Domestication and breed-cultivating in aquaculture

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Aquaculture is one of the most important sectors of Russia's national economy that directly supplies people with food products of animal origin. In many countries of the world aquaculture is developing rapidly. The products from aquatic organism culture often compete with wild fish caught in natural water bodies. Not long ago, the main supplier of fish and non-fish food products was the world's oceans and its potential was thought to be limitless. But now mankind is confronted with the phenomenon of exhaustion of marine and freshwater fish and non-fish resources because of anthropogenic factors, most of which have an irreversible influence upon the ocean and inland water bodies. Under these conditions, the cultivation of fish and other aquatic animals and plants valuable for nourishment of people become increasingly important.

Scientific and technical progress in the development of aquaculture is mostly determined by progress in the genetic improvement of cultured organisms and in making the complex of breeds, types, lines and crosses, which are fitted to the new habitat conditions and pressure.

Diversity of Fish-breeding Waters as the Basis of New Fish Breed Development

The main factor in breeding fish for specific characteristics is the ecological diversity of water systems. Species suitability and desirable genetic characteristics vary with the intensity of the culture system. For example, in extensive aquaculture the human influence consists only in

Figure 1. Fish breeding zones in Russia.

Table 1. Types of fish-breeding farms according to the extent of control of ecological factors.

Ecological factors	Types of fish-breeding farms				
	extensive	cage	pond	tank-rearing	recirculating
Abiotic:					
• temperature	- - -	- - -	- - -	- - +	+ + +
• oxygen	- - -	- - +	- + +	- + +	+ + +
• pH	- - -	- - -	- + +	- + +	+ + +
• flowage	- - -	- - +	- + +	+ + +	+ + +
• lucidity	- - -	- - +	- + +	- + +	+ + +
• light day length	- - -	- - -	- - -	- - +	+ + +
Biotic:					
• culture approach	- - +	+ + +	+ + +	+ + +	+ + +
• packing density	- - +	+ + +	- + +	+ + +	+ + +
• forage reserve	- - -	- + +	- + +	+ + +	+ + +
• prophylaxis	- - -	- - +	+ + +	+ + +	+ + +
Extent of controllability	none	weak	half	strong	complete

-- uncontrollable parameters;
+ + controllable parameters.

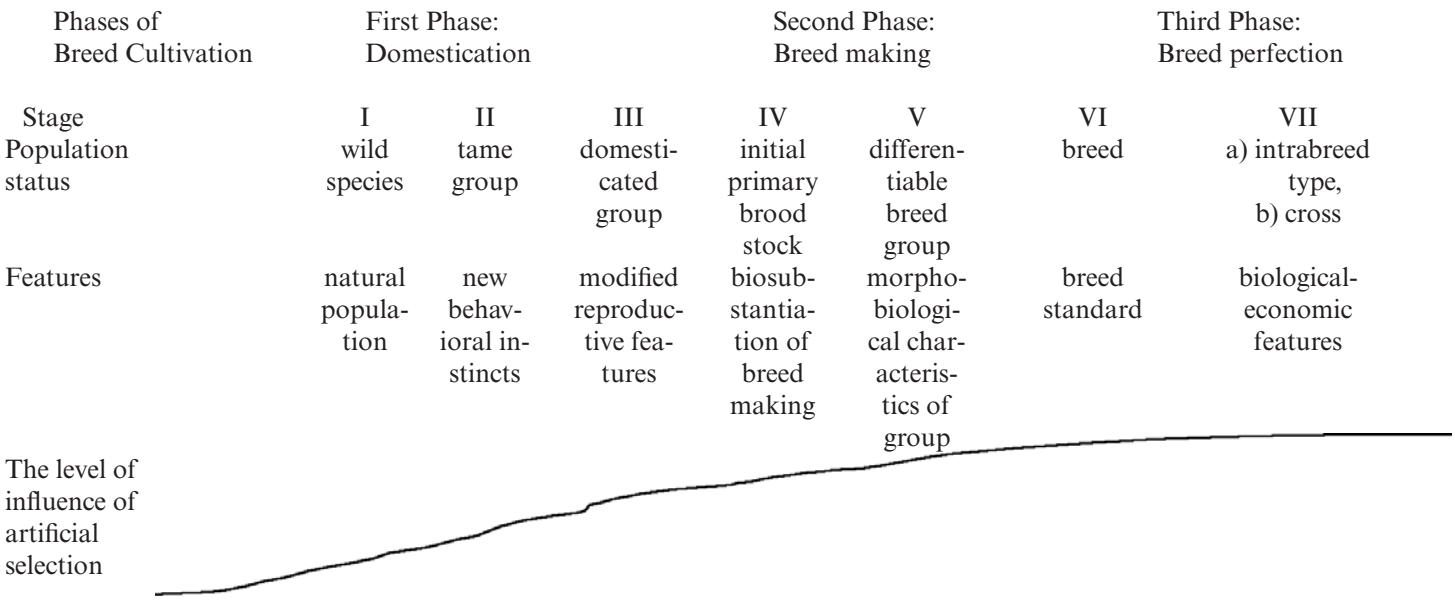

Figure 2. Phases and stages of domestication process from wild species of animal to the breed and other selection achievements.

selection of fish species composition and, perhaps, stocking density. At the other extreme, which is recirculating systems, all abiotic and biotic factors are under the control of the culturist. Other types of water systems lie between those extremes (Table 1). Hence in the extensive system, species selection is determined by food habits, growth rate and nutritional value; characteristics that developed under the influence of a long period of natural selection. In more intensive systems the fish are under the influence of artificial selection.

In the Eastern European countries, pond fish breeding farms play a special role in the development of commercial aquaculture. These farms are located under the zonal principle. In particular, in the Russian Federation, there are six fish-breeding zones according to the peculiarities of temperature conditions and soil-climatic variety (Figure 1; Boguerouk and Maslova 1998). In Russian aquaculture, there are several types of fish breeding farms: lake farms, pond farms, cage farms and tank rearing farms. The management of these farms is associated with the ecological peculiarities of the various water bodies. The extent of controllability of ecological factors of such water bodies is different as summarized in Table 1.

The most important prerequisites for animal domestication during the progress of mankind are the increase of humans and the considerable reduction in the populations of wild food animals. Centuries-old experience in solving the problem of leading different animal species into domestication shows that positive results were obtained only when the species of animal selected for domestication, including fish, had the following characteristics:

- Wide adaptive abilities;
- Specific food habits;
- High growth potential;
- High taste quality; and lately,
- Desirable structure and color patterns

We know that the unit of the process of evolution is the population. During the domestication process we consider the group of one species of animal, consisting of several hundred or thousand individuals as mini-populations, because such populations exhibit the same behaviors as natural populations:

- Stability over time – quantity sufficient for continuation of future generations;
- Independence in space – presence of more or less clear isolation;
- Density of population enough to guarantee panmixia.

A mini-population has genetic characteristics and reproductive suitability. Therefore, we can define the 'wild' population as the population gene pool that is under direct influence of natural selection and the mutation process. A 'domesticated' population, on the other hand, has a gene pool that is under direct or partial influence of artificial selection controlled by humans.

During domestication from wild to cultured, animals go through a series of transformations (Figure 2). As a result, the stable morpho-physiologic ties begin to break down because of the changes of some factors in the environment. These factors are often regulated by humans. All of this results in a series of changes; first of all, idioadaptation.

In this period, the population feels the influence of two types of selection: natural and artificial. Both of them play a large part in the evolutionary process, though the importance of each selection is different during various stages of domestication. First, they have different influences on the population. During natural selection, negative deviations and, during the artificial selection, positive ones are selected. The directional selection plays the most important part in the initial stage. And the potency of this promotes the success of selection and new breed cultivation. Selection

Pedigree trout-breeding farm in the Sochi region

Cherepetskaya breed of carp

Ctenopharyngodon idella Rich

together with variability and inheritance are the three factors determining the biological changes in the species and, also because of selection, the rate and success in new breed cultivation.

Domestication and selection of cultured species has its own specificity. Fish and other aquatic animals differ from traditional agricultural species in many biological characteristics, such as:

- Diversity of species which may be cultured in the same water-body (polyculture);
- Gregarious behavior;
- External fertilization and high fecundity;
- Easy interbreeding between species and even genera and as a result highly fertile hybrids.

Several fish species are included in the State Register of the Russian Federation. These species are in different stages of the domestication process, and mostly adapted to the natural climatic and habitat conditions and the peculiarities of some types of aquaculture farms (Table 2).

The final result of the domestication is breed cultivation; in other words, some organisms with new morpho-biological features that differ from their wild congeners in terms of economically valuable characteristics that are stable over time and space.

Breed

A breed is a productively isolated group of fish that was cultivated by the intentional activity of humans and that has genetically acquired biological and morphological characteristics and features. Some of these characteristics and features are specific to this group of fish and differ from other groups of fish. Breed can be represented by female or male individuals or by stock material. There are several measures of performance of the brood stock when it is related to one or another breed.

Structure and quantity. The breed should include not less than two structural units. For fish it can be lines or interbreeding types. The quantity of breed individuals should guarantee its genetic stability during reproduction. For inbreeding not to exceed the level required for outbred populations, up to 1 percent, it is necessary to use not less than 25 pairs of unrelated broodstock during the receiving of the posterity (reproduction for pedigree purposes) of the breed. In the Russian Federation, it is accepted that the number of broodstock employed should be not less than 300 pairs.

Distinction. A breed is a genetically isolated system and its cultivation is accompanied by a transformation of morphological aspects in the fish. Physcial features are often used to distinguish one breed from another. In addition, proteins and other biochemical markers are used as genetic marks. During recent years, special methods for distinguishing among fish breeds have been developed that employ molecular-genetic analysis of DNA.

Stability and homogeneity. These are indexes of breed consolidation. Homogeneity is a similarity of all the representatives of the breed according to their genetic, morphologic, biologic and economic features. Particularly, during the appraisal of quantitative attributes in selected carp stocks, the variability rate on mass should not be higher than 20 percent, on fecundity – 15 percent, on external appearance – 8 percent. One can analyze the degree of pedigree homogeneity through the level of biochemical polymorphism. The breed can be considered as stable in time if its signatures have been relatively invariable along several generations. In the Russian Federation, it is necessary to have not less than 4-5 selection generations for breed consolidation.

Each breed is cultivated for specific purposes and calls for the maintenance of special cultivating technologies, so it is accompanied by normative-technological documentation where the technological process of pedigree material, cultivating and rearing is described.

Twenty three breeds of carp, trout

Table 2. The List of domesticated fish – aquaculture objects, included in the State Register of Russia.

	Name of domesticated fish	Main differences
1	*Ctenopharyngodon idella* Rich.	Actively and efficiently use macrophytes, biological land-reclamation
2	*Mytopharingodon piceus* Rich.	Actively and efficiently use molluscs, biological land-reclamation
3	*Huso huso* L.	Perspective subject of marketable sturgeon-breeding
4	*Polyodon spathula* W.	Perspective subject of marketable extensive pond sturgeon-breeding
5	*Acipenser gueldenstaedtii* Br.	Perspective subject of marketable industrial sturgeon-breeding with hybridization
6	*Acipenser baerii* Br.	Perspective subject of marketable industrial sturgeon-breeding with hybridization
7	*Coregonus peled* G.	Perspective subject of coldwater extensive pond fish-breeding
8	*Acipenser ruthenus* L.	Perspective subject of marketable extensive pond sturgeon-breeding
9	*Hypophthalmiethus molitrix* Val.	Phytoplanktophage, important object of pond and extensive pond fish-breeding, biological land-reclamation
10	*Aristichthus nobilis* Ricn.	Zooplankton feeder, important object of extensive and controlled pond fish-breeding

Paddlefish

Rainbow trout

Dr. Andrei Boguerouk

and other fish are registered in the State Register of the Russian Federation by 2004 (Table 3). As examples, we can describe some characteristics of various carp breeds that differ from each other on the level of adaptation to different natural-climatic zones and in production rate (Tables 4 and 5).

Farming Enterprises

Enterprises of four types can be the material base for maintenance and duplication of selective achievements in aquaculture. These enterprises are: farms-originators, stock-bred plants, stock-bred reproducers and gene pool farms.

Farms-originators are responsible for preservation and maintenance of selective breed standards.

Stock-bred plants are organizations engaged in pedigree livestock breeding, which have the pure breed animal stock of one or another breed and use these pure breeds for rearing of pedigree animals. The activity of stock-bred plants is built on the basis of the license on the breed (breeds) included in the State Register of Selective Achievements allowed for use. The stock-bred plant specializes in the production and sale of certified pedigree products to the organizations and enterprises that specialize in artificial insemination, stock-bred reproducers,- and natural and legal persons working in the agricultural field.

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Parskaya breed

Hypophythalmichthus molitrix *Val.*

Table 3. The list of prospective aquaculture species included in the State Register of Russia.

	Name of breed	Main differences
1	*Acipenser nikotjudini* "Aksay"	Object of marketable sturgeon-breeding with production of marketable fish from one female – 4.7 tons
2	*Acipenser nikotjudini* "Burtsev"	Object of marketable sturgeon-breeding with production of marketable fish from one female – 16.9 tons.
3	*Acipenser nikotjudini* "VNIRO"	Object of marketable sturgeon-breeding with production of marketable fish from one female – 25.7 tons.
4	*Cyprinus carpio* L. "Altajsky mirror"	Adapted to the strong continental climate; assimilates artificial feeds well.
5	*Cyprinus carpio* L. "Angelinsky mirror"	Is characterized by resistance to infectious diseases such as *Aeromonas* sp.
6	*Cyprinus carpio* L. "Angelinsky scaly"	Is characterized by resistance to infectious diseases such as *Aeromonas* sp.
7	*Cyprinus carpio* L. "Cherepetsky frame"	Is adapted to high water temperatures, high density and resistant to stress and parasitic diseases
8	*Cyprinus carpio* L. "Cherepetsky scaly"	Is adapted to high water temperatures, high density and resistant to stress and parasitic diseases
9	*Cyprinus carpio* L. «Parsky»	Is adapted to the natural-climatic conditions of the Central Russia with producton of marketable fish from one female – up to 100 tons
10	*Cyprinus carpio* L. "Ropshinsky"	Cold tolerant. Survives well during winter and grows well at water temperatures of 15-18° C
11	*Cyprinus carpio* L. "Sarbojansky"	Is adapted to the strong continental climate; tolerates low oxygen and rapidly falling temperature
12	*Cyprinus carpio* L. «Tatajsky»	Pond type. Known for high productivity and good growth rate with production of marketable fish from one female – up to 120 tons
13	*Cyprinus carpio* L. «Stavropolsky»	Fast-ripening; is adapted to intensive rearing technology with production of marketable fish from one female – up to 60 tons
14	*Cyprinus carpio* L. "Chuvashsky scaly"	Is remarkable for high stress resistance and plasticity; few intermuscular bones in the marketable meat
15	*Coregonus peled* G. "Ropshinskaya"	Known for high productivity and good survival rate during rearing to market size
16	*Oreochromis niloticus* L. "Timiryazevskay"	Tolerant of poor water quality
17	*Hypophthalmicthus molitrix* Val. "BT-58"	Adapted to intensive rearing methods
18	*Aristichthys vinogradovy* "PBT-63"	Broad food habits and adapts to relatively poor water quality and low water temperatures
19	*Aristichthus nobilis* Ricn. "PT-58"	Adapted to intensive rearing methods
20	*Oncorhynchus mikiss* W. "ADLER"	Grows well under relatively high water temperatures (15-18° C); is stress resistant
21	*Oncorhynchus mikiss* W. "ROSTAL"	Survives well high density; is adapted to coldwater reservoirs
22	*Oncorhynchus mikiss* W. "ROFOR"	Demonstrates high productivity, viability and good growth rate
23	*Oncorhyinchus mikiss* W. "AMBER"	Resists stress, tolerates low oxygen and resists diseases; survives temperature change.

Table 4. Primary biological characteristics of the females of carp breeds presently in use.

Indexes	Ropshinskaya	Altajskaya	Parskaya	Angelinskaya	Tatajskaya	Cherepetskaya
Age of puberty (yr)	5-6	5-6	5-6	4-5	5	3
Body weight (kg) 3.5-4	3.5-4.3	5-6	4.7	5-6	6.7	
Body length (cm) 48.3	51.7	56.0	56.5	56.3	59.6	
Circumference (cm)	44.9	46.9	52.5	44.4	55.1	53.0
Productivity (000's)						
• working	350-400	695-887	820-1200	650-700	800	750
• relative	87.5-126	100-200	136-210	158-170	160	133

Domestication

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Stock-bred reproducers are the organizations of pedigree livestock breeders. They rear pedigree animals for agricultural commodity producers. The activity of stock-bred reproducers is built on the basis of the license on the breed (type, line, cross) included in the State Register of Selective Achievements allowed for use and originated from the animals cultivated in stock-bred plants and received from import. The stock-bred reproducer specializes in producing and selling certified pedigree production to persons working in the agricultural field. The stock-bred reproducer fulfils the needs for numbers of individuals from initial lines, crosses and their interbreeding according to the selection program or plan.

Gene pool farms. These organizations concentrate on pedigree livestock breeding by cultivating breeds, types and populations of animals having some features and characteristics formed during a long evolutionary development and the source of genetic material for making new breeds and types of agricultural animals. The activity of gene pool farms is built on the basis of the license on rare guarded breeds included in the State Register of Selective Achievements allowed for use and on the list of breeds needed as approved by the Ministry of Agriculture of Russia. On the gene pool farm, there is selection aimed at preservation of rare breeds according to the federal and regional programs on preserving the gene pool of agricultural animal breeds.

Thanks to the high reproductive ability of fish the activity of stock-bred enterprises in aquaculture should be changed from forming and using brood stocks in every fish breeding farm to the production concentration and specialization in a small number of specialized fish breeding farms.

The principle of 'specialization and concentration of production' means to conduct pedigree activity with certain categories of selective achievement registered in the State Register of Selective Achievements allowed for use (animal breeds) and on the basis of powerful enterprises which can supply a large region of the country with pedigree production according to another most important principle of pedigree work organization, 'breed zoning'. This principle relates to pond fish breeding where the main cultivated species are carp of various species. Fish breeding zones are an important technological element for rearing of these fish species.

Table 5. Productivity of carp breeds reared in Russia.

Carp breeds	Production of marketable fish from one female. (tons per year)
Carp: Altajsky mirror	45.0
Carp: Angelinsky scaly	41.5-44.5
Carp: Angelinsky mirror	39.0-42.0
Carp: Parsky	64.0-80.0
Carp: Ropshinsky	39.0-45.0
Carp: Sarbojansky	39.1
Carp: Tatajsky	43.0-57.0
Carp: Cherepetsky frame	91.0-99.0
Carp: Cherepetsky scaly	117.0-126.0
Carp: Stavropolsky	59.4-64.2

Currently, production volume of marketable fish in fish breeding farms of the Russian Federation amounts to 115-120 thousand tons per year. The main species for cultivation are carp. Their part in total production volume exceeds 80 percent. Production of trout, sturgeon and white fish is some 15-17 thousand tons. Recently, the volumes of introduction of various highly productive fish breeds into industrial aquaculture have increased. The activities related to introduction of sturgeon and the *Coregonus peled* breeds are now in the initial stages of industrial development.

Notes

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