

## **STATUS OF THE WORLD'S FISHERY GENETIC RESOURCES**

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### **Summary**

The world's fisheries are composed of 974 taxa of fin-fish, 143 crustacean, 114 mollusks, 26 plants and 73 taxa of miscellaneous animals, whereas aquaculture production is composed of 153 species of fish, 60 mollusks, 44 crustaceans, 11 plants and several other miscellaneous taxa. These figures are certainly underestimates. Stocks of wild populations and farmed species exist, but are poorly documented for all but a few species.

### **Keywords**

Capture fisheries; aquaculture; genetic diversity;

### **What are fishery genetic resources? What needs to be characterized?**

The Convention on Biological Diversity (CBD)<sup>1</sup> would define aquatic genetic resources as: “(Aquatic) genetic material of actual or political value.” Moreover, genetic material is defined by the CBD as: “any material of plant, animal, microbial or other origin containing functional units of heredity.” Bartley and Pullin (1999)<sup>2</sup> asked the questions, “Are aquatic genetic resources then the sum total of all the aquatic plants, animals and microorganisms on the planet? Does everything aquatic and alive and all of its DNA have actual or potential value?” This might indeed be the best assumption at present, because of the large knowledge gaps that remain in a. understanding how aquatic ecosystems function to support fisheries; b. how to choose aquatic species, for domestication; c. how to make rapid progress in domesticating them; and d. how to harness aquatic bio-chemicals and biological processes for the benefit of humankind. Such a broad definition would make, for the time being, the terms ‘aquatic genetic resources’ and ‘aquatic biodiversity’ nearly synonymous. Thus, there are different levels of genetic diversity including ecosystems, communities, populations, genotypes and individual genes. Each level of the hierarchy has specific functions as well as supporting the level above it (citation<sup>2</sup>).

Since genetic resources have value, in terms of economic, ecological, and social uses, they need to be characterized. This is central to FAO's mandate concerning information, but is also vitally necessary for fishery management and aquaculture development. Both wild and farmed groups of fishes need to be characterized. Aquaculture is the fastest growing food producing sector; by 2025 it is expected that 1 out of every 2 fish eaten will be from aquaculture. Although capture fisheries is the last major source of food that is derived from “hunting”, fishing is important as an economic, social and cultural activity in much of the world.

Here I report on the status of aquatic species that are fished or farmed throughout the world; number of species and production were derived from FAO's databases. Unlike the terrestrial plant and animal sectors, there is no systematic effort to describe the state of the world's fishery genetic resources below the species level. Therefore selected examples of well-studied groups or organisms are included to demonstrate the diversity and usefulness of fishery genetic resources.

### Capture fisheries

In 2002 Members reported that 974 taxa of fin-fish, 143 taxa of crustacean, 114 taxa of mollusks, 26 taxa of plants and 73 taxa of miscellaneous animals such as sea urchins, sea cucumbers, and marine mammals were taken from the world's capture fisheries (Figure 1).

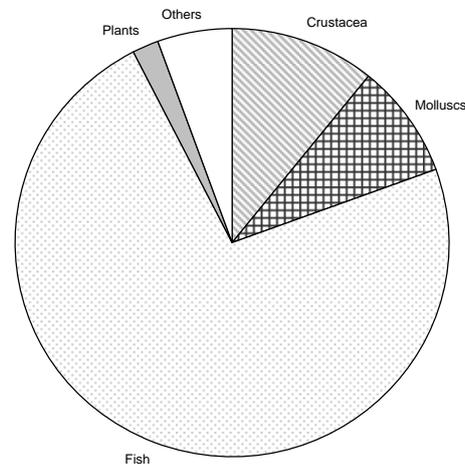


Figure 1. Taxa reported taken from the world's capture fisheries in 2003

The 15 most productive fisheries in terms of quantity are listed in Table 1 with their production figures. Although over 1000 taxa are represented in this data set, about 10 species make up about 1/3 of total production. Overall production from the world's capture fishery increased up to the late 1980's and has now reached what most fishery scientists think is a plateau, i.e. not much more production can be expected (Figure 2).

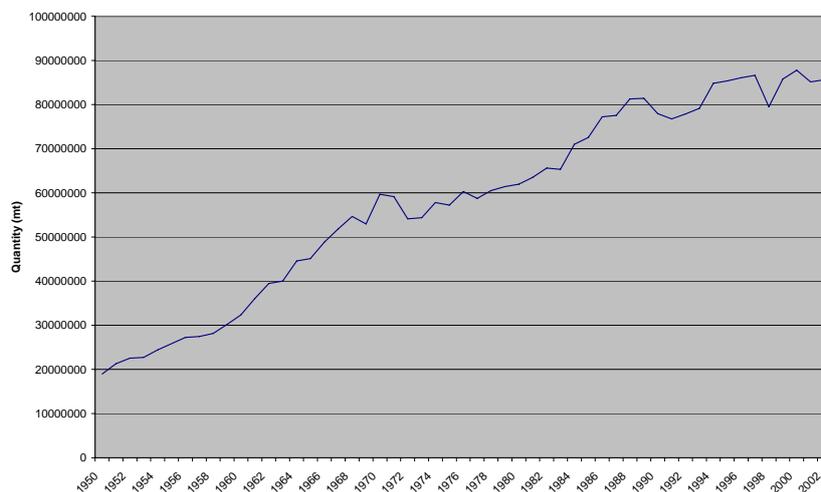


Figure 2. Production from the world's capture fisheries from 1950-2002

This information which is officially reported to FAO, is certainly an underestimate of the number of species and genetic diversity contributing the worlds capture fisheries. The categories “nei” (Table 1) refer to organisms “not elsewhere included”; this is generally catch that is not identified to species or to major group. The “nei” groups account for over 20% of the global catch. Unfortunately, the information reported to FAO is getting worse in regards

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 Villa Gualino, Turin, Italy – 5-7 March, 2005

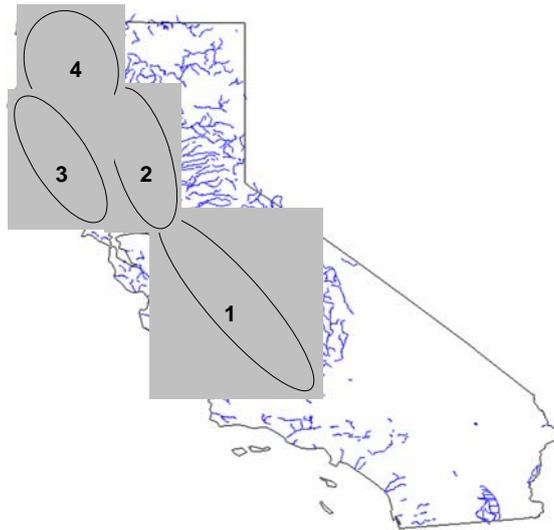
to reporting by species, as more production is reported as coming from species “nei”, than previously<sup>3</sup>.

*Table 1. Most important capture fisheries in terms of quantity in 2002<sup>4</sup>*

<b>Taxa</b>	<b>Quantity (mt)</b>	<b>Percent</b>	<b>Cumulative</b>
Marine fishes nei*	10693764	12.5	12.5
Anchoveta	9702614	10.1	23.8
Freshwater fishes nei	4389297	5.1	29.0
Alaska pollock	2654854	3.1	32.1
Skipjack tuna	2030648	2.4	35.4
Capelin	1961724	2.3	36.7
Atlantic herring	1872013	2.2	38.9
Japanese anchovy	1853936	2.2	41.1
Chilean jack mackerel	1750078	2.0	43.1
Blue whiting	1603263	1.9	45.0
Marine molluscs nei	1491849	1.7	46.8
Chub mackerel	1470673	1.7	48.4
Largehead hairtail	1452209	1.7	50.1
Marine crustaceans nei	1372522	1.6	51.2
Yellowfin tuna	1341319	1.5	53.3
* nei = not elsewhere included and generally refers to catch not identified to species or group			

Below the species level, many of the world’s fisheries are composed of numerous stocks. Definitions of what constitute a “stock” have not been agreed, however, here I use the term to

mean a group of similar individuals within a species that preferentially breed within the group. Good examples of stocks are the various spawning migrations of salmon and trout. These runs, or stocks, can be differentiated spatially by river systems and temporally by seasons. For example, the chinook salmon fishery in the Pacific Northwest of North America is composed of hundreds of genetically differentiated stocks that correspond to river systems and time of spawning (Figure 3)<sup>5</sup>. The US Endangered Species Act has recognized the value of this intra-specific diversity and has afforded protection to numerous endangered runs under the Act. Most of worlds fisheries have not been genetically characterized to the extent that many salmonid fisheries have, none-the-less, stock structure has been found in many species. Genetic differentiation depends on a variety of factors, and can be useful in setting management and conservation goals.



*Figure 3. Major watersheds inhabited by Chinook salmon in California. Chinook salmon stocks within a watershed are genetically more similar to one another than to stocks in other watersheds. Watersheds are: 1=San Joaquin River; 2=Sacramento River; 3= Eel River and coastal rivers; 4= Trinity River*

### **Aquaculture**

In 2002 Members reported that 153 species of fish, 60 species of mollusks, 44 species of crustaceans, 11 species of plants and several other miscellaneous taxa such as echinoderms, frogs, and crocodiles, were farmed in various parts of the world (Figure 4). Contrary to the leveling in production from capture fisheries, aquaculture is expanding rapidly (Figure 5), especially in the developing world, and many governments have increased aquaculture development as development goals<sup>6</sup>.

Aquaculture is a relatively new enterprise except for a few species, such as common carp that was domesticated several thousand years ago. Although there are a number of genetic techniques available to improve aquatic species (Table 2), the aquaculture sector lags behind the crop, livestock and poultry sectors in regards to the development of domesticated and genetically improved strains. However, progress is being made in domesticating species of fish such as rainbow and brown trouts, Atlantic salmon, channel catfish, common carp, Chinese and Indian carps, and tilapia. Pacific oyster and other oyster species have been genetically improved, but very few crustaceans due to the problems in artificial breeding. Several projects have been developed or are currently operating to characterize these important aquatic species.

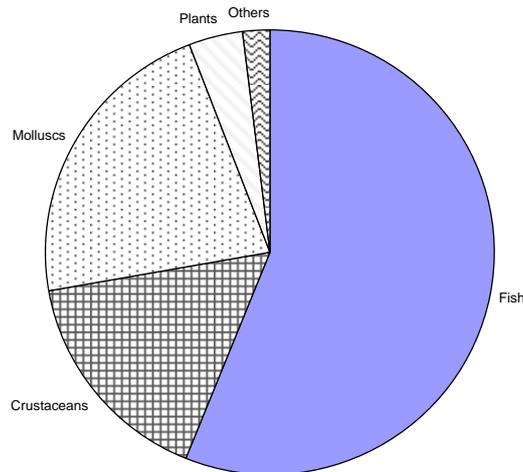


Figure 4. Composition of the reported aquaculture production in 2002.

For example a European Union project SALMAP to characterize salmonids found 200 micro-satellite markers for rainbow trout, 299 for Atlantic salmon and 232 for brown trout<sup>7</sup>. Other fish species for which genetic databases and linkage maps are being created are tilapia<sup>8</sup>, and channel catfish<sup>9</sup>. The fish with the longest history of genetic alteration and improvement is the common carp<sup>10</sup>. Breeding centers in Eastern Europe list over one hundred genetically distinct varieties, many of which are differentiated morphologically<sup>11</sup>.

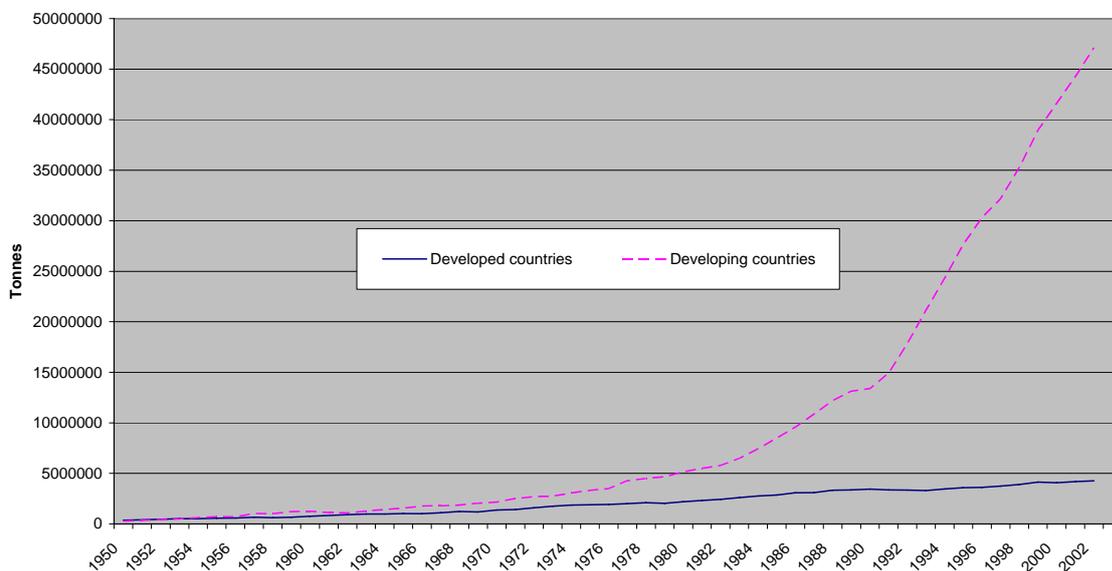


Figure 5. Global aquaculture production 1950-2002.

The Genetic Improvement of Farmed Tilapia (GIFT) programme increased Nile tilapia growth rate by about 11%/generation<sup>12</sup> through selective breeding; the GIFT fish is now a registered trademark. Chromosome set manipulation has also been used to improve tilapia growth through the creation of all male tilapia or “genetically male tilapia” (GMT)<sup>13</sup>. Male

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Villa Gualino, Turin, Italy – 5-7 March, 2005

tilapia grow faster than females and a single-sex population does not have the problem of unwanted reproduction.

Interspecific hybridization has been used to develop some animals that are useful for aquaculture: sunshine bass is a hybrid between white and striped bass, the bester is a popular sturgeon hybrid of beluga and starlet sturgeons, red tilapia are produced by several crosses of various tilapia species<sup>14</sup>. In general, hybridization is not a good mechanism for creating stable varieties for production because the progeny may not be fertile, or when fertile the second generation (F2) yields a group of fish with diverse phenotypes.

*Table 2. Genetic improvement strategies<sup>15</sup>*

Genetic manipulation	Improvement
<b>Long-term strategies</b>	
Selective breeding for: growth rate	As high as 50% increase after 10 gen. in coho salmon; gilthead sea bream mass selection gave 20% increase/generation; mass selection for live wt and SL in Chilean oysters found 10 - 13% gain in one generation.
body confirmation	High heritabilities in common carp, catfish and trout
physiological tolerance (stress)	Rainbow trout selected for high response showed increased levels of plasma cortisol levels.
disease resistance	Increased resistance to dropsy in common carp but disease resistance difficult to select for
pollutant resistance.	Tilapia progeny from lines selected for resistance to heavy metals Hg, Cd, and Zn survived 3 - 5 times better than progeny from unexposed lines
maturity and time of spawning	60d advance in spawning date in rainbow trout
Gene transfer	Coho salmon with a growth hormone gene and promoter from sockeye salmon grew 11 times (0 - 37 range) as fast as non-transgenics. Atlantic salmon grew 400% faster than normal during first year
<b>Short-term strategies</b>	
Intra-specific crossbreeding	Heterotic growth seen in 55 and 22% of channel catfish and rainbow trout crosses, respectively. Chum salmon and largemouth bass showed no heterosis. Heterosis for wild x hatchery <i>S. aurata</i> ); crossbreeds of channel catfish common carp showed 30 - 60% heterosis;
Sex reversal and breeding	All male tilapia show improvements in yield of almost 60% depending on farming system and little unwanted reproduction and stunting. All female rainbow trout grew faster and had better flesh quality.
Chromosome manipulation	<i>Pagrus major</i> triploids had similar growth rate to diploids at 10 months of age, but were smaller and presumed to be sterile at 18 months. <i>Dicentrarchus labrax</i> triploids showed inconsistent growth in relation to diploids and had lower GSI. Improved growth and conversion efficiency in triploid rainbow trout, channel catfish, at plaice flounder hybrids; triploid Nile tilapia grew 66-90% better than

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Villa Gualino, Turin, Italy – 5-7 March, 2005

diploids and showed decreased sex-dimorphism for body weight, but other studies found no advantage. GxE interactions also influence performance  
 Triploid Pacific oysters show 13 - 51% growth improvement over diploids at 8 - 10 months of age and better marketability due to reduced gonads; triploid Sydney rock oysters showed 41% increase in body weight at 2.5 yrs  
 Polyploidization makes certain interspecific crosses viable

Gene transfer in fish is a technology that may have potential once environmental and human health issues are better understood by consumers. There are tremendous possibilities available to create new varieties, improve efficiencies, and increase farming areas through genetic engineering. Advances in molecular genetics have allowed numerous useful genes to be identified and inserted into aquatic species (Table 3). At present, there are no trans-genetic aquatic species available to the consumer.

*Table 3. Examples of gene transfer involving aquatic species<sup>16</sup>*

Species	Foreign gene	Desired effect and comments	Country
Atlantic salmon	AFP AFP salmon GH	Cold tolerance Increased growth and feed efficiency	United States, Canada United States, Canada
Coho salmon	Chinook salmon GH + AFP	After 1 year, 10- to 30-fold growth increase	Canada
Chinook salmon	AFP salmon GH	Increased growth and feed efficiency	New Zealand
Rainbow trout	AFP salmon GH	Increased growth and feed efficiency	United States, Canada
Cutthroat trout	Chinook salmon GH + AFP	Increased growth	Canada
Tilapia	AFP salmon GH	Increased growth and feed efficiency; stable inheritance	Canada, United Kingdom
Tilapia	Tilapia GH	Increased growth and stable inheritance	Cuba
Tilapia	Modified tilapia insulin-producing gene	Production of human insulin for diabetics	Canada
Salmon	Rainbow trout lysosome gene and flounder pleurocidin gene	Disease resistance, still in development	United States, Canada
Striped bass	Insect genes	Disease resistance, still in early stages of research	United States
Mud loach	Mud loach GH + mud loach and mouse promoter genes	Increased growth and feed efficiency; 2- to 30-fold increase in growth; inheritable transgene	China, Korea, Rep.
Channel catfish	GH	33% growth improvement in culture conditions	United States
Common carp	Salmon and human GH	150% growth improvement in culture conditions; improved disease resistance; tolerance of low oxygen level	China, United States
Indian Major carps	Human GH	Increased growth	India
Goldfish	GH AFP	Increased growth	China
Abalone	Coho salmon GH + various promoters	Increased growth	United States
Oysters	Coho salmon GH + various promoters	Increased growth	United States

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<b>Fish to other life forms</b>			
Rabbit	Salmon calcitonin-producing gene	Calcitonin production to control calcium loss from bones	United Kingdom
Strawberry and potatoes	AFP	Increased cold tolerance	United Kingdom, Canada
<i>Note:</i> The development of transgenic organisms requires the insertion of the gene of interest and a promoter, which is the switch that controls expression of the gene. AFP = anti-freeze protein gene (Arctic flatfish). GH = growth hormone gene.			

**Looking ahead**

Looking into the future we see aquaculture growing rapidly and capture fisheries leveling off. According to the *Economist*<sup>17</sup> aquaculture will supply the majority of the world's supply of fish by 2030. In many developed countries, inland food fisheries have been replaced by recreational fisheries and this trend is also seen in some developing countries. To keep pace with human population growth fishery production must increase if we are to enjoy the same level of consumption of fish products that we have today. Improved management of natural fisheries, taking into account genetic stock structure and the resilience and resistance that genetic resources gives to natural populations, will be one strategy to provide additional food. Another will be the further development of aquaculture. But this development must be responsible.

In the terrestrial agriculture sectors, species have been domesticated over millennia into diverse breeds. The fishery and aquaculture sectors use many more species, but some have suggested that there should be a reduction in this number and that these few domesticated species should be widely used throughout the world. This would mean an increase in the use of alien species and genotypes. At present, aquaculture is the primary reason for the deliberate movement of aquatic species and these movements have both good and bad impacts<sup>18</sup>. What model should the aquatic sector follow: domesticate local species for local use; introduce a few "good" species throughout the world; manage wild fisheries better? Improved knowledge on the genetic diversity of aquatic species and how it functions in populations and ecosystems will help in evaluating these options.

Advances in biotechnology have and will continue to provide valuable information on aquatic diversity. However, molecular analysis has demonstrated that cows are genetically more similar to dolphins than to horses, but we do not think of putting cows in the sea or dolphins on the open range (paraphrased from Lewin<sup>18</sup>). Biotechnology is one tool that can be used with others to help us develop, use and enjoy the tremendous aquatic diversity around us.

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Villa Gualino, Turin, Italy – 5-7 March, 2005

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