Food and Agriculture Organization of the United Nations

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

DRAFT

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

This document is based on a commissioned study prepared by Devin M. Bartley and Xiaowei Zhou in support of the State of the World on Aquatic Genetic Resources for Food and Agriculture to facilitate the Commission’s deliberations when it will review the agenda item on Aquatic Genetic Resources at its Sixteenth Regular Session.

The content of this document is entirely the responsibility of the authors, and does not necessarily represent the views of the FAO or its Members.

This draft is being made available as an *Advance Copy* for comments and feedback.

January 2017

TABLE OF CONTENTS

List of tables

ACKNOWLEDGEMENTS

We gratefully acknowledge the participants of the Food and Agriculture Organization of the United Nations (FAO) Expert Workshop on Incorporating Genetic Diversity and Indicators into Statistics and Monitoring of Farmed Aquatic Species and Their Wild Relatives for their technical contributions to this document and the funding support to D. M. Bartley from the Government of Germany.

ABBREVIATIONS AND ACRONYMS

AqGR	aquatic genetic resources
AQUAGRIS	aquatic genetic resources information
ASFIS	Aquatic Sciences and Fisheries Information System
CBD	Convention on Biological Diversity
CGIAR	Consultative Group on International Agricultural Research
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
the Commission	FAO Commission on Genetic Resources for Food and Agriculture
DAD-IS	Domestic Animal Diversity Information System
ISCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
ISSCFC	International Standard Statistical Classification of Fisheries Commodities
IUCN	International Union for Conservation of Nature and Natural Resources
SOFIA	State of World Fisheries and Aquaculture
SoW AqGR	State of the World's Aquatic Genetic Resources for Food and Agriculture
SPF	Specific pathogen free
SPR	Specific pathogen resistant
UPOV	International Union for the Protection of New Varieties of Plants

EXECUTIVE SUMMARY

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 incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives.

Information about aquatic genetic resources can be extremely useful to resource managers, policy-makers, private industry and the general public. Not only is genetic diversity the basic building block for selective breeding programmes in aquaculture and for natural populations to adapt to changing environments and evolve, but information on genetic diversity can also 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 submitting information to FAO do not use or have sufficient access to information on aquatic genetic diversity 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 reporting this production is the Aquatic Sciences and Fisheries Information System (ASFIS) list and the classification system of the International Standard Statistical Classification of Aquatic Animals and Plants (ISCAAP). The International Standard Statistical Classification of Fisheries Commodities (ISSCFC) does not include taxa below the species level and does not include any hybrid taxa. To date, the ASFIS list nomenclature includes only eleven taxa below the species level, i.e. interspecies hybrids (see Table 6, section 6). The nomenclature does not include any subspecies, stocks, strains or varieties of farmed species or their wild relatives. FAO as the developer and curator of the ASFIS nomenclature is reluctant to add additional items to the list unless it can be shown that the new taxon, i.e. new hybrid or species, would be reported in a reliable and consistent manner by the Members of FAO. There is no mechanism within the structure of the ASFIS list to include strains, stocks or subspecies.

An examination of the literature, discussions with experts, scientists, industry and farmers, and some of the country reports submitted for the production of the first *State of the World's Aquatic Genetic Resources for Food and Agriculture* revealed several more hybrids and numerous stocks and strains of farmed species and their wild relatives that are contributing to global fishery production. These additional species for which documented genetic diversity exists include, *inter alia,* tilapias, snakehead, groupers, barbs, sturgeon, common carp and catfishes. For some natural populations, genetic differentiation has been acknowledged by declaring them subspecies, e.g. cut-throat trout in North America, common carp in Asia and Eastern Europe, and Nile tilapia in Africa. However, this diversity is seldom if ever reported to FAO.

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 or strains of most species is a much more recent practice, and thus the nomenclature and characterization of breeds is not standardized. Stock designation 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. 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, the availability of which is limited for many species. The high financial and technical requirements for using genetic diversity for fishery management render this option beyond the capacity of many areas.

The lack of a standardized description of a "strain" or "stock" constrains the use of information below the species level in national and global reporting. Further constraining the use of genetic diversity is the lack of complete baseline data that genetically characterize a strain or stock, and the fact that the private aquaculture industry often views genetic information on the product as proprietary. Any database or information system would need to be able to categorize information in a standard and consistent manner. In spite of the above constraints, options do exist for incorporating genetic diversity into statistics and monitoring programmes and include:

- regular reporting by national resource managers using ASFIS after the standard and consistent nomenclature has been established and agreed upon;
- semi-regular reporting, e.g. every two to four years, by national resource managers or groups of experts (with or without modifying the ASFIS list);
- reporting on a limited number of commercially important species as case studies in order to establish nomenclature and reporting standards;
- 10-year reporting through the State of the World's Aquatic Genetic Resources for Food and Agriculture process and coordinated by national focal points on aquatic genetic resources from FAO Members; and
- ad hoc listing of strains and/or stocks of important species.

These options all entail increased resources and capacity, as well as the participation and cooperation of private industry. As a result, some options may not be practical or cost-effective in many areas. A plausible first step could be the establishment of a standard nomenclature for strains or stocks of key aquatic species, and then creating an inventory of important strains and stocks of aquatic species.

Once clear designations of what level of genetic diversity will be monitored and reported, appropriate production, conservation and biodiversity indicators can be developed and agreed upon. At present, the main indicator of the state of genetic diversity of a breed or stock is the number of individuals. In general, genetic diversity is directly related to population size. Other indicators at the genetic level include the level of heterozygosity, allelic diversity, rate of gene flow, inbreeding coefficient, and effective population size. These indicators have been used in specific cases involving important high-value or endangered species.

In light of the need to efficiently feed a growing human population, national resource managers and the public 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. This will involve increased resources and capacity building in many areas of the world.

1. INTRODUCTION

The FAO Commission on Genetic Resources for Food and Agriculture (the Commission) recognized the importance and vulnerability of aquatic genetic resources, their roles in an ecosystem approach for food and agriculture, and their contributions to meeting the challenges presented by climate change. The Commission agreed that its Multi-year Programme of Work would cover aquatic genetic resources for the development of sustainable and responsible fisheries and aquaculture.[1]

Further realizing that substantial production from aquaculture and capture fisheries is based on groups below the level of the species (infraspecific) and that genetic information has a variety of uses in fishery management (Bartley, Harvey and Pullin, 2007), the Commission requested FAO to undertake a thematic study to explore incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives.[2]

Regular reporting and monitoring of fishery and aquaculture production using genetic information, i.e. using information on stocks, breeds, monosex groups, polyploids, products of modern biotechnology and hybrids, would allow aquaculturists to assess which breeds or strains could be most useful for production, and help fishery managers better manage and trace products from capture fisheries. Genetic information would be useful to both aquaculturists and fishery managers in assessing which stocks were under threat or endangered and in traceability requirements for the origin and handling of aquatic food products. However, the capacity and information requirements for incorporating genetic information into national and global statistics is significant and, in many cases, currently prohibitive.

A key source of information for this paper was the reports currently being submitted to the FAO Fisheries and Aquaculture Department by countries as part of the process to produce the first *State of the World's Aquatic Genetic Resources for Food and Agriculture* (SoW AqGR). Through this country-driven process, FAO is receiving information on stocks, varieties, strains and other farmed types that are currently being used in aquaculture and fisheries or that are being actively researched for future use. The country reports will further attempt to include relevant policies and constraints relating to the collection and monitoring of genetic data.

This paper will review current statistical reporting and monitoring activities and explore possible options and strategies to consider in order to incorporate genetic data into national and FAO official statistics and monitoring. Once key statistics are delineated, indicators can be developed. Key constraints for national governments, private industry and FAO will be discussed and general conclusions will be presented. A summary of this paper served as a background document for an international workshop (FAO, 2016a) and specific guidance recommendations from that workshop are included in this paper.

2. GENETIC INFORMATION IN FISHERIES AND AQUACULTURE

Using genetic diversity and indicators to assess and monitor farmed aquatic species and their wild relatives presents special problems for resource managers and statisticians. The status of marine fisheries (FAO, 2014) is based on in-depth analysis by selected experts on over 400 marine commercial fish stocks. There is no comparable mechanism to assess and monitor the status of aquaculture stocks or inland capture fisheries. For terrestrial plants and animals, there are well-established breeds and varieties that have been domesticated for millennia and are well recognized by farmers and resource managers (see, for example, FAO, 2007). Given the facts that breeding and domestication in aquaculture have only been widely practised for only a few decades (Duarte, Marbà and Holmer, 2007) and inland capture fisheries are poorly monitored and often not reported even at the level of the species (Bartley *et al.*,

[1] CGRFA-11/07/Report, paragraph 58 (www.rfp-europe.org/fileadmin/SITE_ERFP/FAO/CGRFA_11_2007_Report.pdf).
[2] CGRFA-15/15 Report (http://www.fao.org/fileadmin/templates/nr/documents/CGRFA/CGRFA-15-15-REP.PDF); CGRFA-15/15/17, Appendix 1 (www.fao.org/3/a-mm170e.pdf).

2015), the use of genetic data in national fishery and aquaculture management is uncommon at the global level.

Genetic information, especially at the subspecific level, e.g. stocks and strains, is not commonly used in fishery and aquaculture management, although there are exceptions for high-value species, e.g. salmon. For some natural populations, genetic differentiation has been acknowledged by declaring them subspecies. Subspecies of cut-throat trout in the Great Basin of North America (Benhke, 2002) have been recognized and managed as such. Nielsen *et al*. (1998) reported a new subspecies of rainbow trout (*Oncorhynchus mykiss*) trout from the Rio Yaqui, Mexico. Seven subspecies of Nile tilapia from different environments in Aftrica were reported by Trewavas (1983). In aquaculture, strains of certain commercially important species have been recognized, for example, the strains of carp maintained in Hungary (Bakos and Gorda, 2001) and India (Reddy, 1999).

For genetic diversity information to be useful in fisheries and aquaculture management, baseline information is needed. Stocks and strains must be characterized phenotypically, e.g. colour, body shape and scale pattern, but also genotypically, e.g. the DNA, genes, sequences or gene products that can identify a particular species, stock or strain regardless of its environment. This baseline information is available at the species level for most commercially important aquatic species; at the level of stock or strain, the baseline exists for relatively few species that are usually of high value and in developed countries.

Table 1: Uses of information on aquatic genetic resources in conservation, fisheries and aquaculture

Aquaculture	
	Identify organisms for selective breeding programmes
	Monitor inbreeding and genetic diversity in farmed groups
	Select and manage broodstock in culture-based fisheries
	Design breeding programmes in conservation hatcheries
	Establish breed registry
	Create specific pathogen resistance strains
	Identify useful genes or markers for breeding programmes
	Improve traceability of farmed species and products
Fisheries	
	Identify stocks of aquatic species
	Identify cryptic species
	Manage fisheries
	Assess introgression with farmed or introduced species
	Improve traceability of species and products from capture fisheries
	Improve conservation
	Assess genetic viability
	Identify alien or invasive species
	Determine effective population size
	Monitor inbreeding
	Identify compatible species or stocks for population recovery programmes
Conservation	
	Monitor genetic viability
	Identify alien species
	Monitor effective population size
	Monitor inbreeding
	Identify compatible species or stocks for population recovery programmes
	Identify cryptic species

Genetic information from individuals, species, populations and communities has numerous applications in fisheries and aquaculture (Table 1). For aquaculturists, genetic diversity is the basic building block for selective breeding programmes and allows fish farmers to help meet production and consumer demands, as well as to help adapt to climate change (Pullin and White, 2011); capture fishery managers are using the genetic profile of fish stocks to help set fishery policy on catch, season and trade (Martinsohn *et al*., 2011) and to combat illegal fishing (Martinsohn and Ogden, 2009). Genetic information at the species level is being used in trade and consumer protection where fish are purposefully mislabelled to avoid trade barriers or to command a higher price in the market (Martinsohn and Ogden, 2009). With the growing importance of aquaculture and the need to distinguish between farmed species and those in nature, genetic information can help distinguish farmed fish from wild fish of the same species (Martinsohn and Ogden, 2009). Recently, environmental DNA (eDNA) is emerging as a tool to assess a given species' presence or absence in a particular habitat. For example, eDNA is providing information on the extent of the invasiveness of non-native species of carp in the drainages of the North American Great Lakes (Jerde *et al*., 2013).

3. THE PROBLEM OF NOMENCLATURE IN AN INFORMATION SYSTEM: WHAT IS A BREED, STRAIN, CULTIVAR OR VARIETY?

Any information system must have a standard and accepted format for entering data. In fisheries and aquaculture, there is a lack of standardization regarding terminology below the species level.

In terrestrial agriculture, designations below the species level have been used for millennia. A breed is a specific group of domestic animals having homogeneous appearance (phenotype), homogeneous behaviour, and/or other characteristics that distinguish it from other organisms of the same species and that were arrived at through selective breeding. Despite the centrality of the idea of "breeds" to animal husbandry and agriculture, no single, scientifically accepted definition of the term exists (FAO, 2007). "A breed is therefore not an objective or biologically verifiable classification, but is instead a term of art amongst groups of breeders who share a consensus around what qualities make some members of a given species members of a nameable subset" (Lush, 1994).

In the plant sector, a cultivar is a plant or grouping of plants selected for desirable characteristics that can be maintained by propagation. The International Union for the Protection of New Varieties of Plants (UPOV) offers legal protection of plant cultivars to people or organizations who introduce new cultivars to commerce. This legal protection is usually in the form of plant breeders' rights. UPOV requires that a cultivar be distinct, uniform and stable. To be distinct, it must have characteristics that easily distinguish it from any other known cultivar. To be uniform and stable, the cultivar must retain these characteristics under repeated propagation.

For plant breeders' rights to be granted, the UPOV states that the new variety must meet four criteria:

(i) The new plant must be novel, which means that it must not have been previously marketed in the country where rights are applied for.
(ii) The new plant must be distinct from other available varieties.
(iii) The plant must display homogeneity.
(iv) The trait or traits unique to the new variety must be stable so that the plant remains true to type after repeated cycles of propagation.

The aquatic sector has no such system of nomenclature or protection for strains developed in aquaculture. The private industry has trademarked and promoted particularly successful strains or hybrids to help sales. For example, there are recognized strains of common carp that consumers prefer and that perform well under farm conditions (Bakos and Gorda, 2001); there are strains of tilapia that have desirable colour patterns, e.g. cherry snapper (in reality, a tilapia: www.ilovetilapia.com), as well as good growth characters (e.g. the genetically improved farmed tilapia, see ADB, 2005). Strains with specific disease resistance have been developed for the shrimp industry under the title of specific pathogen free (SPF) and specific pathogen resistant (SPR) shrimp (Briggs *et al*., 2005). The SPR strains have the genetic basis for pathogen resistance, whereas the SPF strain merely has not been exposed to the pathogen.

The terminology in Table 2 has been adopted for the SoW AqGR and is based in part on terminology from the terrestrial sector. For the SoW AqGR, “strain” will be used for farm types of aquatic organisms below the species level (similar to breed or cultivar) and “stock” will refer to groups in the wild.

Table 2: Nomenclature to designate genetic diversity*

Term	**Definition**
Breed	A specific group of domestic animals having homogeneous appearance and behaviour, and/or other characteristics that distinguish it from other organisms of the same species.
Cultivar or variety	A plant or grouping of 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 species, hybrid, triploid, monosex group, other genetically altered form, variety or strain.
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.

*As suggested by the Expert Workshop on Incorporating Genetic Diversity and Indicators into Statistics and Monitoring of Farmed Aquatic Species and Their Wild Relatives (FAO, 2016a).

4. GENETIC DIVERSITY FROM COUNTRY REPORTS: DATA FOR AN INFORMATION SYSTEM

The information from country reports has been incorporated into a database to produce the synthesis in the SoW AqGR. As part of this process, countries submit national reports on their aquatic genetic resources to FAO. These country reports are the main source of information for the State of the World Report and contain information on the species, strains and stocks used in fisheries and aquaculture. An information system such as requested by the Commission would need to be able to accommodate relevant genetic data on these taxa and farmed types and would include, *inter alia*:

- selectively bred organisms;
- hybrids;
- monosex organisms;
- polyploids;
- disease-resistant organisms; and
- transgenics.

Indicative farmed types listed in country reports include, *inter alia*, the genetically improved farmed tilapia, cold- and salt-resistant tilapia strains, genetically male tilapia, and GenoMar selected tilapia. A preliminary review of some of the country reports indicated several more species and species units are being farmed than are currently listed in the Aquatic Sciences and Fisheries Information System (ASFIS) (see below) and identified additional hybrids, including *Oreochromis mossambicus* × *O. niloticus* from the Philippines; *Epinephelus lanceolatus* × *E. coides, E. coides* × *E. fuscoguttatus, E. lanceolatus* × *E. fuscoguttatus* from Viet Nam and Malaysia; *Oncorhynchus mykiss* × *O. masou* from Japan; *Barbonymus gonionotus* × *B. schwanenfeldii*, *Clarias batrachus* × *C. macrocephalus* and *Channa micropeltes* × *C. striata* from the Lao People’s Democratic Republic.

5. FAO STATISTICS: STRENGTHS AND LIMITATIONS AS AN INFORMATION SYSTEM FOR AQUATIC GENETIC RESOURCES

The Food and Agriculture Organization of the United Nations is the specialized agency responsible for receiving production information on aquatic species from member countries. Over 130 countries and territories report aquaculture production figures to FAO, and over 200 countries and territories report capture fishery production. Thus, FAO maintains the world's largest and most complete statistics on fishery and aquaculture production.

The information from member countries is contained in the FAO Fisheries and Aquaculture Database (FishStatJ).[3] The international standard for reporting this production is the ASFIS list and the classification system of the International Standard Statistical Classification of Aquatic Animals and Plants (ISCAAP) (Table 3). ISSCAAP is a nomenclature developed by FAO to classify commercial species into 50 groups and 9 divisions on the basis of their taxonomic, ecological and economic characteristics. This is the standard nomenclature used by FAO and its Members to report fisheries and aquaculture production. Related to the ISCAAP is the International Standard Statistical Classification of Fisheries Commodities (ISSCFC) that has been developed by FAO for the collection of commodities statistics.[4]

Table 3: The current International Standard Statistical Classification of Aquatic Animals and Plants in use from 2000*

Code and division	Group of species
1 Freshwater fishes	11 Carps, barbels and other cyprinids 12 Tilapias and other cichlids 13 Miscellaneous freshwater fishes
2 Diadromous fishes	21 Sturgeons, paddlefishes 22 River eels 23 Salmons, trouts, smelts 24 Shads 25 Miscellaneous diadromous fishes
3 Marine fishes	31 Flounders, halibuts, soles 32 Cods, hakes, haddocks 33 Miscellaneous coastal fishes 34 Miscellaneous demersal fishes 35 Herrings, sardines, anchovies 36 Tunas, bonitos, billfishes 37 Miscellaneous pelagic fishes 38 Sharks, rays, chimaeras 39 Marine fishes not identified
4 Crustaceans	41 Freshwater crustaceans 42 Crabs, sea spiders 43 Lobsters, spiny-rock lobsters 44 King crabs, squat lobsters 45 Shrimps, prawns 46 Krill, planktonic crustaceans 47 Miscellaneous marine crustaceans
5 Molluscs	51 Freshwater molluscs 52 Abalones, winkles, conchs 53 Oysters 54 Mussels 55 Scallops, pectens 56 Clams, cockles, arkshells

[3] www.fao.org/fishery/statistics/software/fishstatj/en.
[4] ftp://ftp.fao.org/FI/DOCUMENT/cwp/handbook/annex/AnnexS2listISSCAAP2000.pdf and ftp://ftp.fao.org/FI/DOCUMENT/cwp/handbook/annex/ANNEX_RII.pdf.

Code and division	Group of species
	57 Squids, cuttlefishes, octopuses 58 Miscellaneous marine molluscs
7 Miscellaneous aquatic animals (code 6 is aquatic mammals; 8 is miscellaneous aquatic animal products)	71 Frogs and other amphibians 72 Turtles 73 Crocodiles and alligators 74 Sea squirts and other tunicates 75 Horseshoe crabs and other arachnoids 76 Sea urchins and other echinoderms 77 Miscellaneous aquatic invertebrates
9 Aquatic plants	91 Brown seaweeds 92 Red seaweeds 93 Green seaweeds 94 Miscellaneous aquatic plants

*ftp://ftp.fao.org/FI/DOCUMENT/cwp/handbook/annex/AnnexS2listISSCAAP2000.pdf. See also Appendix A in Garibaldi and Busilacchi, 2002.

ASFIS rarely considers nomenclature below the species level, i.e. there are no stocks, strains or varieties of aquatic species included, and only eleven hybrids are listed. Similarly, the information reported in FishStatJ is rarely below the species level and is of varying levels of completeness. FishStatJ provides a good indication of the production at the species level of farmed aquatic species (Table 4) and marine capture fisheries, but for inland capture fisheries the majority of production is not reported at the species level (Table 5).

Table 4: Number of species units reported to FAO

Inland aquaculture		**Africa**	**Americas**	**Asia**	**Europe**	**Oceania**
	Finfish	66	86	115	82	22
	Molluscs	0	3	5	1	0
	Crustaceans	0	8	16	7	5
	Other animals	0	4	5	3	0
	Algae	3	4	4	2	0
Total inland aquaculture		**69**	**105**	**145**	**95**	**27**
Marine and coastal aquaculture						
	Finfish	26	41	106	59	15
	Molluscs	16	40	27	35	21
	Crustaceans	9	13	27	15	12
	Other animals	3	0	7	5	1
	Algae	5	8	20	12	3
Total marine and coastal aquaculture		**59**	**102**	**187**	**126**	**52**
All aquaculture						
	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 types		**122**	**194**	**298**	**198**	**7**

Table 5: Catch from inland capture fisheries (2014)

FAO English name	Catch in 2014 (tonnes)	Percent
Freshwater fishes nei	6 566 216	55
Cyprinids nei	713 104	6
Tilapias nei	410 929	3
Silver cyprinid	353 242	3
Freshwater molluscs nei	334 192	3
Nile perch	251 484	2
Nile tilapia	233 811	2
Freshwater siluroids nei	167 340	1
Common carp	145 566	1
Oriental river prawn	137 677	1
Siberian prawn	137 676	1
Hilsa shad	133 114	1
Torpedo-shaped catfishes nei	116 672	1
Snakeheads (= murrels) nei	103 550	1
Other 314 species included in the FAO database	2 091 308	18
Total	11 895 881	100

Note: nei = not elsewhere included, i.e. not identified to species (FAO, 2016b).

The information in FishStatJ forms the basis for one of FAO's most read flagship publications, *The State of World Fisheries and Aquaculture* (SOFIA). The status and trends of fishery and aquaculture are widely cited in both scientific and popular media. As the application of genetic technologies for food production increases, resource managers, scientists and the general public will need regular and reliable information on how these technologies and the products derived from them are impacting food production.

6. ASFIS LIST: CURRENT STATUS

Currently, there are no subspecies, stocks or strains listed in the ASFIS list; eleven hybrids are listed, five of which have production data submitted by countries (Table 6). Fishery managers and the common public regularly recognize the stocks of brown trout that migrate to the ocean and designate them as "sea trout" in common usage (X. Zhou, personal observation). From extensive discussions with aquaculturists, the number of hybrids in commercial use in aquaculture is more than eleven. An examination of the country reports submitted for the SoW AqGR also revealed more hybrids being used in aquaculture than are reported in the ASFIS list (see below). However modifying the ASFIS list to include additional hybrids, or any taxon below the species level, e.g. stock or strain, has been discouraged because of a lack of reliable, consistent and detailed nomenclature and reporting. In the event standard nomenclature and consistent reporting became a global reality, consideration would be given to modifying the ASFIS list (L. Garibaldi, FAO Fishery Resources Officer, personal communication). Thus, to accommodate aquatic genetic resources below the species level, existing information systems would need to be modified substantially or a new information system would need to be created.

Table 6: Hybrids listed in the ASFIS list and indication of whether data are reported to FAO

Scientific name	English name	Family	Data
Piaractus mesopotamicus × *Colossoma macropomum*	Tambacu hybrid	Characidae	Yes
C. macropomum × *P. brachypomus*	Tambatinga hybrid	Characidae	Yes
Clarias gariepinus × *C. macrocephalus*	Africa bighead catfish hybrid	Clariidae	Yes
Morone chrysops × *M. saxatilis*	Striped bass hybrid	Moronidae	Yes
Oreochromis aureus × *O. niloticus*	Blue Nile tilapia hybrid	Cichlidae	Yes
O. andersonii × *O. niloticus*	-	Cichlidae	No
P. mesopotamicus × *P. brachypomus*	Patinga hybrid	Characidae	No
Ictalurus punctatus × *I. furcatus*	Channel-blue catfish hybrid	Ictaluridae	No
Channa maculata × *C. argus*	-	Channidae	No
Leiarius marmoratus × *Pseudoplatystoma reticulatum*	-	Pimelodidae	No
P. corruscans × *P. reticulatum*	-	Pimelodidae	No

Although hybrids are the only subspecies category in ASFIS, they are substantially different from other taxa in the list because they are dependent on the parental species to make the hybrid. That is, to produce the hybrids, the parental stocks must be conserved, well managed and bred.

A hybrid would never qualify as a variety, breed or strain. Breeding a hybrid group together would not perpetuate the hybrid, but would result in a heterogeneous group of individuals with a mixture of parental genotypes and phenotypes. That is, the hybrids would not breed true. Similarly, triploids, i.e. organisms having one extra set of chromosomes, would not qualify as a strain because triploids are sterile and require manipulation of the gametes of non-triploid individuals, or the mating of a diploid and tetraploid individual.

7. EXAMPLES OF MONITORING AND REPORTING OF GENETIC DIVERSITY

Currently, there is no global information system on aquatic genetic diversity that would allow monitoring and assessment, and this system would need to be created. Some current databases contain genetic information and could serve as sources of information and as models for any new database (Table 7).

Examples do exist where countries and other entities have incorporated genetic diversity information into databases or other types of information repositories (Table 7). However, only in a few cases is this information routinely used in monitoring and statistical analyses. Notable exceptions are the genetic stock identification programmes in North America, Europe and Scandinavia (see Griffiths *et al*., 2010, and references therein). In these cases, genetic diversity information is monitored and sometimes used in real-time fishery management, e.g. to set catch limits and establish fishing seasons (Pacific Salmon Commission, 2008). These programmes deal with valuable commercial species or iconic species, are extremely well funded by local and national public agencies and public-private partnerships, and often involve international collaboration on transboundary stocks. Therefore, this model of using genetic diversity information may not be applicable to many developing areas.

Table 7: Examples of databases or information sources on aquatic genetic diversity

Database	Description
Genetic	
FishTrace	Species identification using genetic markers (https://fishtrace.jrc.ec.europa.eu)
Fish Barcode of Life (FISH-BOL)	Species identification using genetic markers (www.fishbol.org)
FishPopTrace	Origin assignment; genetic information accessible, but genetic data not yet available (https://fishpoptrace.jrc.ec.europa.eu)
AquaTrace	Origin assignment; data not yet publicly accessible – work in progress (https://aquatrace.eu)
Northwest Fisheries Science Center	Genetic stock identification of Pacific salmon (https://www.nwfsc.noaa.gov/publications/documents/Genetic%20Stock%20Id%20of%20Pacific%20Salmon.pdf)
U.S. Geological Survey Strain Registry	Information on strains of important species in the United States of America (https://pubs.er.usgs.gov/publication/95452)
SALSEA	Potentially a very valuable and comprehensive database on Atlantic salmon genetics, but not publicly available (www.nasco.int/sas/salsea.htm)
SoW AqGR country reports	Official country reports from the members of the FAO Commission on Genetic Resources for Food and Agriculture on aquatic genetic resources for food and agriculture (www.fao.org/fishery/AquaticGeneticResources/en)
Non-genetic	
Data Collection Framework	Data available through data dissemination (https://datacollection.jrc.ec.europa.eu)
FishFrame	Regional database for fisheries assessments (www.ices.dk/marine-data/data-portals/Pages/RDB-FishFrame.aspx)
EMODnet	Overarching database and information portals (www.emodnet.eu)
BlueBRIDGE	Data management services (www.bluebridge-vres.eu)

The establishment of a baseline level of genetic diversity for wild and farmed stocks of aquatic species has been undertaken at various levels and is an essential element in the genetic stock identification programmes mentioned above (Pauly and Froese, 2001). The Fish Barcode of Life (Table 7) has established unique genetic descriptors for several aquatic species (Steinke and Hanner, 2011).

Ad hoc listing of strains and/or stocks of important species has been undertaken in some areas. The United States Geological Survey and the United States Fish and Wildlife Service created the National Fish Strain Registry that contains information on registered strains of important species such as sturgeon, catfish, perch and pike, and trout. The objective of these national registries is to help resource scientists manage fisheries and collections of broodstock for aquaculture and stock enhancement. Information in these national registries include the names, locations, contacts, provenance, breeding histories and method. For channel catfish (*Ictalurus punctatus*) alone, the registry contains information on 190 farm stocks, 45 hatchery and introduced stocks, and 38 research stocks (Dunham and Smitherman, 1984).

The country reports submitted for the SoW AqGR have been incorporated into a database in order to produce the SoW AqGR. Once the SoW AqGR has been released, this database could be made publicly available, similar to other databases maintained at FAO (e.g. FishStatJ at www.fao.org/fishery/statistics/software/fishstatj/en).

The State of the World Reports from other sectors have occasionally included information on breeds and varieties (e.g. FAO, 2007). In forestry, *The State of the World's Forest Genetic Resources* (www.fao.org/3/a-i3827e.pdf) identified the lack of information systems incorporating genetic information as a key constraint to the use and conservation of forest genetic resources.

8. POSSIBLE OPTIONS AND STRATEGIES TO INCORPORATE GENETIC DATA INTO NATIONAL AND FAO STATISTICS

8.1 Aquatic genetic resources information (AQUAGRIS)

Based on the above discussion, a potential information system for recording and monitoring aquatic genetic resources (Table 8) was designed and tentatively called AQUAGRIS (FAO, 2016a). Information needs on farmed types and wild relatives are slightly different and therefore treated separately in the information system. Key information for any information system include accepted name, location, distinguishing character, and who collected or supplied the information.

Table 8: Data structure for AQUAGRIS – aquatic genetic resources of farm 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 and species	Taxonomic status, genus and species
Genetic characteristics of the farmed type	Genetic status and characteristics 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 characteristics
Where farmed	Records of occurrence
Farming system(s)	Habitat(s), distribution and range
Time series of production	Exploitation or use
Status	Status, presence and abundance
Source of further information	Source of further information

8.2 Monitoring

The monitoring of aquatic genetic resources is necessary to track changes in the status and trends in use and conservation of aquatic genetic resources. This is routinely being done at the species level in fisheries and aquaculture (see, for example, FAO SOFIA publications) and in other sectors at the breed or variety level (FAO, 2007).

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 report on *The State of the World's Aquatic Genetic Resources for Food and Agriculture*, currently scheduled for once every ten years. However, there is a need for monitoring at shorter intervals to provide more current information on change, opportunities and threats. Another aspect that indicates monitoring is needed more frequently is the speed at which the field of genetics and genetic technologies is progressing, e.g. the rapid development of genomics and new technologies such as CRISPR (Jao, Wente and Chan, 2013).

Monitoring and assessment of the state of aquatic genetic resources reporting intervals should be ideally two to three years to capture the trends, threats and opportunities (FAO, 2016a). This schedule of reporting would further promote capacity building and continuity, i.e. a body of experts, resource managers, industry representatives, and other interested stakeholders that would provide, analyse and use the information.

Very few specific aspects were identified regarding the modality for collection and input of data and institutional aspects of a new information system such as AQUAGRIS. The Domestic Animal Diversity Information System (DAD-IS)[5] is open to continuous input, for example, and the AQUAGRIS system could also accept data in this manner.

The data structure in Table 8 would allow for the monitoring of the status and trends in use and conservation of aquatic genetic resources. However, certain fields in the data structure, e.g. genus and species, name and distinguishing characteristics, would provide an inventory of farmed strains and their wild relatives. This inventory of aquatic genetic resources would be useful to fishery managers, private industry, regulators and consumers. Thus, an information system that contained an inventory and description of aquatic genetic resources for food and agriculture could be created in advance of a system that required regular reporting to monitor status and trends. This inventory would serve as an indicator of the vast genetic resources being used in fisheries and aquaculture; it would also serve as a source of aquatic genetic resources to be accessed as appropriate by stakeholders.

8.3 Indicators

Once data have been entered into the information system and a monitoring plan has been established, indicators of the status of aquatic genetic resources will be necessary in order for resource managers and other stakeholders to make informed decisions. Potential indicators should address use and conservation status of the farmed type and wild relatives (Table 9).

Table 9: Indicators for assessing the status of genetic diversity of farmed types and wild relatives

Indicators for farmed types	**Indicators for wild relatives**
Country level/regional level trends, e.g. increasing or decreasing	Extent of distribution
Diversity of production systems, cages, ponds and raceways	Level of abundance: – Change in level of abundance – Change in trends and level of effective population size (Ne)
Number of species, number of farmed types, population data	Extent of exploitation, e.g. sustainably harvested, overfished, catch per unit effort
Extent of use and conservation of each farmed type: – Distribution of production – Total number of farms/farmers using farmed type – Number and size of hatcheries producing the species – Threats to farmed aquatic genetic resources – Genetic diversity (e.g. measures of heterozygosity, number of alleles, gene diversity, polymorphisms and level of inbreeding) – Effective population size (Ne) – change in trends and level of Ne	Conservation status or risk of loss: – Estimate the risk of introgression/hybridization between farmed types and wild relatives (e.g. escapees, stocking of farmed stock into open waters, translocations) – Level of gene flow between wild relative and farm type – Altered phenotypic traits (e.g. body shape, environmental tolerance) – Altered life history traits (e.g. early maturation, migration pattern) – Loss or change of habitat
In situ and *ex situ* conservation facilities	Accessions found in gene banks (cryobanks or living gene banks): – *Ex situ* collections kept for breeding purposes – Number of dedicated reserves or protected areas for maintaining wild relative, farm type, stock or strain

[5] http://dad.fao.org.

Once clear designations of what level of genetic diversity will be monitored and reported, appropriate indicators can be developed and agreed upon. At present, the main indicator of the state of genetic diversity of a breed or stock is the number of individuals. In general, genetic diversity is directly related to population size. Country reports have provided some insight into whether or not a species/strain or stock was increasing, decreasing or remaining stable. However, this indicator must be viewed in the proper context. Shifts in consumer preference or migration patterns may also influence the effort applied to farming or fishing. A decreasing fishery combined with loss of habitat would indicate a significant threat. For example, the catch of silver perch, *Leiopotherapon plumbeus*, endemic to the Philippines, is declining and so is its habitat. According to FishBase,[6] it has not been evaluated for inclusion on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List or the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendices.

Country reports are being analysed now; the report from the Philippines presents data that indicate the production for the majority of farmed species is either increasing or stable (24 taxa), whereas 8 taxa are decreasing, and for 14 taxa the production is fluctuating. The taxa that are decreasing include genetically altered varieties of Nile tilapia such as genetically male tilapia. For wild relatives, however, three taxa were decreasing and only one was increasing; for most taxa (seven), the status in the wild was reported as unknown. This type of information would be extremely valuable in a global information system in that it could initiate national and global efforts to restock or rebuild the certain strains.

8.4 Reference points for management

Once a monitoring system is in place, reference points are needed to indicate when a certain management action is required. The value of AQUAGRIS is that it would provide a basis for the development of effective monitoring tools and reference points for countries and stakeholders. For example, it would enable a country or sector to determine:

- when the level of inbreeding for a farmed type has reached unacceptable levels;
- the risk of losing a strain or wild relative;
- the extent of monopolization/diversification of supply of a species; and
- the risk of introgression of farmed type with wild relatives.

Indicators for the status of capture fisheries are common and often relate to the harvest level, e.g. maximum sustainable yield or overexploitation, or level of endangerment, e.g. the IUCN Red List[7] and the CITES Appendices.[8] The level of endangerment as determined by population size has been used as an indicator of risk for aquatic species as well as for domestic plants and animals (FAO, 2007).

FAO has commonly used target and limit reference points as indicators in relation to the precautionary approach to fisheries management and species introduction (FAO, 1996). Target reference points indicate a desirable situation, whereas limit reference points indicate a situation to be avoided. Some reference points were identified in relation to aquatic species for possible inclusion in a monitoring system (Table 10).

[6] www.fishbase.org/summary/4872.
[7] www.iucnredlist.org/about/summary-statistics.
[8] https://cites.org/eng/app/index.php.

Table 10: Some reference points regarding aquatic genetic resources

Description	Reference point
Number of broodstock for long-term maintenance of genetic diversity	Ne = 500 (T)
Number of broodstock for short-term maintenance of genetic diversity	Ne = 50 (T)
Levels of inbreeding (F) in the short term	F < 18 (L)
Levels of inbreeding (F) in the long term	F < 5 (L)
Percent sterile fish in production system	100% (T); 90% (L)
Level of gene flow between farmed type and wild relative	Less than 1 migrant/generation (L)
Fishing mortality	Fishing mortality less than 20% of unfished biomass (L); MSY (T)
Risk of extinction	Ne < 50 in the wild (L); order of magnitude decrease in population size (L)

Note: L = Limit reference point; MSY = maximum sustainable yield; Ne = effective population size; T = Target.

Reference points are related to actions to manage aquatic genetic resources. For example, if the level of inbreeding reached the limit reference point, new genes would be introduced through new broodstock; if fishing mortality was consistently lower than the limit reference point, additional harvest could be allowed. These actions would be taken at national or subnational level in response to the evidence that emerges from the monitoring process. The IUCN Red List and the CITES Appendices employ a variety of criteria and reference points that indicate when a species should be listed. For CITES, it is not management actions that are undertaken in response, but rather actions related to international trade.

8.5 Incentives to incorporate information on aquatic genetic resources

The data requirements and the technical and human resource requirements for an information system such as AQUAGRIS are significant. FAO and partners have tried, without success, to establish an information system on aquatic genetic resources in the past (D. Bartley, personal observation). Reasons for past failures centred on the lack of dedicated resources and a funding mechanism for such a large undertaking. In order for an information system such as AQUAGRIS to function properly, there must be incentives for countries, resource managers and the private industry to adopt the system and participate in data submission.

Significant constraints to the establishment of an AQUAGRIS, in addition to financial and technical limitations, include the fact that private industry is often reluctant to disclose proprietary information on the farmed types. Farmers are often reluctant to report on:

- species illegally imported;
- species not permitted for culture or possession (e.g. piranha, CITES or IUCN protected species, and invasive species); and
- new, better-performing strains that are under development for which the farm wishes to keep the information confidential.

Nonetheless, there are significant benefits to be gained by contributing to an information system on aquatic genetic resources (Table 11). At the national level, contribution to the information system would be seen as part of the sustainable management and advancement of the aquaculture sector. National governments who are signatories to the Convention on Biological Diversity (CBD) and are members of FAO have committed themselves to implementing the articles of the CBD; to developing and implementing National Biodiversity Strategies and Action Plans under the CBD; and to implementing the articles of the FAO Code of Conduct for Responsible Fisheries. Contributing to AQUAGRIS would be a significant step in meeting those commitments and would open the door for financial assistance to facilitate meeting the commitments. National governments would use the information system to coordinate regional actions to enable producers to sustain their access to specific genetic resources.

Private industry would be motivated to participate in order to reinforce the image of aquaculture as a sustainable and responsible food production sector and make the sector more attractive to improved investment flows. At the farm level, improved reporting could qualify farms for subsidies in the case of loss of production or some other forms of financial support. For example, in the United States of America, farmers were compensated for increased feed costs if they could demonstrate the levels of production that involved the use of fish feed (D. Bartley, personal observation). Communities have been compensated for loss of marine biodiversity following oil spills when accurate fish harvests from the affected area could document the loss.[9]

With the increasing use of markets to promote conservation and sustainability, the information system would help meet traceability and labelling requirements, as there is usually a requirement for producers to clearly identify the stock being produced and its origin.[10] This has proved successful in pond to fork traceability systems, e.g. in shrimp, tilapia and channel catfish, and in efforts to distinguish between farmed and wild species, e.g. seabass in Europe.[11]

Table 11: Incentives for contributing to an information system on genetic diversity

National governments	Incentives
	Improved sustainable management and advancement of the aquaculture and fisheries sector
	Meeting commitments to international instruments such as the Convention on Biological Diversity and the FAO Code of Conduct for Responsible Fisheries
	Access to multilateral or bilateral funding sources to help meet commitments to international instruments
	Improved coordination of the aquaculture and fisheries sector to ensure access to and conservation of aquatic genetic resources
Private sector	Strengthened image of the aquaculture sector as sustainable and responsible
	Improved market access through better traceability and through meeting requirements of ecolabelling and certification schemes
	At the farm level, to better document production to qualify for subsidies or other financial assistance in the event of lost production
	Improved dissemination and awareness of productive or otherwise important strains or stocks
International	Global record on the status and use of aquatic genetic resources for food and agriculture to complement other global databases, such as DAD-IS[12] and the IUCN Red List

8.6 Institutionalization and implementation issues

Although still at the conceptual stage, there are institutional aspects that will be important to consider early on and that will eventually help define an indicative budget for the development of the information system. As stated earlier, information gained through the country reports on new aquatic species farmed and fished and on new hybrids will be provided to FAO for incorporation into the ASFIS list as appropriate. At the infraspecies level, the names and description of new strains or stocks could be added

[9] www.itopf.com/fileadmin/data/Documents/TIPS%20TAPS/TIP15PreparationandSubmissionofClaimsfromOilPollution.pdf.
[10] FAO Technical Guidelines on Aquaculture Certification (www.fao.org/docrep/015/i2296t/i2296t00.htm and FishPop Trace https://fishpoptrace.jrc.ec.europa.eu).
[11] AquaTrace (https://aquatrace.eu).
[12] Domestic Animal Diversity Information System (http://dad.fao.org).

to the Fisheries and Aquaculture Species Fact Sheets.[13] An inventory of new species, farmed types and stocks could be established without the need for monitoring and assessment and would serve as a global registry on the diversity of aquatic genetic diversity for food and agriculture.

The information system would need a central hub or home to control and ensure quality of the submission. The mechanisms used by FAO through DAD-IS could serve as a model. FAO would be a logical centre for the system; however, as with other information systems, e.g. FishBase, the development of partners or a consortium would be important to move the process forward. Several entities exist (Table 12) that would serve both as information sources and potential partners in a consortium. Members of the consortium could further help leverage funding, as in the Genetic Gain Platform model[14] used by the annual reporting mechanism of the CGIAR breeding programmes to report to multiple donors.

Table 12: Potential partners in a consortium to host and manage AQUAGRIS

Entity	Description
FishBase/SeaLifeBase	Consortium maintaining relational databases on living aquatic resources: http://fishbase.org; www.sealifebase.org
Fish Barcode of Life	International consortium developing DNA barcoding for species identification: www.fishbol.org
WorldFish Center	Body within the CGIAR that deals with aquaculture and fisheries: www.worldfishcenter.org
Bioversity International	Body within the CGIAR that deals with biodiversity: www.bioversityinternational.org
Coordinating Working Party on Fishery Statistics	FAO body that provides a mechanism to coordinate fishery statistical programmes of regional fishery bodies and other intergovernmental organizations with a remit for fishery statistics (oversees ASFIS list): www.fao.org/fishery/cwp/en
Regional commissions and unions	May advise or set policies on regional and transboundary issues: e.g. www.fao.org/fishery/rfb/eifaac/en
National resource agencies and universities	Local expertise and responsibility for resource characterization, development, management and conservation

At the country level, the responsibility for the maintenance of the database could be lodged with the national focal point for aquatic genetic resources.[15] Formal establishment of this function with an accompanying committee or group of experts will facilitate initial institutionalization of the development of a regular monitoring and reporting system. Questionnaires similar to the ones developed for the country reports[16] would further facilitate data entry and reporting.

Thus, in addition to the updated ASFIS list and the country reports, there could be two related information systems: (i) a global inventory of aquatic genetic resources; and (ii) a monitoring system that can generate trends, indicate status and suggest management responses.

An important consideration is who has authority on data submission and quality control on the data. The information from country reports is official information endorsed by national governments and could be made publicly available. The information in AQUAGRIS could have the same status, or it could include unofficial information, for example, from research groups, universities, government facilities, aquaculture associations, private industry, and inter- and non-governmental organizations such as regional fishery bodies, centres of the CGIAR and the IUCN. This non-official information would be a valuable component of AQUAGRIS and could become entered in public domain, i.e. an open source of

---

[13] www.fao.org/fishery/factsheets/en.
[14] http://repository.cimmyt.org/xmlui/bitstream/handle/10883/4818/57801.pdf?sequence=1.
[15] ftp://ftp.fao.org/FI/DOCUMENT/aquaculture/AqGR/List_of_NFPs.pdf.
[16] www.fao.org/nr/cgrfa/cthemes/aqua/en.

information, especially if the establishment of the information system were paid for by public funds (FAO, 2016c).

8.7 Selected species for proof of concept

Experts recognized the challenges involved in improving existing information systems, such as ASFIS and in creating a new system such as AQUAGRIS, and recommended initially focusing on a few key species to demonstrate the utility and challenges of the endeavour (FAO, 2016a). Thirteen aquatic taxa were identified that represent the breadth of aquatic genetic diversity (Table 13) to serve case studies to demonstrate the proof of concept for the information system. The 13 taxa represent a range of species and aquatic habitat, they are all both farmed and fished, and they have significant infraspecific variability. Other species considered as potential case studies were the gastropods Anadara and Abalone (*Haliotis* spp.); the crustacean Artemia (as a feed species); the ornamental species of giant clam (*Hippopus hippopus*); and the additional finfish turbot, red drum, barramundi and gilthead seabream.

Table 13: Potential case studies for inclusion in AQUAGRIS. Taxa are both farmed and fished and represent a global coverage of aquatic genetic resources.

Taxon	Species	Geographic area	Marine (M) Inland (I)
Plant (alga and vascular)	Elkhorn sea moss (*Kappaphycus alvarezii/cottonii*)	Asia, Africa	M
	Lotus (*Nelumbo nucifera*)	Asia	I
Micro-organism	Spirulina (*Spirulina* species and varieties)	Worldwide	I
Mollusc	Pacific oyster *(Crassostrea gigas*)	North and South America, Asia	M
	Manilla clam (*Ruditapes philippinarum*)		M
Crustacea	Whiteleg shrimp *(Lito)penaeus vannamei*	North and South America, Asia	M
	Giant freshwater prawn (*Macrobrachium rosenbergii)*	Southeast Asia, South Asia, Guyana	I
Fish	Atlantic salmon (*Salmo salar*)	Europe, Chile, Australia, New Zealand	I/M
	Common carp (*Cyprinus carpio*)	Global – temperate to tropical	I
	Nile tilapia (*Oreochromis niloticus*)	Global tropical	I
	Pacu (*Piaractus brachypomus/ Colossoma macropomum*)	Latin America, Asia	I
	European seabass (*Dicentrarchus labrax*)	Europe	M
	Catfish (African/*Pangasius* and *Clarias* spp.)	Africa, Europe and Asia	I

9. CONCLUSIONS AND RECOMMENDATIONS

At present, genetic diversity is not routinely used in fishery and aquaculture reporting and monitoring. However, production from capture fisheries, and especially aquaculture, will need to increase substantially in order to meet a growing demand for seafood. Knowledge on the genetic diversity of farmed species and their wild relatives is and will be extremely beneficial to farmers, fishers and resource managers to help identify, among other things:

- the strains of farmed fish that are most productive;
- aquatic species that are responsibly used;
- the strains of farmed fish most suitable to deal with climate change;
- stocks of wild relatives for improved fishery management;
- the wild populations that are being impacted by escaped fish from aquaculture facilities;
- the strains of farmed aquatic species with disease resistance;
- the source or origin of seafood products; and
- fish or fish products hard to identify by conventional means, e.g. fillets or eggs.

National resource managers and the public 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.

Although tremendous progress has been made in the genetic improvement, genetic stock identification and genomics of aquatic species, in order to establish and maintain an information system for aquatic genetic resources (AqGR), further work is needed to:

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

Many Members of FAO cannot fulfil their commitments to FAO for the routine reporting on fisheries and aquaculture: the majority of inland capture fisheries production is not reported to species; numbers of fish released for culture-based fisheries are seldom reported; and many farmed aquatic plants are not reported. The analysis of the country reports has demonstrated that countries are farming many more aquatic species and hybrids than are being reported through the regular fishery and aquaculture statistics process. In order for countries to initiate monitoring programmes at the genetic level, it will be necessary to communicate the benefits of embarking on this extra level of detail and then develop capacity and infrastructure. However, the responsible management of AqGR is in the long-term best interest of biodiversity, private industry and consumers.

Substantial benefits can be derived from incorporating information on genetic diversity into national reporting and monitoring systems, but significant challenges exist in developing an information system that would compile and analyse this information. General conclusions regarding the incorporation of genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives are as follows:

- Genetic information can help improve the reporting at the species level in national and global databases.
- Nomenclature is non-standard and inconsistent and therefore needs to be standardized and the standard widely promoted.
- Monitoring genetic diversity would provide a variety of benefits to resource managers, private industry and consumers.
- An information system that would contain an inventory of genetic diversity, i.e. farmed types and wild relatives, would be useful, even without the capacity to monitor changes in genetic diversity.
- Financial resources and capacity building will be required to establish and maintain an information system that would allow monitoring, and status and trend analyses.
- Incentives need to be promoted more widely as to why governments and private industry should establish and contribute to existing information systems, e.g. FishStat of FAO at the species level, and any new information system at the genetic level.
- Structures already exist that could accommodate descriptions of genetic diversity as part of an inventory of genetic diversity of farmed types and wild relatives.
- Examples exist of more extensive information systems that allow monitoring of genetic diversity.
- In-depth analysis of the genetic diversity of 13 important species would serve as a useful proof of concept for the development of a new information system.
- Institutional arrangements and a home for the information system need to be defined.

As the cost of genetic analyses decreases and expertise increases, the use of genetic data in fishery and aquaculture management should become easier and more routine. It is essential that governments and private industry see the advantages of genetic resource management and become strong partners. An information system for monitoring and assessment would be ideal, but costly in terms of financial and human resources. An information system that provides an inventory of the diversity of farmed types with their desirable characteristics would be an extremely valuable resource for consumers, the aquaculture industry and Members of FAO.

REFERENCES

ADB. 2005. *An impact evaluation of the development of genetically improved farmed tilapia and their dissemination in selected countries*. Bangkok Asian Development Bank.

Bakos, J. & Gorda, S. 2001. *Genetic resources of common carp at the Fish Culture Research Institute, Szarvas, Hungary*. FAO Fisheries Technical Paper No. 417. Rome, FAO. 106 pp. (also available at www.fao.org/docrep/005/Y2406E/Y2406E00.htm).

Bartley, D.M., Harvey, B.J. & Pullin, R.S.V., eds. 2007. *Workshop on status and trends in aquatic genetic resources: a basis for international policy*. 8–10 May 2006, Victoria, British Columbia, Canada. FAO Fisheries Proceedings No. 5. Rome, FAO. 179 pp. (also available at www.fao.org/docrep/010/a1337e/a1337e00.htm).

Bartley, D.M., De Graaf, G.J., Valbo-Jørgensen, J. & Marmulla, G. 2015. Inland capture fisheries: status and data issues. *Fisheries Management and Ecology*, 22: 71–77. doi:10.1111/fme.12104.

Behnke, R.J. 2002. *Trout and salmon of North America*. New York, the Free Press.

Briggs, M., Funge-Smith, S., Subasinghe, R.P. & Phillips, M. 2005. *Introductions and movement of two penaeid shrimp species in Asia and the Pacific*. FAO Fisheries Technical Paper No. 476. Rome, FAO. 78 pp. (also available at www.fao.org/docrep/009/a0086e/A0086E02.htm).

Duarte, C.M., Marbà, N. & Holmer, M. 2007. Rapid domestication of marine species. *Science,* 316: 382–383.

Dunham, R.A. & Smitherman, R.O. 1984. *Ancestry and breeding of catfish in the United States*. Auburn, Alabama, Auburn University. 93 pp.

FAO. 1996. *The precautionary approach to fisheries management and species introduction*. FAO Technical Guidelines for Responsible Fisheries No. 2. Rome.

FAO. 2007. *The state of the world's animal genetic resources for food and agriculture*. B. Rischkowsky & D. Pilling, eds. Rome. (also available at ftp://ftp.fao.org/docrep/fao/010/a1260e/a1260e00.pdf).

FAO. 2014. *The State of World Fisheries and Aquaculture 2014*. Rome. 243 pp. (also available at www.fao.org/3/a-i3720e.pdf).

FAO. 2016a. *Report of the expert workshop on incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives*. Rome.

FAO. 2016b. *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all*. Rome. 200 pp. (also available at www.fao.org/3/a-i5555e.pdf).

FAO. 2016c. FAO yearbook. Fishery and aquaculture statistics. 2014 capture production. Rome. (Data downloadable at www.fao.org/fishery/statistics/software/fishstatj/en.)

Garibaldi, L. & Busilacchi, S. (comps.). 2002. *ASFIS list of species for fishery statistics purposes/Liste ASFIS des espèces pour les besoins des statistiques des pêches/Lista ASFIS de especies para los fines de estadísticas de pesca.* ASFIS Reference Series/Série de références ASFIS/Serie de Referencias ASFIS. No. 15. Rome/Roma,

Griffiths, A.M., Machado-Schiaffino, G., Dillane, E., Coughlan, J., Horreo, J.L, Bowkett, A.E, Minting, P., Toms, S., Roche, W., Gargan, P., McGinnity, P., Cross, T., Bright, D., Garcia-

Vazquez, E. & Stevens, J.R. 2010. Genetic stock identification of Atlantic salmon (*Salmo salar*) populations in the southern part of the European range. *BMC Genetics*, 2010, 11:31. doi:10.1186/1471-2156-11-31.

Jao, L., Wente, S.R. & Chen, W. 2013. Efficient multiplex biallelic zebrafish genome editing using a CRISPR nuclease system. *Proceedings of the National Academy of Sciences*, 110: 13904–13909.

Jerde, C.L., Chadderton, W.L., Mahon, A.R., Renshaw, M.A., Corush, J., Budny, M.L., Mysorekar, S. & Lodge, D.M. 2013. Detection of Asian carp DNA as part of a Great Lakes basin-wide surveillance program. *Can. J. Fish. Aquat. Sci*., Vol. 70: 522–526.

Lush, J.L. 1994. *The genetics of populations*. Iowa City, USA, Iowa State University Press.

Martinsohn, J. & Ogden, R. 2009. FishPopTrace – Developing SNP-based population genetic assignment methods to investigate illegal fishing. *Forensic Science International. Genetics Supp. Ser*., 2, 294–296. (also available at www.sciencedirect.com/science/article/pii/S1875176809001218).

Martinsohn, J.T., Geffen, A.J., Maes, G.E., Nielsen, E.E., Waples, R.S. & Carvalho, G.R. 2011. Tracing fish and fish products from ocean to fork using advanced molecular technologies. *In* J. Hoorfar, K. Jordan, F. Butler & R. Prugger, eds. *Food chain integrity: a holistic approach to food traceability, safety, quality and authenticity*, pp. 259–282. Woodhead Publishing. (also available at www.sciencedirect.com/science/book/9780857090683).

Nielsen, J.L., Fountain, M.C., Favela, J.C., Cobble, K. & Buddy, L.J. 1998. *Oncorhynchus* at the southern edge of their range: a study of mtDNA control-region sequence with special reference to an undescribed subspecies of *O. mykiss* from Mexico. *Env. Biol. Fish*, 51: 7–23.

Pacific Salmon Commission. 2008. *Recommendations for application of genetic stock identification (GSI) methods to management of ocean salmon fisheries: special report of the Genetic Stock Identification Steering Committee and the Pacific Salmon Commission's Committee on Scientific Cooperation*. Pacific Salmon Committee Technical Report No. 23. 35 pp.

Pauly, D. & Froese, R. 2001. Fish stocks, p. 801–814. *In* S. Levin, ed. *Encyclopedia of Biodiversity*. *Volume 2*. San Diego, USA, Academic Press. Summary in this document: http://imbriw.hcmr.gr/en/wp-content/uploads/2014/01/FISHONLINE_100623.pdf.

Pullin, R.S.V. & White, P. 2011. Climate change and aquatic genetic resources for food and agriculture: state of knowledge, risks and opportunities. Commission on Genetic Resources for Food and Agriculture. Rome, FAO. (also available at www.fao.org/docrep/meeting/022/mb507e.pdf).

Reddy, P.V.G.K. 1999. *Genetic resources of Indian major carps*. FAO Fisheries Technical Paper No. 387. Rome, FAO. 76 pp. (also available at www.fao.org/docrep/006/X3850E/X3850E00.htm).

Steinke, D. & Hanner, R. 2011. The FISH-BOL collaborators' protocol. *Mitochondrial DNA*, 22, sup1, 10–14. (also available at http://dx.doi.org/10.3109/19401736.2010.536538).

Trewavas, E. 1983. *Tilapiine fishes of the genera* Sarotherodon, Oreochromis *and* Danakilia. London, British Museum (Natural History). 583 pp.

Annex 1

Terms of reference of the thematic background study on incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives

Title of the study: Incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives.

Rationale: Reporting the production and value statistics for farmed aquatic species and their wild relatives is often at the species or higher taxonomic levels. However, many reports do not even identify the species used. Management of fish stocks, traceability of fish and fish products, and oversight and development of responsible aquaculture requires identification and management of genetic diversity, linked to production. Increasingly, resource managers and the development communities are asked to identify indicators of the status of aquatic genetic resources (AqGR). Once better production data are available below the species level, indicators can be developed for monitoring and assessment of AqGR, which will then inform better management practices.

The objective of the study is to explore how improved collection, monitoring and reporting of genetic data can help illustrate the current and potential value of AqGR and better inform genetic resources management.

Deadline for submission:

- Abstract (to be presented as a background document during the expert consultation): April 2016
- Full report: June 2016

Topics to be covered (indicative page numbers):

- Introduction (3–5 pages)
- FAO statistics: official data overview and main limitations (3 pages)
- ASFIS list: current status and main limitations (3 pages)
- Possible options and strategies to incorporate genetic data into national and FAO official statistics (15–20 pages)
- Inclusion of data collected through the State of the World's Aquatic Genetic Resources for Food and Agriculture process into FAO official statistics (5–8 pages)
- Major conclusions and recommendations (5 pages)