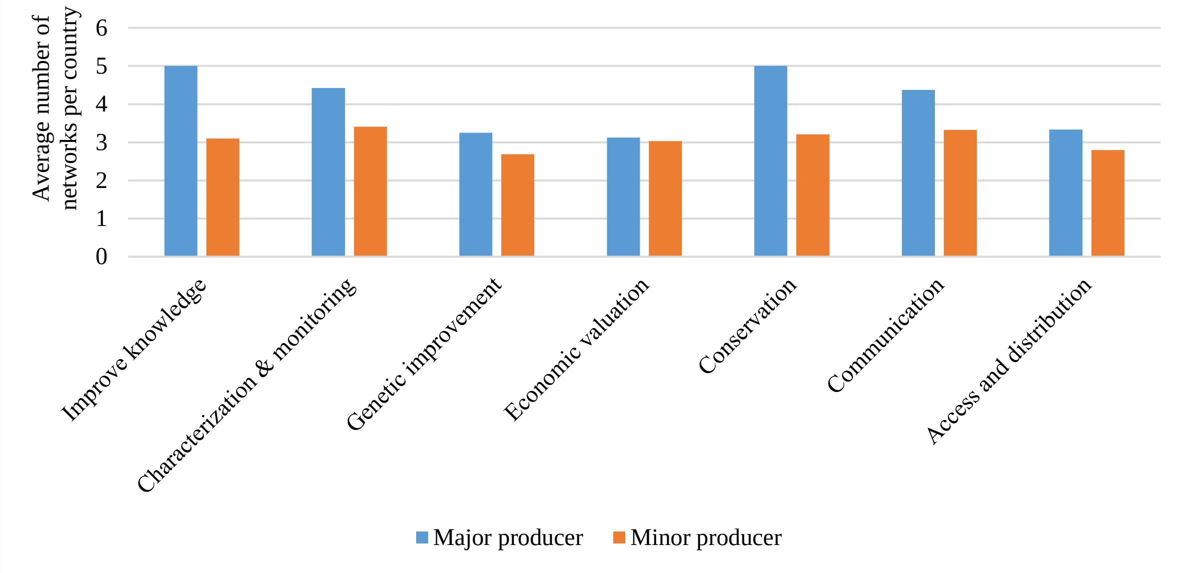


Figure 8.4b
Average number of networks per country with a given objective by level of production



8.5 Information systems on AqGR

Countries were asked to list information systems existing in their respective countries for receiving, managing and communicating information about the conservation, sustainable use and development of aquatic genetic resources of farmed aquatic species and their wild relatives. A total of 171 information systems related to aquatic genetic resources were listed by 64 countries (70 percent of surveyed countries), which gives an average of 2.6 information systems on aquatic genetic resources per country. Mexico reported the most information systems on AqGR (18) followed by India (9) and the Philippines (9) (Table 8.24).

Table 8.24
Number of information systems (N) on AqGR

Country	N	Country	N
Algeria	4	Japan	3
Argentina	2	Republic of Korea	1
Bangladesh	2	Madagascar	7
Belgium	1	Malawi	5
Benin	4	Malaysia	4
Bhutan	2	Mexico	18
Brazil	1	Morocco	7
Bulgaria	1	Mozambique	1
Cabo Verde	1	Netherlands	6
Cambodia	1	Niger	1
Cameroon	1	Nigeria	6
Chile	1	Norway	4
China	1	Palau	1
Colombia	5	Panama	1
Costa Rica	2	Philippines	9
Croatia	3	Poland	2
Cuba	2	Romania	3
Cyprus	1	Samoa	1
Czechia	2	Senegal	2
Democratic Republic of the Congo	1	Sierra Leone	1
Denmark	2	Slovenia	1
Dominican Republic	2	South Africa	1
Egypt	1	Sri Lanka	3

El Salvador	1	Sweden	1
Finland	2	United Republic of Tanzania	1
Germany	5	Thailand	3
Ghana	1	Tunisia	2
Guatemala	1	Uganda	3
Honduras	1	Ukraine	1
Hungary	2	United States of America	1
India	9	Viet Nam	1
Iran (Islamic Republic of)	3	Zambia	2
		Grand Total	**171**

The region with the highest absolute number of information systems on AqGR is Africa and the region with the highest average number of information systems per country related to aquatic genetic resources is Latin America and the Caribbean, followed very closely by Asia (Table 8.25).

Table 8.25
Number and average number per country of information systems on aquatic genetic resources by region

Geographic region	Number of information systems	Number of countries	Average
Africa	52	20	2.60
Asia	43	14	3.07
Latin America and the Caribbean	37	12	3.08
Europe	36	15	2.40
North America	1	1	1.00
Oceania	2	2	1.00
Grand Total	171	64	2.67

Other developing countries have an average of 3.03 information systems on aquatic genetic resources per country, while developed countries have listed an average of 2.28 information systems per country. The major producer countries had on average more information systems on AqGR than the lesser producing countries (Table 8.26a, b).

Table 8.26a
Number and average number per country of information systems on aquatic genetic resources by region

Economic class	Number of information systems	Number of countries	Average
Developed countries or areas	41	18	2.28
Least Developed Countries	33	14	2.36
Other developing countries or areas	97	32	3.03
Grand Total	171	64	2.67

Table 8.26b
Number and average number per country of information systems on aquatic genetic resources level of production

Level of production	Number of information systems	Number of countries	Average
Major producer	32	10	3.20
Minor producer	139	54	2.57
Grand Total	171	64	

8.5.1 Main users of information systems

Countries also assessed main users and the extent of use of the information systems on AqGR that are available at National level. Main users identified by countries and the extent of use of the aforementioned 171 information systems is provided in Table 8.27.

The users of information on AqGR provided in the questionnaire were:

1. fish farmers
2. fishers in capture fisheries
3. fish hatchery people
4. people involved in marketing
5. government resource area managers
6. fisheries or aquaculture associations
7. aquatic protected area managers
8. university and academia people
9. non-governmental organization
10. inter-governmental organization
11. policy makers
12. donors
13. consumers
14. politicians

The main users of information systems identified by surveyed countries are Universities and Academia and by Government resource managers. Stakeholders, i.e. users, with limited use of these information systems are consumers, politicians, donors and people involved in marketing. Aquaculture producers (hatcheries, farmers), fishers in capture fisheries and people involved in marketing of aquatic genetic resources also have a medium level of use of information systems (Table 8.27).

Table 8.27
Main users of information systems on aquatic genetic resources and number of information systems

Main users	Number of information systems
Government resource area managers	134
University and Academia people	134
Non-Governmental Organization	107
Fisheries or aquaculture associations	104
Policy makers	99
Fish farmers	98
Inter-Governmental Organization	91
Fishers in capture fisheries	84
Aquatic protected area managers	84
Fish hatchery people	79
People involved in marketing	64
Donors	62
Politicians	52
Consumers	50

8.5.2 Type of information stored in information systems on AqGR

The type of information stored in national information systems on AqGR was assessed by countries, with the various types listed as:

- DNA sequence
- genes and genotype
- breeds, strains and stocks
- species names
- production figures
- distribution
- level of endangerment

Most of the information systems available at national levels are focused on species names, distribution of aquatic genetic resources and production data, while very few information systems contain information on DNA sequences, genes and genomics and breeds, strains and stocks (Figure 8.5 and Table 8.28). This pattern was observed regardless of how countries were grouped. Major producing countries had on average more information systems on a particular class of information except for *Production figures* (Figure 8.6).

Figure 8.5
Types of information stored in information systems on aquatic genetic resources

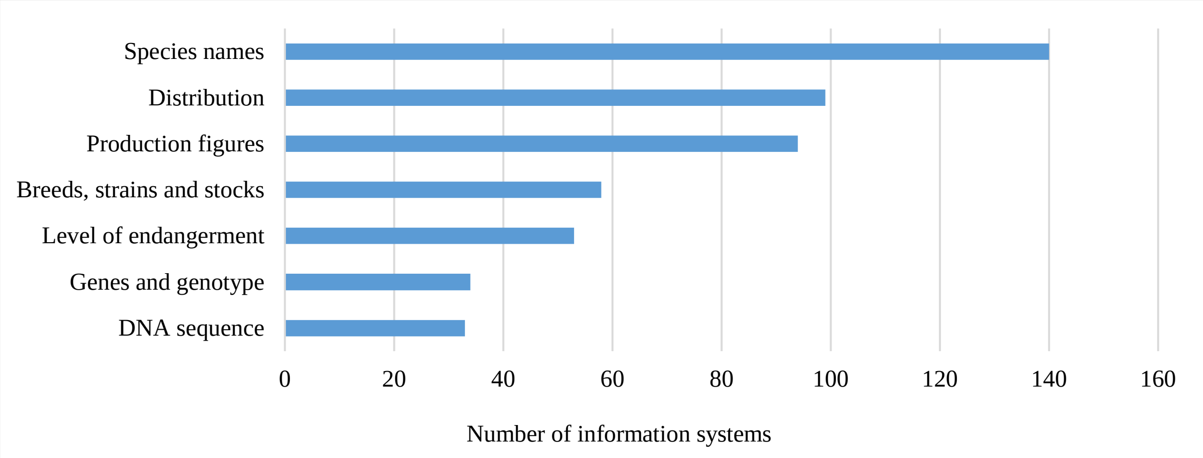
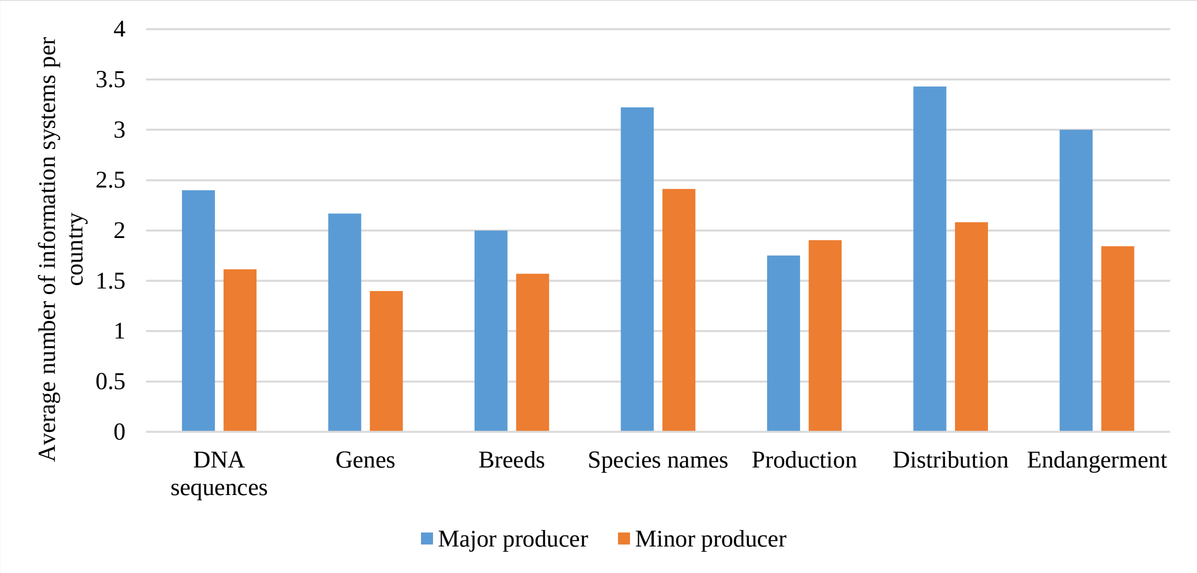


Table 8.28
Type of information stored and numbers of information systems in national information systems by economic class

Economic class	DNA sequences	Genes	Breeds	Species names	Produc-tion	Distribu-tion	Endanger-ment
Developed countries or areas	7	10	19	36	25	30	12
Least developed countries	4	4	18	28	19	14	9
Other developing countries or areas	22	20	21	76	50	55	32

Figure 8.6
Average number of information system addressing a specific type of aquatic genetic resources per country by level of production



8.6 Key findings and conclusions

Most countries have at one research facility to address AqGR	Eighty percent of the countries noted that research on AqGR (conservation, use and/or management) is covered under their national research programs with Mexico, China, the Philippines and India each reporting more than 20 cases where AqGR is covered in national research programmes.
	Basic knowledge on aquatic genetic resources was the most often reported research topic.
	Globally the most important capacity need identified by countries regarding research is *to improve characterization and monitoring of aquatic genetic resources*, whereas on a regional level to *Improve capacities for genetic improvement* and *Improve capacities for characterization and monitoring of aquatic genetic resources* were often very highly ranked research needs.
Training and education centres addressing AqGR are also common	Three hundred ninety-eight training and education centres dealing with use, conservation and/or management of AqGR were identified by 83 countries.
	The main areas of training at global level are genetic resource management and characterization and monitoring of AqGR. The least covered area was economic valuation of AqGR.
	Education also included courses at the PhD level.
Mechanisms for inter-sectoral collaboration exist	One hundred ninety-nine inter-sectoral collaboration mechanisms were listed by 67 countries.
	Increase technical capacities of institutes was reported to be the most important capacity need to strengthen inter-sectoral collaboration.
National networks address AqGR are present in most countries.	Seventy-seven percent of the respondents reported that the most important objective of these networks at the global level was to *improve communication on aquatic genetic resources,* however on a per country basis *to Improve capacities for characterization and monitoring of aquatic genetic resources* was the main objective.
Information systems containing AqGR at some level are present in most countries	One hundred seventy-one information systems on AqGR were listed by 64 countries.
	Major producing countries reported higher number of information systems per country than did the minor producing coutries.
	Main users of national information systems on AqGR are universities and academia, and government resource managers.
	Species names, distribution; and production data on AqGR were the types of information maintained.
	Very few information systems are focused on DNA sequences, genes and genomics and strains, breeds and stocks of aquatic genetic resources.

8.7 References and key documents

Key documents and information sources being consulted include:

- Country Reports.
- CGRFA reports (14th and 15th sessions).
- CGRFA working documents, information documents and background study papers.
- FAO Fisheries Glossary.
- Convention on Biological Diversity.

CHAPTER 9
INTERNATIONAL COLLABORATION ON AQUATIC GENETIC RESOURCES OF FARMED AQUATIC SPECIES AND THEIR WILD RELATIVES

PURPOSE: The purpose of this chapter is to review the mechanisms and instruments through which a country participates in international collaboration on aquatic genetic resources of farmed aquatic species and their wild relatives. The specific objectives are to:

- identify a country's current participation in bilateral, sub-regional, regional and global collaboration on aquatic genetic resources. Countries were requested to list their national memberships or status as a Party as well as other forms of affiliation in agreements, conventions, treaties, international organizations, international networks and international programmes;
    - identify any other forms of international collaboration on AqGR;
- review the benefits from existing international collaboration on AqGR; and
- identify needs and priorities for future international collaboration on AqGR.

KEY MESSAGES:

- Countries participate through a wide range of mechanisms and instruments relating to international collaboration on AqGR of farmed aquatic species and their wild relatives;
- The number of international agreements of relevance regarding AqGR use, conservation and management varies from 1-24 agreements per country, with a total of 169 different types of international collaboration reported;
- The impact of international agreements on sustainable use, conservation and management of AqGR has been assessed from positive to strongly positive for 85 percent of the agreements;
- All eight identified areas of collaboration were ranked as being fairly important, scoring between 2 and 3 on a scale of 1 (highest importance) to 10 (no importance). The highest priority is for improved communication and improved capacities for the conservation and economic valuation of AqGR followed by improved basic knowledge, improved capacities for characterization and monitoring, improved access and distribution of AqGR, and improved information technology and database management; and
- Regional and international collaboration can be a key driver for successful conservation, use, management and development of AqGr, as nicely demonstrated by the global and regional case studies on tilapias, common carp, Atlanti salmon and the summary of reports from international organizations documented in this chapter.

9.1 Introduction

Countries participate through a wide range of mechanisms and instruments relating to international collaboration on aquatic genetic resources of farmed aquatic species and their wild relatives. This introductory chapter lists several key international instruments which have been considered by countries as being of relevance to aquatic genetic resources use, conservation and management.

9.1.1 The Convention on Biological Diversity (CBD)

Opened for signature at the Earth Summit in Rio de Janeiro in 1992, and entering into force in December 1993, the Convention on Biological Diversity is an international treaty for the conservation of biodiversity, the sustainable use of the components of biodiversity and the equitable sharing of the benefits derived from the use of genetic resources. With 196 Parties (as of March 2018),[1] the Convention has near universal participation among countries. The Convention seeks to address all threats to biodiversity and ecosystem services, including threats from climate change, through scientific assessments, the development of tools, incentives and processes, the transfer of technologies and good practices, and the full and active involvement of relevant stakeholders including indigenous and local communities, youth, women, NGOs and the business community. The Cartagena Protocol on Biosafety and the Nagoya Protocol on Access and Benefit Sharing are supplementary agreements to the Convention. The Cartagena Protocol, which entered into force on 11 September 2003, seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern

[1] www.cbd.int/information/parties.shtml [Cited 08 March 2018].

biotechnology. To date (March 2018) 171 Parties[2] have ratified the Cartagena Protocol. The Nagoya Protocol aims at sharing the benefits arising from the utilization of genetic resources in a fair and equitable way, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies. It entered into force on 12 October 2014 and by March 2018 has been ratified by 105 Parties.[3]

9.1.2 The FAO's Code of Conduct for Responsible Fisheries (CCRF)

The FAO Committee on Fisheries (COFI) in 1991 called for the development of new concepts which would lead to responsible and sustained fisheries and aquaculture. Following significant developments in international fishing, such as, inter alia, the International Conference on Responsible Fishing in Cancun (1992, Mexico), the 1992 United Nations Conference on Environment and Development (UNCED) in Brazil, and the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks in New York, the FAO Governing Bodies recommended the formation of a global Code of Conduct for Responsible Fisheries which would be consistent with these instruments. The CCRF, in a non-mandatory manner, established principles and international standards of behavior for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity. The CCRF was unanimously adopted on 31 October 1995 by the FAO Conference and is now the cornerstone for the work of the FAO Fisheries and Aquaculture Department. Although the CCRF is non-mandatory, countries, as members of FAO, are committed to its implementation to the extent possible. Certain parts of it are based on relevant rules of international law, including those reflected in the United Nations Convention on the Law of the Sea. The CCRF also contains provisions that may be or have already been given binding effect by means of other obligatory legal instruments amongst the parties (Bartley, Marttin and Halwart, 2005).

9.1.3 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement between governments with the aim to ensure that international trade in specimens of wild animals and plants does not threaten their survival.

9.1.4 Ramsar Convention (RAMSAR)

The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It currently (February 2018) has 169 Contracting Parties and the number of Ramsar Sites is 2 299, which are distributed across the globe, with a total surface of designated sites amounting to 225 517 367 ha (Ramsar, 2018).

9.1.5 United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) has 197 Members and is the parent treaty of the 1997 Kyoto Protocol. The Kyoto Protocol has been ratified by 192 of the UNFCCC Parties (UNFCCC, 2018). The ultimate objective of both treaties is to stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system.

9.1.6 United Nations Convention on the Law of the Sea (UNCLOS)

The United Nations Convention on the Law of the Sea (UNCLOS) of 10 December 1982 is the international agreement that resulted from the third United Nations Conference on the Law of the Sea

[2] http://bch.cbd.int/protocol [Cited 08 March 2018].
[3] www.cbd.int/abs/nagoya-protocol/signatories/default.shtml [Cited 08 March 2018].

(UNCLOS III), which took place between 1973 and 1982. The Law of the Sea Convention defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. UNCLOS came into force in 1994 and has been ratified by 168 Parties.[4]

9.2 International agreements and their impacts on aquatic genetic resources and on stakeholders: overview by region, sub-region and economic class

This sections deals with the impacts of international agreements on aquatic genetic resources of both farmed aquatic species and their wild relatives, as well as on stakeholders. Countries were asked to summarize the most important international agreements to which they subscribe that cover aquatic genetic resources of farmed species and their wild relatives. Countries were also asked to assess the impact of those agreements on aquatic genetic resources and stakeholders, such as for example on:

- Establishment and management of shared or networked aquatic protected areas;
- Aquaculture and culture-based fisheries in transboundary or shared water bodies;
- Sharing aquatic genetic material and related information;
- Fishing rights, seasons and quotas;
- Conservation and sustainable use of shared water bodies and watercourses; and
- Quarantine procedures for aquatic organisms and for control and notification of aquatic diseases.

9.2.1 Participation in international fora of relevance for aquatic genetic resources

Reporting countries listed between 1 to 24 agreements with relevance to aquatic genetic resources in which they participate.

Table 9.1
Number of international agreements by country

Country	Number of international agreements	Country	Number of international agreements	Country	Number of international agreements
Algeria	8	El Salvador	8	Norway	24
Argentina	8	Estonia	1	Palau	7
Armenia	5	Fiji	1	Panama	16
Australia	11	Finland	11	Paraguay	1
Bangladesh	8	Georgia	4	Peru	8
Belgium	3	Germany	21	Philippines	12
Belize	1	Ghana	2	Romania	17
Benin	6	Guatemala	3	Samoa	2
Bhutan	4	Honduras	6	Senegal	4
Brazil	8	Hungary	3	Sierra Leone	4
Bulgaria	5	India	5	South Africa	2
Burkina Faso	7	Indonesia	6	Sri Lanka	4
Burundi	1	Iran (Islamic Republic of)	8	Sudan	6
Cabo Verde	8	Japan	3	Sweden	13
Cambodia	5	Kiribati	2	United Republic of Tanzania	6
Cameroon	3	Republic of Korea	3	Thailand	4
Canada	2	Lao People's Democratic Republic	2	Togo	6
Chad	7	Madagascar	5	Tonga	2
Colombia	10	Malawi	6	Tunisia	13
Democratic	5	Malaysia	6	Turkey	9

[4] www.un.org/Depts/los/reference_files/chronological_lists_of_ratifications.htm [Cited 08 March 2018].

Republic of the Congo					
Costa Rica	8	Mexico	7	Uganda	11
Croatia	9	Morocco	8	Ukraine	3
Cuba	6	Mozambique	3	United States of America	11
Czechia	4	Netherlands	5	Vanuatu	2
Djibouti	1	Nicaragua	4	Venezuela (Bolivarian Republic of)	3
Dominican Republic	11	Niger	3	Viet Nam	5
Ecuador	8	Nigeria	10	Zambia	11
Egypt	1				

Countries reported 169 different types of international collaboration at various regional levels and with different scope ranging from bilateral or sub-regional agreements on certain aquatic taxa to full-fledged conventions, protocols, and treaties covering all genetic resources including fish. Table 9.2 lists the most important international agreements that were reported by 92 countries. The CBD and CITES were most often cited, followed by the Nagoya Protocol, the Cartagena Protocol, the RAMSAR Convention, UNCLOS, CCRF, and UNFCCC. The Barcelona Convention and Convention on the Conservation of Migratory Species of Wild Animals (CMS) were below 10 percent or reporting countries. In the aggregate for all countries, a total of 515 agreements were counted. Seventy-eight percent of the countries reported only one international agreement of relevance to AqGR, indicating the relatively low priority this subject is still given despite the growing global importance of farmed aquatic production.

Table 9.2
The top ten important international agreements dealing with use, conservation and management of Aquatic Genetic Resources, by region

International agreements	Total countries	North America	LAC	Europe	Asia	Oceania	Africa
CBD	60	1	13	12	12	5	17
CITES	60		12	10	15	5	18
Nagoya Protocol	46		13	11	10	2	10
Cartagena protocol	40		12	7	11	1	9
Ramsar	35		9	4	8	1	13
UNCLOS	25		2	8	7	1	7
CCRF	21		2	4	5	2	8
UNFCCC	15		3	1	2		9
Barcelona Convention	6			1	1		4
CMS	6			2			4

The number of international agreements by region ranges from 13 in North America to 147 in Africa (Table 9.3), and by economic class from 115 in the ‘Least developed countries’ to 243 in the ‘Other developing countries or areas’ (Table 9.4). The number of international agreements by minor and major producers is 448 and 67, respectively (Table 9.5).

Table 9.3
Number of international agreements by region

Geographical regions	Number of international agreements	Total number of countries
Latin America and the Caribbean	116	17
North America	13	2
Europe	119	13
Asia	93	17
Africa	147	26
Oceania	27	7

Table 9.4
Number of international agreements by economic class

Economic class	Number of international agreements	Total number of countries
Developed countries or areas	157	20
Least Developed Countries	115	23
Other developing countries or areas	243	39

Table 9.5
Number of international agreements by minor/major producer

Economic class	Number of international agreements	Total number of countries
Minor producer	448	73
Major producer	67	9

The impact of international agreements on AqGR has generally been assessed from positive to strongly positive for a total of 399 agreements, 67 agreements have been considered as having "no effect" and three agreements have been reported as having a "negative impact" (Table 9.6).

Table 9.6
Impact of international agreements on aquatic genetic resources, presented as number of responses per country

Impact on aquatic genetic resources	Number of agreements	Country (Number of agreements having impact)
Strongly positive	87	Argentina (1); Benin (6); Burkina Faso (5); Cambodia (2); Costa Rica (7); Cuba (1); Czechia (1); Djibouti (1); Dominican Republic (2); Guatemala (3); India (1); Japan (3); Republic of Korea (1); Lao People's Democratic Republic (1); Malawi (1); Malaysia (3); Mexico (7); Nicaragua (1); Niger (1); Paraguay (1); Peru (6); Philippines (12); Senegal (1); Sierra Leone (2); Sweden (2); United Republic of Tanzania (4); Togo (1); Tunisia (3); Turkey (1); Uganda (5); Viet Nam (1)
Positive	312	Algeria (6); Argentina (7); Australia (3); Bangladesh (7); Belgium (3); Bulgaria (3); Burkina Faso (2); Burundi (1); Cabo Verde (1); Cambodia (3); Cameroon (1); Canada (2); Chad (7); Colombia (10); Democratic Republic of the Congo (5); Costa Rica (1); Croatia (4); Cuba (5); Czechia (2); Dominican Republic (8); Ecuador (8); Egypt (1); El Salvador (8); Finland (9); Germany (18); Ghana (2); Honduras (6); India (4); Indonesia (6); Iran (Islamic Republic of) (6); Kiribati (2); Republic of Korea (2); Lao People's Democratic Republic (1); Madagascar (3); Malawi (5); Malaysia (3); Morocco (8); Mozambique (3); Netherlands (5); Nicaragua (2); Niger (2); Nigeria (5); Norway (22); Palau (7); Panama (15); Peru (2); Romania (6); Samoa (2); Senegal (3); Sierra Leone (2); South Africa (2); Sri Lanka (4); Sudan (6); Sweden (1); United Republic of Tanzania (2); Thailand (4); Togo (3); Tonga (2); Tunisia (8); Uganda (6); Ukraine (3); United States of America (7); Vanuatu (2); Viet Nam (4); Zambia (9)
No effect	67	Armenia (1); Australia (8); Bhutan (4); Brazil (8); Bulgaria (2); Croatia (1); Czechia (1); Dominican Republic (1); Estonia (1); Fiji (1); Finland (2); Georgia (4); Germany (2); Hungary (3); Iran (Islamic Republic of) (1); Madagascar (1); Nicaragua (1); Norway (2); Romania (11); Togo (2); Tunisia (2); United States of America (4); Venezuela (Bolivarian Republic of) (2); Zambia (2)
Negative	3	Bangladesh (1); Cameroon (2)

A presentation by geographical region confirms that in all regions the impact of international agreements on aquatic genetic resources has been considered to be either positive or strongly positive. Europe followed by Latin America and the Caribbean, Asia and then Africa has the highest number of international agreements where "no effect" predominates (Table 9.7). Three international agreements were considered to have a negative impact.

Table 9.7
Impact of international agreements on aquatic genetic resources by geographical region (number of responses)

Geographical region	Impact on aquatic genetic resources			
	Strongly positive	Positive	No effect	Negative
Latin America and the Caribbean	29	72	12	
North America		9	4	
Europe	3	76	25	
Asia	25	44	10	1
Africa	30	93	7	2
Oceania		18	9	
TOTAL	**87**	**312**	**67**	**3**

9.2.2 International collaboration – needs assessment: overview by region, sub-region and economic class

This section focuses on the needs for international collaboration as assessed by reporting countries. All areas of collaboration were ranked as being fairly important, with collaboration for improved information technology and database management, basic knowledge on AqGR, and improved capacities for characterization and monitoring, genetic improvement and conservation purposes scoring slightly higher.

When analyzing the data according to the extent to which the assessed need is not met or is only partially met, the highest priority is for improved communication and improved capacities for the conservation and economic valuation of AqGR followed by improved basic knowledge, improved capacities for characterization and monitoring, improved access and distribution of AqGR, and improved information technology and database management (Table 9.8).

Table 9.8
Average rank and extent to which the assessed need is not/partially met for international collaboration needs regarding aquatic genetic resources sustainable use, conservation and management

Assessed need for collaboration	Average rank*	Extent to which the assessed need is met**
Improve information technology and database management	2	61
Improve basic knowledge on aquatic genetic resources	2	79
Improve capacities for characterization and monitoring of aquatic genetic resources	2	76
Improve capacities for genetic improvement	2	74
Improve capacities for economic valuation of aquatic genetic resources	3	80
Improve capacities for conservation of aquatic genetic resources	2	82
Improve communication on aquatic genetic resources	3	84
Improve access and distribution of aquatic genetic sources	3	74

**A score of 1 is very important, a score of 10 indicates no importance*
***calculated as the percent of countries reporting "not met" or "only met to some extent"*

The information from Country Reports was also analyzed at the regional level for the five assessed needs given a higher priority by the respondents (Tables 9.9 to 9.13). In all cases, Africa represents the region with the highest number of countries where collaboration needs are not met.

Table 9.9
Extent to which the needs for international collaboration regarding improved information technology and database management are met

Response	Africa	Asia	LAC	Europe	North America	Oceania	Grand Total
To a great extent	3	5	5	3	1		17
To some extent	10	8	9	8	1	7	43
None	9	4	2	3			18
Unknown	3		2	2			7
Grand Total	**25**	**17**	**18**	**16**	**2**	**7**	**85**

Table 9.10
Extent to which the needs for international collaboration regarding improved basic knowledge on aquatic genetic resources are met

Response	Africa	Asia	LAC	Europe	North America	Oceania	Grand Total
To a great extent	4	3	3	4	1		15
To some extent	15	12	15	8	1	7	58
None	4	3		2			9
Unknown	2			1			3
Grand Total	**25**	**18**	**18**	**15**	**2**	**7**	**85**

Table 9.11
Extent to which the needs for international collaboration regarding improved capacities for characterization and monitoring of aquatic genetic resources are met

Response	Africa	Asia	LAC	Europe	North America	Oceania	Grand Total
To a great extent	3	6	1	1	1	1	13
To some extent	13	6	15	9	1	5	49
None	7	4	1	2		1	15
Unknown	2	1	1	3			7
Grand Total	**25**	**17**	**18**	**15**	**2**	**7**	**84**

Table 9.12
Extent to which the needs for international collaboration regarding improved capacities for genetic improvement are met

Response	Africa	Asia	LAC	Europe	North America	Oceania	Grand Total
To a great extent	4	4	3	1		1	13
To some extent	10	8	12	8	2	3	43
None	7	4	2	3			16
Unknown	3		1	3			7
Grand Total	**24**	**16**	**18**	**15**	**2**	**4**	**79**

Table 9.13
Extent to which the needs for international collaboration regarding improved capacities for conservation of aquatic genetic resources are met

Response	Africa	Asia	LAC	Europe	North America	Oceania	Grand Total
To a great extent	2	4	1	2	1		10
To some extent	19	10	12	10	1	7	59
None	3	2	2	1			8
Unknown		1	1	3			5
Grand Total	**24**	**17**	**16**	**16**	**2**	**7**	**82**

9.3 Selected successful examples of international collaboration

The last section of this chapter presents some successful examples of international collaboration. The story of the collaborative development and international dissemination of tilapia is presented in Box 9.1. An excellent example of international collaboration regarding common carp genetic resources has been provided by the “HAKI-live gene bank of common carp” from Hungary (Box 9.2).

The cooperative approach to conservation of sturgeon in the Danube as presented in Chapter 5 provides a very good example both of international cooperation as well as of the integration of *in situ* and *ex situ* conservation (Box 9.3).

Similarly, the regional cooperation of bordering countries of the River Rhine for the reintroduction of migratory species and the successful return of Atlantic salmon into the river basin demonstrates the important role of targeted international cooperation (Box 9.4).

As part of the preparation of the SoW AqGR, FAO requested feedback from international organizations working with AqGR in a development context. The main issues prioritized by one or more of these organizations in regional cooperation included (i) capacity building for breed improvement, especially of indigenous species, (ii) improving information on AqGR, (iii) *in situ* conservation, (iv) knowledge development on diverse locally-developed aquaculture breeds, (v) capacity building on mechanisms for biosecure exchange of aquaculture genetic material, and (vi) policy development.

Box 9.1

The case of the two Tilapias

Tilapia is one of the most globally ubiquitous species for aquaculture, with production having been reported in over 140 countries around with world with current world production at nearly 1.8 million tonnes. Tilapias are a species complex made up of three genera *Oreochromis, Sarotherodon and Tilapia* (Trewavas, 1983) with the maternal mouthbrooding genus *Oreochromis* dominating aquaculture production. Two species have predominated, the Nile tilapia (*O. niloticus*) and the Mozambique tilapia (*O. mossambicus*). There are contrasting histories in distribution of these species around the world, which demonstrates the value of effective management of genetic resources for aquaculture.

The first species for which potential in aquaculture was realised was *O. mossambicus,* which originates from the southeast Africa. The first record of this species outside its natural range was the identification of five individuals in Indonesia in the 1930s. Subsequent generations of their progeny were transferred to other countries in Southeast Asia (Agustin, 1999). Fishbase (Froese and Pauly, 2018) currently records the introduction of this species to 93 countries. It was adopted for aquaculture in many of these countries and also formed feral populations. Genetic analysis of some feral populations around Asia and Oceania (Agustin, 1999) revealed low levels of genetic variation compared to reference native populations, consistent with one or more significant genetic bottlenecks. It is thus quite feasible that a large proportion of the global population for this species, outside of its natural range, may have been derived from this small founder population in Indonesia. *O. mossambicus* is now rarely cultured outside its natural range (with small scale production reported from just 14 countries in which it is non native). It is widely considered to be an inferior culture species compared to *O. niloticus*, exhibiting slower growth rates, precocious reproduction and a tendency to stunting. These properties may well be a result of inbreeding depressing resulting from genetic bottleneck effects. *O. mossambicus* has now been largely displaced by *O. niloticus* in aquaculture, although remnant feral populations are commonplace in countries to which it was introduced.

Pullin and Capili (1988) report that the initial distribution of *O. niloticus* had a broader base that than outlined for *O. mossambicus,* with multiple source populations. In the past two decades, the GIFT (Genetic Improvement of Farmed Tilapia) project has played an important and proactive role in the distribution of Nile tilapia. The GIFT project was an international collaboration to improve the genetic performance of farmed Nile tilapia, implemented from 1988-98 (Gjedrem, 2012). This project demonstrates what can be achieved through a systematic and collaborative approach to collection, development and distribution of germplasm for aquaculture. Under this project source stock was collected from native and introduced stock and used to create a mixed synthetic strain based on data on the performance of these founder stocks. Subsequent genetic selection for commercial traits over multiple generations produced significant enhancement of culture performance. The GIFT tilapia and

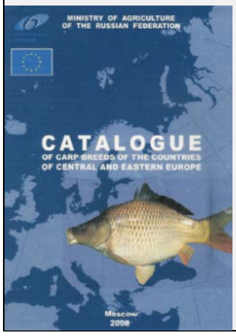
GIFT derived strains have been introduced into many countries, through both public and private sectors. In many cases selective breeding of the strain was continued in the receiving country. This systematic approach would not only have avoided the negative impacts of inbreeding or poor genetic management but also resulted in superior performance in many aquaculture stocks as a result of maintenance of high levels of genetic variation and genetic selection for important traits.

The development and widespread introduction of the GIFT tilapia has undoubtedly had a major impact on the prioritization and expansion of the culture of this species globally. Nile tilapia is now reported as being cultured in 87 countries and through the SoW AqGR reporting process seven countries recorded production of GIFT tilapia but it is likely that GIFT derived strains are impacting production in many more.

Box 9.2

Regional cooperation in carp gene banking

As described in Chapter 5, the "HAKI-live gene bank of common carp" was established through intensive international collaboration worldwide. The foreign carp strains were introduced mainly from Central and Eastern Europe, including the Soviet Union, but also from South-East Asia including Thailand and Viet Nam (Bakos and Gorda, 2001). Upon completing the collection, it became a supporting genetic resource of common carp for the region and globally. Requests for the high quality genetic material held in the gene bank came from all around the world and HAKI was able to satisfy these requests according to regulations (translocation and biosecurity) but being dependent on financial resources. Often these translocations took place under the auspices of R&D projects including introductions to India (Basavaraju, Penman and Mair, 2004) and Viet Nam (Phuong et al., 2002). After the deep socio-economic changes in Central and Eastern Europe, most of the well-established carp genetic programmes and gene banks collapsed. As a result, there is currently a growing demand for high quality strains of common carp. The Eurocarp project (http://eurocarp.haki.hu/index.php), led by HAKI and focussed on the development of disease and stress resistant carp using a range of molecular approaches, is an example of a multinational research collaboration (supported by the EU) utilizing the genetic diversity of carp in the HAKI gene bank. One output of the Eurocarp project is an inventory list of existing genetic resources of common carp in Central and Eastern Europe, a bilingual catalogue of strains identifying 60 national and 25 introduced strains in seven major carp producing countries in Europe (Bogeruk, 2008).



There are also a number of restocking programs using appropriate resources of the HAKI-gene bank (e.g. after the Tisza river pollution in Hungary, as well as after the loss of local strains due to the war in Croatia).

In conclusion, it is evident that the common carp gene bank of HAKI, originally developed using state funding, has played an important role in the management of carp genetic resources in the region and globally.

Box 9.3

Key issues for international cooperation

In the preparation of this report, FAO requested feedback from international organizations* working with AqGR in a development context. Part of the feedback covered the issues around AqGR that are being prioritized by one or more of these organizations in regional cooperation:

- Capacity building for breed improvement, especially of indigenous species (including R&D, post graduate training and extension) to ensure quality broodstock and seed and minimize hybridization or poor genetic management that might threaten biodiversity and production. This includes programs for small farms and community based programs.

- Improving information on AqGR through techniques of molecular characterization including genetic mapping but also capacity building on techniques for cost effective monitoring of genetic status of farmed types and simple techniques for verifiable certification of broodstock origin and purity.
- *In situ* conservation through designation of specific gene pools, genetic mapping and establishment of protected areas which should be well demarcated and monitored.
- Knowledge development on diverse locally-developed aquaculture breeds.
- Capacity building on mechanisms for biosecure exchange of aquaculture genetic material including support for aquaculture broodstock exchange networks such as those that are successful and economically self-sustaining in terrestrial domesticated animals.
- Policy development for effective conservation and management of AqGR.

The aforementioned are issues directly impacting on AqGR but regional cooperation also dealt with issues that indirectly impact AqGR such as: transboundary issues of aquaculture; community based aquaculture management; promotion of regional and international collaboration; collection and compilation of aquaculture related data; dissemination of scientific information on sustainable aquaculture and food safety; and understanding of gender and entrepreneurship issues in aquaculture.

*Respondents included the Network of Aquaculture Centres in Asia-Pacific (NACA), Worldfish Centre (WFC), Pacific Community (SPC), Lake Victoria Fisheries Organization (LVFO), Mekong River Commission (MRC), and the Southeast Asian Fisheries Development Centre (Aquaculture Center).

Box 9.4

Migratory species of the Rhine River – a successful example of regional cooperation

By the end of the nineteenth century there were still hundreds of thousands of Atlantic salmon (*Salmo salar*) in the River Rhine, annually migrating upstream to their spawning grounds. Historical data indicates a catch of almost 250 000 salmon in 1885. After that peak, the catches declined, until the complete extinction of the Rhine salmon in the 1950s. This extinction is closely correlated with the construction of obstacles to migration although there were other contributory factors including deterioration of water quality and overexploitation of the remaining stocks.

When starting an ambitious program for the ecological rehabilitation of the Rhine in 1987, the Member States of the International Commission for the Protection of the Rhine (ICPR)[34] agreed that migratory fish species, such as the Atlantic salmon, should again colonize the river and its tributaries. To achieve this goal, measures were taken to improve water quality and river continuity and a restocking program was initiated in several areas of the Rhine basin.

The ICPR – with headquarters in Koblenz, Germany, coordinates the ecological rehabilitation programme and involves all countries in the catchment of the river Rhine. The Convention on the Protection of the Rhine[35] is the legal basis for international cooperation for the protection of the Rhine within the ICPR. It was signed on 12 April 1999 by representatives of the governments of the Rhine bordering countries of France, Germany, Luxembourg, the Netherlands, Switzerland and the European Community. These countries thus formally confirmed to continue to protect the valuable character of the River Rhine, its banks and floodplains, through increased cooperation.

[34] www.iksr.org

[35] www.iksr.org/fileadmin/user_upload/Dokumente_en/Convention_on_the_Protection_of_the_Rhine_12.04.99-EN_01.pdf

One of the issues in the ICPR is ecological river restoration, for which the Atlantic salmon has become a key species, since the introduction of the "Salmon 2000" programme in 1987. Today, the 'Master Plan Migratory Fish Rhine' (ICPR, 2009) acts as a demonstration of how self-sustaining, stable populations of migratory fish can be reintroduced to the Rhine catchment within a reasonable period of time and at reasonable cost. On 18 October 2007, the Conference of Rhine Ministers confirmed its intent to gradually restore river continuity in the Rhine as far as Basel. Atlantic salmon is representative of other long-distance migratory fish species, such as sea trout (*Salmo trutta trutta*), sea lamprey (*Petromyzon marinus*), allice shad (*Alosa alosa*), and European Eel (*Anguilla anguilla*). Measures aimed at reintroducing salmon and sea trout will likely have positive effects on the incidence of many more animal and plant species and on the entire ecology of the Rhine.

Since 1990 more than 8 000 adult salmon have been registered within the catchment and natural reproduction has been regularly recorded in an increasing number of accessible tributaries of the River Rhine. The successful return of Atlantic salmon into the River Rhine demonstrates that it is possible to reintroduce regional extinct migratory fish species, and targeted international cooperation has played a key role in this.

ICPR 2009. Master Plan Migratory Fish Rhine. Report no. 179. Also available at: www.iksr.org/uploads/media/179_e.pdf

9.4 Key findings and conclusions

- Countries participate through a wide range of mechanisms and instruments relating to international collaboration on AqGR of farmed aquatic species and their wild relatives.
- The number of international agreements of relevance regarding AqGR use, conservation and management varies from 1-24 agreements per country, with a total of 169 different types of international collaboration reported;
- The impact of international agreements on sustainable use, conservation and management of AqGR has been assessed from positive to strongly positive for 85 percent of the agreements;
- All eight identified areas of collaboration were ranked as being fairly important, scoring between 2 and 3 on a scale of 1 (highest importance) to 10 (no importance). The highest priority is for improved communication and improved capacities for the conservation and economic valuation of AqGR followed by improved basic knowledge, improved capacities for characterization and monitoring, improved access and distribution of AqGR, and improved information technology and database management;
- Regional and international collaboration can be a key driver for successful conservation, use, management and development of AqGr, as nicely demonstrated by the global and regional case studies on tilapias and common carp and the summary of reports from international organizations documented in this chapter.

9.5 References

Key documents and information sources that were consulted in the preparation for this Chapter include Country Reports, CGRFA reports, CGRFA working documents, information documents and background study papers.

Agustin, L.Q. 1999. *Effects of population bottlenecks of levels of genetic diversity and patterns of differentiation in feral populations of Oreochromis mossambicus*. Doctoral dissertation. Queensland University of Technology.

Bakos, J. & Gorda, S. 2001. *Genetic Resources of Common Carp at the Fish Culture Research Institute Szarvas, Hungary*. FAO Fisheries Technical Paper 417. Rome, FAO. 106 pp. www.fao.org/docrep/005/Y2406E/Y2406E00.HTM

Bartley, D.M., Marttin, F.J.B. & Halwart, M. 2005. *FAO mechanisms for the control and responsible use of alien species in fisheries*. In Bartley, D.M.; Bhujel, R.C.; Funge-Smith, S.; Olin, P.G.; Phillips, M.J. (comps./eds.) *International mechanisms for the control and responsible use of alien* *species in aquatic ecosystems*. Report of an Ad Hoc Expert Consultation. Xishuangbanna, People's Republic of China, 27–30 August 2003. Rome, FAO. 2005. 195p. Also available at: www.fao.org/docrep/009/a0113e/A0113E02.htm#ch2.1.1

Basavaraju, Y., Penman, D.J. & Mair, G.C. 2003. *Stock evaluation and development of a breeding program for common carp (Cyprinus carpio) in Karnataka, India: progress of a research project*. NAGA, WorldFish Center. Quarterly Vol. 26 No. 2. pp. 30–32.

Bogeruk, A.K. Editor. 2008. *Catalogue of carp breeds of the countries of Central and Eastern Europe*. Moscow. 354 pp. In English and in Russian.

Froese, R. & Pauly, D. Editors. 2018. *FishBase*. World Wide Web electronic publication. [Cited February 2018]. Also Available at: www.fishbase.org

Gjedrem, T. 2012. *Genetic improvement for the development of efficient global aquaculture: a personal opinion review*. Aquaculture, Volumes 344–349. pp.12–22.

International Commission for the Protection of the Rhine (ICPR). 2009. *Master Plan Migratory Fish Rhine*. International Commission for the Protection of the Rhine. Koblenz, Germany. Report No. 179. 32 pp. Also available at: www.iksr.org/fileadmin/user_upload/Dokumente_en/Reports/179_e.pdf

Phuong, N.T, Long, D.N., Varadi, L., Jeney, Z. & Pekar, F. eds. Edwards, P., Little, D. & Demaine, H. 2002: *Farmer-managed trials and extension of rural aquaculture in the Mekong Delta, Vietnam*. In: Rural aquaculture. pp. 275–284.

Pullin, R.S.V. & Capili, J.B. 1988. *Genetic improvement of tilapias: problems and prospects*. pp. 259–266. In Pullin R.S.V., Bhukaswan, T., Tonguthai, K. & Maclean J.L. eds. The Second International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 15. Department of Fisheries, Bangkok, Thailand, and ICLARM, Manila, the Philippines.

RAMSAR. 2018. *The list of Wetlands of International Importance*. Ramsar (Iran), The Secretariat of the Convention on Wetlands of international importance. pp. 57. [Cited 27 February 2018]. Also available at: www.ramsar.org/sites/default/files/documents/library/sitelist.pdf

Trewavas, E. 1983. *Tilapiine fishes of the genera Sarotherodon, Oreochromis and Danakilia*. British Museum (Natural History): no. 878.

UNFCCC. 2018. *Status of Ratification of the Kyoto Protocol*. In: UNFCCC [online]. [Cited 08 March 2018]. Also available at: http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php

CHAPTER 10

SYNTHESIS OF KEY FINDINGS AND CONCLUSIONS

This Chapter will synthesize the key findings and conclusions from chapters 1 to 9.