The development system of biotech management of reproduction fish populations based on neuroendocrinological research

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Abstract. The participation of the hypothalamo-hypophysial neurosecretory system (HHNS) in fish reproduction was established by ecologo-histophysiological research with the help of light-, electron-microscopy and immunocytochemistry. At the beginning of migrations of passing fish an active synthesis of neurosecretory products in pericarions of neurosecretory cells and their excretion into the cavity of the III brain ventricle was stated, while a mass accumulation of them in neurohypophysis occurs. Firstly, the excretion of neurohormones into the brain's liquor should cause their neurotropic effect on the CNS behavior centers in the form of a dominant state of arousal, designated as “migration impulse”. Then HHNS initiates spawning behavior at the beginning of spawning and completes it by participating in overcoming natural physiological stress. In fish reproduction the main functional role of HHNS is to initiate reproductive energy-intensive processes of migratory and spawning behaviors, and to completion spawning by suppressing the hyperactivity of the target glands, ensuring the body's transition to energy-saving plastic metabolic exchange. The analysis of the key role of HHNS in fish reproduction has allowed to present a constructive working scheme of its neuroendocrine integration by the principle of self-regulation and to develop, on this basis, the system management of biotech reproduction of fish populations.

1 Introduction

Nonapeptidergic neurosecretory cells (NP-NSC) in hypothalamo-hypophysial neurosecretory system (HHNS) are of the most degree plasticity among all NSC of different ergicity, which is provided by their capability for functional reversion [1]. It is shown that they are organized by the principle of the “triad of the balanced system”, which consists of two alternative states: accumulation and release of neurosecretory products and the self-regulating center controlling the dynamics of their interrelations (Fig. 1).

The degree of NP-NSC plasticity turns out to be sufficient for participation in the integration of fish reproduction. It is supposed that the functional possibilities of the key chains of biological integrational systems are realized at different levels of organization by

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this common structural–functional principle as the basis of the high degree of plasticity [1-3].

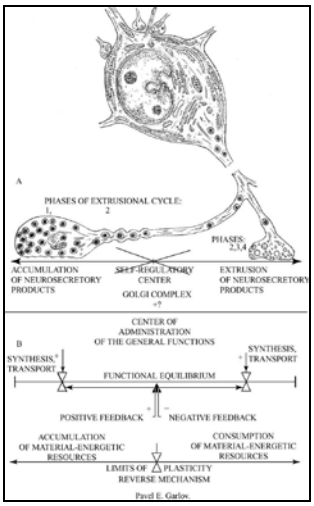

Fig. 1. Principle of structural–functional organization of NP-NSC in fish hypothalamus and neurohypophysis (working scheme) [1]. A – Structural aspect. B – Functional aspect. Their comparison indicates that the principle of organization of ‘‘analytical balance’’ (A) is replaced with an alternate principle of ‘‘lever of action’’ (B) at unbalance of the system.The last effect appears to be proportional to a degree of influence of signal factors (+, - feedback).

By means of ecological-histophysiological and experimental full-system studies using morphometric methods of light-, electron microscopy and immunocytochemistry the participation of HHNS in fish reproduction was firstly established [1]. At the beginning of spawning migrations of sturgeon and salmon there is activation of synthesis neurohormonal products (nonapeptide neurohormones, particularly) in neurosecretory cells of the preoptic nucleus and transport them to neurohypophysis, where, however, their mass accumulation occurs. This violation of the long-adapted type of osmoralulation (at sea-areas during foraging) is the main physiological stimulus of habitat change (from sea to river). At the same time, there is the extrusion of nonapeptide neurohormones from dendrites of neurosecretory cells and its neurosecretory axonal terminals into cerebrospinal fluid (liquor) of the III brain's ventricle, which causes their neurotropic effect in the behavioral centers of the central nervous system in the form of a dominant physiological excitation state – “migration impulse” [2].

At the beginning of spawning, a strong activation of HHNS is established, followed by a decrease in its functional activity by the end of spawning, which reflects its participation in the body's protective and adaptive responses to natural physiological stress (Fig. 2).

Thus, the main functional role of the HHNS in fish reproduction is to initiate energy-intensive processes of migratory and spawning behavior (“spawning reflex”) and to finish spawning by suppressing the hyperactivity of the target glands, which ensures the body's transition to energy-saving plastic metabolism. The analysis of this key role of the HHNS in the integration of fish reproduction, by self-regulation principle, has led to the development of a constructive working scheme on the basis of which effective managing principles have been formulated and new methods of management of breeding, producers survival and youngs growth rates have been developed in order to improve the effectiveness of fish-farm populations reproduction (Fig. 3) [3].

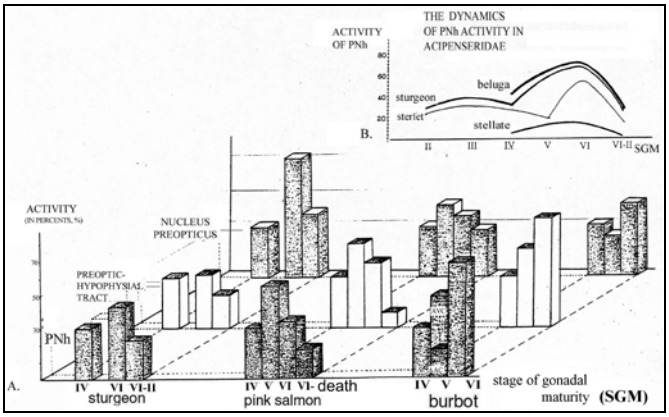

Fig. 2. Functional activity of fish HHNS during spawning: A. – Histogram of the functional activity of all HHNS departments at different stages of gonadal maturity (SGM: IV-VI-II) according to cytomorphometry in light- and electron-microscopic integrated studies; B. **–** The dynamics changes of functional activity HHNS in all studied fish species during spawning. Symbols: PNh – posterior neurohypophysis; II, IV, V, VI, VI-II – SGM.

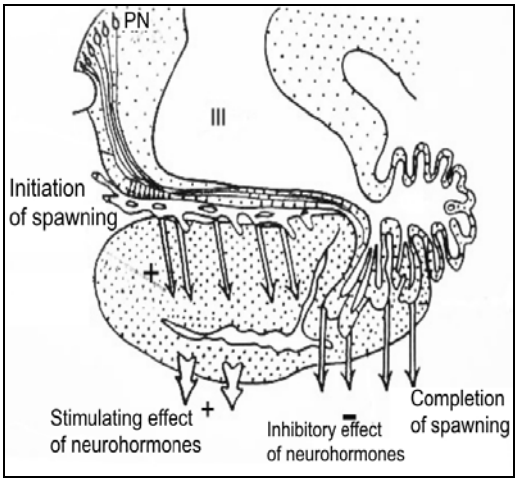

Fig. 3. The basic principle of participation and functional role of HHNS in fish reproduction (principle of self-regulation, by the example of sturgeon).

These methods, combining the effects of complex ecologic and hormonal factors, are presented in the form of 10 inventions. They form a system for managing the fish reproduction biotechnology, which is proposed for use in fish farming and natural conservation fields.

2 Results and discussion

Specifically, in order to increase the degree (%) of fish producers usage in sturgeon farming by stimulating their puberty, a preparate of the isolated anterior pituitary lobe has been developed and introduced into industry (Fig. 4) [4].

For this purpose also, a preparate of the isolated posterior pituitary lobe to stimulate the maturation of male fish in doses, providing waste-free technology of both preparates has been also developed [5]. The increase the degree of fish-breeding use of producers by an average of 15% and save up to 40% of the source biological pituitary material have been

shown by industrial tests of the effectiveness of these drugs at sturgeon farms at the lower Volga and Don rivers [6].

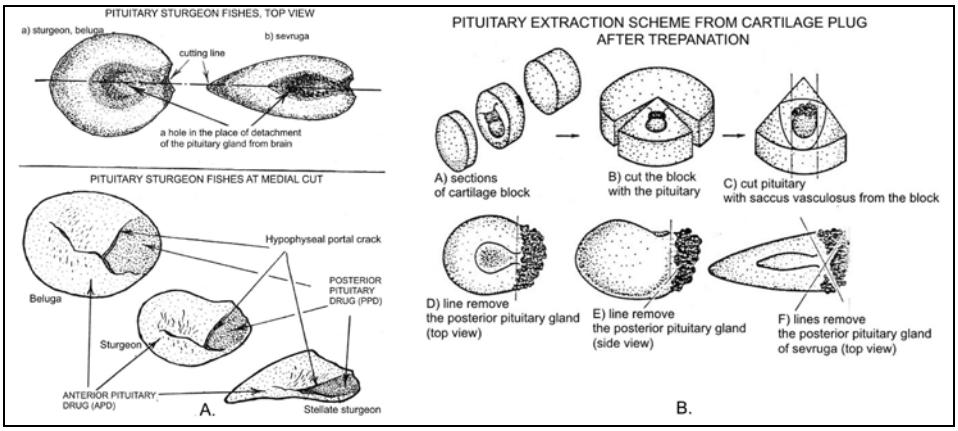

Fig. 4. A. Scheme of sturgeon pituitary gland (hypophysis, pituitary gland drug - PGD: its average optimal dose injection: 30 mg/♀). B. Scheme of pituitary division into anterior pituitary drug (APD: 85 ± 5% of PGD mass) and posterior pituitary drug (PPD: 15 ± 5%).

In order to delay sexual maturation of producers a method of their long-term industrial reserving in the critical salinity medium of 4-8‰, optimal also for maintenance fish brood stocks have been developed [7]. In this habitat the highest survival rate and delayed producers puberty was firstly established and not only in seawater, but also in solutions of industrial table salt of the same concentration.

On this basis, a biotechnology of breeding management was originally developed for farm reproduction of commercial fish populations with different spawning seasons [8]. The ecological and physiological principle of this management is to perform reserving producers in universal (for different fish species and ecological forms), "critical" salinity medium at the species-specific pre-spawning thresholds of "signal" factors (temperature and photo-period) and then to stimulate their maturation and growing youngs by smooth transferring them into a complex of optimal adequate environmental conditions (Fig. 5).

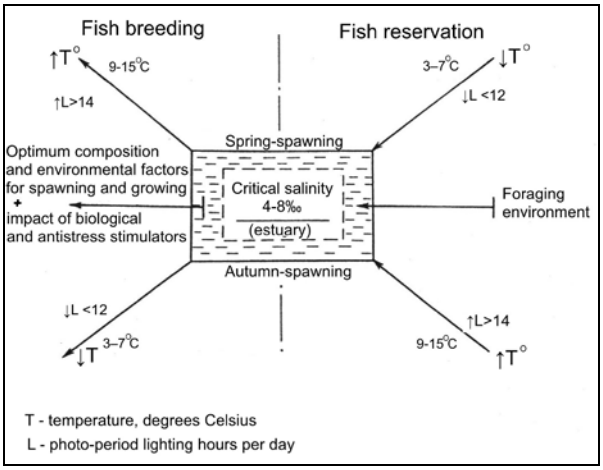

Fig. 5. Principle of fish breeding, reservation and growing acceleration control by the triad of main habitat conditions: signal (T°, L) and phylogenetic (‰) values, providing metabolic (material-energic) body homeostasis based on the primary (ecologic-physiological) mechanism of fish migrations [8].

The new full-system method of artificial reproduction of valuable fish species populations is developed on the basis of additional use of species-specifical phylogenetic adaptations systems of sea foraging, which provide the greatest productivity of populations by the maximum manifestation and usage of adaptive species potentials of breeding, survival and growth (Fig. 6) [9].

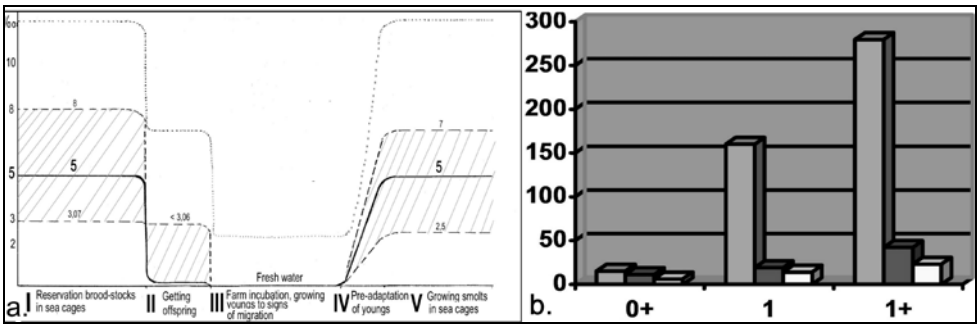

Fig. 6. а. – Salinity changes at main stages of farm biotech. Designations: solid wide curve: optimal salinity, intermittent curve: acceptable salinity, shaded sector: their ranges, point curve: top estimated expected salinity value [9]. **б**. – Comparative body mass indicators of salmon youngs (0-300g; 0+ – one-summer olds, 1 – one- year olds, 1+ – two-summer olds), grown in sea cages (left grey columns), in river fish farm (central) and according to the accepted regional bio-norms (bright right columns).

This method allows to overcome the main shortcomings of the artificial reproduction of salmonid fish biotechnics: low survival in nature (up to 0.4%) of one-year-old factory youths (the final weight of up to 26g) and farm harvesting of producers from spawning grounds at the expense of natural reproduction. The method is carried out by mass harvesting of producers at fishing areas in sea, cages content of brood stocks in brackish sea water (4-8‰) and getting offspring here. Then, after the farm river incubation of fish eggs and the cultivation of larvae and youngs to signs of readiness for migration, grow youngs in marine cages weighing more than 40g, which will ensure their necessary survival in nature, at least 2%. Years of production tests of this method for the first time were established 3 most important fish-breeding and biological effects of growing commercial fish in the medium of critical salinity: 1) the highest survival, 2) long-term preservation of high reproductive quality of producers 3) accelerating the development and growth of youngs.

However, the exclusion of river fishing from spawning grounds affects interests of fish farms and therefore it is proposed firstly to use new our invention in the field of recreational aquaculture to implement the compensation mechanism of feedback in this improved natural-protection system [10].

To further develop new methods in aquaculture, especially year-round fish farming in continental closed water supply systems, the development of a universal method of growing fish in an artificially modified biostimulation medium was started [11]. Its essence is to reserving producers, obtain offspring and then grow youngs in a table salt solution by concentration approximated to isotonic medium, which accelerating the youngs growth rate [12].

Large-scale closed water supply systems for fish farms based on off-season underground conditioning of the fish breeding habitat have been developed in order to industrialize all the proposed biotechnology, develop year-round aquaculture and protect products from pollutions (Fig. 7) [13, 14].

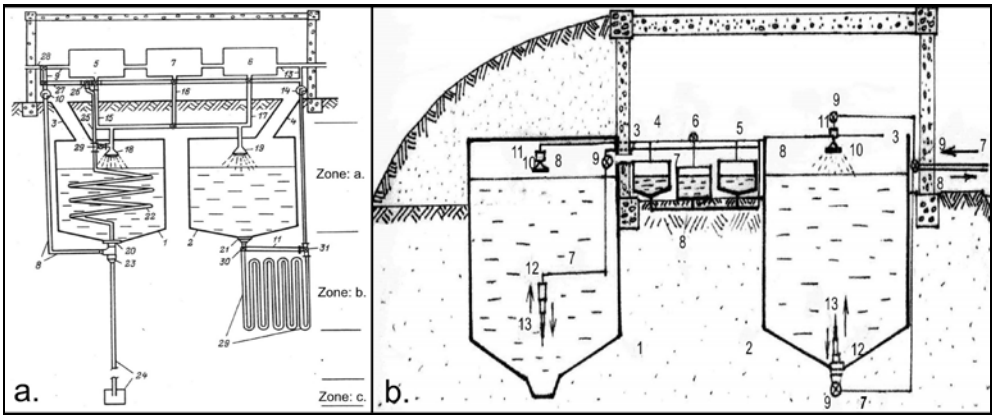

Fig. 7. a. Water supply system of combined type farms for fish species spring- and autumn-spawning reproduction. The system contains 2 underground tanks (1, 2) located below the layer of seasonal frost penetration (zone a.), each of which is connected with fish pools (5, 6), with means of aeration and water purification (7). **b.** Water supply system of the fish hatcheries, which includes sediment tanks, partially buried in the ground (1, 2), fish ponds (4, 5), auxiliary water treatment (6).

These systems operate on a new biotechnology principle of reproduction management and on the natural-industrial principles of engineering ecology, based on the following common biological and bio-geo-ecological patterns (Fig. 7a) [3]:

1) match temperature ranges spring-spawning fish breeding with temperatures reservation autumn-spawning (9-15^{o}C) and vice versa (with 3-7^{o}C), that allows to use 2 temperature modes in two autonomous circulating systems;

2) groundwater and soil temperatures (below freezing) coincide with the seasonal spawning fish bred for local climatic zone (South: sturgeon, carp – 9-15^{o}C; North: whitefish, salmon – 2-7^{o}C with year-round);

3) most common of artesian water temperature (with 5-9^{o}C) close to the essential (3-7^{o}C) tank system 1,

4) any geothermal waters are suitable for additional insulation (with 9-15^{o}C), as well as for different use cases in any system of tanks. Profitability application system must grow in regions with short or generally unfavorable growing season.

Technical-economic calculations shows that already in the volume of water in the tank from 10.000 m^3 speed heat transfer in soil decreases to 0,1^{o}C per month and below, and the degree of water purification progressively increases due to the effect water defense from precipitation. With the increasing volume of reservoirs-hydro-conditioners proportional increases productivity and reduces its system specific cost while maximizing reliability, available for any culture.

3 Conclusion

In the field of biodiversity conservation of North-West region's natural resources, the important problem is to save local population of the Ladoga lake sturgeon as a unique form of Atlantic species. This requires the creation of a sturgeon farm in the Ladoga Lake basin, optimal for the preservation of its natural stock. The presented system of biotechnology management of fish populations reproduction is also proposed for the creation of a sturgeon base farm specialized for North-West region [3].

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