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Electro-technology of feeding fish with flying insects attracted by electro-optical traps

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Abstract. The paper considers the problems of the provision of fish farms with feed and the increase of live feed in the diet of fish, due to the natural food base around water bodies. A review of electro-optical installations for feeding fish with insects attracted to reservoirs by optical emission was carried out. The increase in the efficiency of these electrical installations was achieved by the creation of optical emission with optimal color index coordinates from the point of view of positive phototaxis for insects. The use of electro-optical installations for feeding fish with insects can increase the productivity of ponds, reduce the cost of artificial feed and increase the profitability of fish production.

1. Introduction

One of the most important sectors of food industry in Russia is fishery, designed to supply the population with fish products and ensure the food security of the country. Fish is a source of complete proteins, the presence of which in human bodies supports the normal course of important processes such as metabolism, growth, rehabilitation of the nervous system, reproductive function and thinking [1, 2].

Nowadays the volumes of fish produced in Russia are able to meet the norms of fish consumption by the population established by the Ministry of Health (18-22 kg per person per year). However, as a result of the active export of the catch, the domestic fishing industry is able to meet the needs of the population only partially, namely by 45-48%. In addition to export, the decrease in demand for fish products was caused by the depreciation of the ruble, the transfer of prices from the international market to national one, which led to a significant increase in the cost of fish products. It is possible to solve the problem of the supply of high-quality, and most importantly, affordable fish through the development of fish farms. Inland fisheries can close the market shortage. However, there are difficulties in the provision of farms with high-quality feed, which leads to limited fish stocking and low profitability of production [1, 2].

Artificial feed is produced to meet the needs of fish for the necessary nutrients and energy in order to maintain life when there is an insufficient amount of natural food in reservoirs. As a rule, in the production of compound feed for fish, wastes are used that remain during the processing of livestock, crop, fishing and food industry products. Such concentrated feed is not always nutritionally balanced. This imbalance can contribute to the development of harmful microorganisms, as well as the

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accumulation of heavy metals, pesticides and hydrocarbons in fish. This reduces the profitability of production and poses a threat to the health of consumers of fish production [1, 3].

Unlike warm-blooded animals, fish can not efficiently digest food of plant origin, while the requirements for proteins and lipids in fish, as well as the degree of their assimilation, are much higher (80-95% in full-grown fish, in juveniles this indicator is lower). The consumption of unbalanced feeds causes their overconsumption, leads to slow growth of fish, occurrence of diseases of digestive tract, accumulation of fats and, consequently, a decrease in the nutritional value of products. The increase in fat content in fish body is associated with the cost of the assimilation of substances that are not used to build mass. It is also necessary to take into account the technological parameters of the feed pellets. With insufficient water resistance and particle density, the degree of dissolution of feed in water will increase. This will entail the increase in losses during the introduction of feed, create the environment for diseases and affect the ecology of reservoirs [1, 3].

In order to saturate the diet of fish with the necessary nutrients and reduce the consumption of concentrated feed, it is possible to use the resources of the natural food base of reservoirs. Attracting insects by optical emission, the content of live food in the diet of fish is increased. Thereby it strengthens its immunity and accelerates the gain in live weight. For this purpose, various electro-optical devices can be used in order to attract insects to reservoirs [1].

2. Materials and methods

There are autonomous electro-optical converters [1, 4] created to attract mosquitoes in order to increase the number of eggs they lay in reservoirs in places accessible for fish. The optical emission of the attractant lamps affects the visual organs of mosquitoes, attracting them to the converter. A floating platform is located near it, creating favorable conditions for swarming. Mosquitoes, attracted by the light, sit on the platform and lay their eggs. Larvae subsequently hatch from these eggs, some of which are eaten by fish. The electro-optical converter [4] has LED source of optical emission, which operates in the evening and morning hours, during the active summer of mosquitoes. Power is supplied from a rechargeable battery charged during the day from a solar module. The chromaticity of the optical emission attracting mosquitoes is tuned to the optimal chromaticity coordinates (x_{OPT} = 0.2294; y_{OPT} = 0.2366), corresponding to the maximum phototaxis effect.

LED electro-optical converter with a variable color of emission has high efficiency of attracting mosquitoes by optical emission [1, 5, 6]. The increase in the number of mosquitoes attracted by the installation is achieved through the regulation of optimal (from the point of view of positive phototaxis) color index of LED emission depending surrounding air temperature in accordance with the expressions [1]:

$$\begin{cases} x_{OPT} = 1.070 - 4.714 \cdot 10^{-2} t_A + 6.287 \cdot 10^{-4} t_A^2; \\ y_{OPT} = -0.1323 + 1.835 x_{OPT} - 1.896 x_{OPT}^2, \end{cases} \quad (1)$$

where x_{OPT}, y_{OPT} – optimal color index coordinates of emission attracting mosquitoes; t_A – surrounding air temperature, °C.

When the air temperature rises in the range corresponding to the active fly of mosquitoes, the optimal color index shifts from orange-red shades to blue-violet ones (Figure 1).

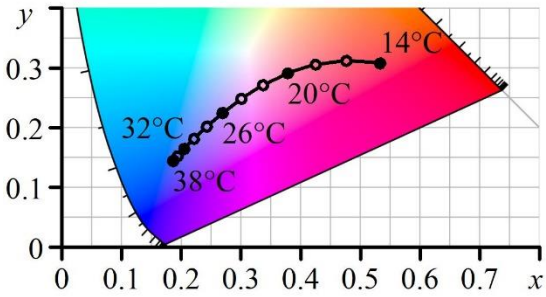


Figure 1. Graphic interpretation of the model (1) on CIE 31 Color index atlas

The developed device regulates the optimal color index coordinates of LED emission in accordance with equations (1) within the limits $\Delta x = 0.5330…0.1862$ and $\Delta y = 0.3073…0.1437$ for the operating range of air temperatures $\Delta t_A = 14…38$°C. The color of light-emitting diode (LED) emission is changed by the regulation of the currents through light-emitting crystals with emission of different colors: R - red, G - green, B - blue. The stabilization and PWM regulation of currents is carried out by linear LED drivers. They are supplied with control voltage signals from the microcontroller with programmed settings for the color control of emission, which are the dependences of *D* coefficient dependences of eight-bit PWM signals (with a frequency of 1.96 kHz) for each of the RGB-LED crystals (Figure 2). The air temperature is controlled by a digital temperature sensor [1].

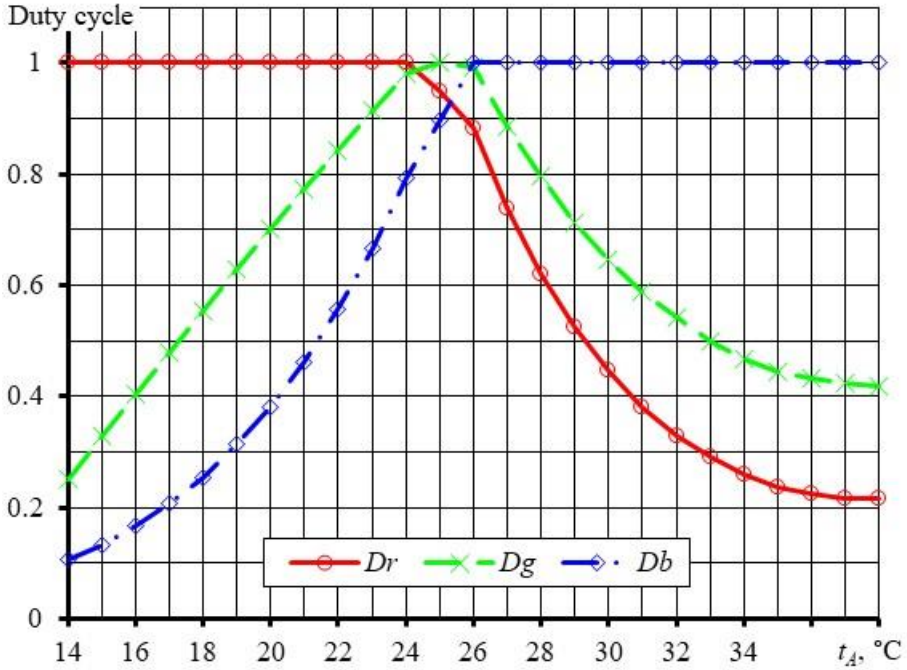


Figure 2. Changes in filling rate of PWM signals from air temperature

The light-technical parameters of LED emission depend on three main factors: forward current, the temperature of the active region of the light-emitting crystal and the operating time. Modern LEDs are capable of operating at currents 1.5-2.5 times higher than their nominal value without a significant decrease in efficiency. The important condition for maintenance of LED operability and its long service life is to provide an acceptable temperature regime for light-emitting crystal up to a temperature of 60-80°C, although crystals can function at temperatures up to 115-120°C. Despite the

high efficiency of LEDs, a significant part of the electrical power they consume is converted into heat, due to which LED is heated [7].

In order to ensure efficient heat removal from the crystal, it is necessary to use a cooling radiator. Heating a light-emitting crystal to 70°C can cause a decrease in the luminous flux by 10-20%. Therefore, the important task in the design of LED light sources is to calculate LED operating temperature [5]. For this purpose, by means of computer simulation, the dependences of the temperature change of R-, G-, B-crystals LED, LED solder point and heatsink from air temperature were obtained (Figure 3) [7, 8].

The optimal color index of the attractive emission changes in accordance with expression (1) by PWM regulation of the currents going through the light-emitting crystals. It depends on air temperature (Figure 1). Therefore, the values of the currents of R-, G-, B-crystals (Figure 2), and, consequently, the thermal power released in them, also vary depending on air temperature. By controlling the chromaticity of LED emission, the maximum heat release in it is observed at air temperature of about 25-26°C. With the increase in the temperature t_A from 14 to 26°C, there is a significant almost linear increase in the temperatures of R-, G-, B-crystals LED (Figure 3). Further, despite the increase in air temperature from 26 to 33°C, the operating temperatures of LEDs decrease. At t_A above 33°C, the temperatures of RGB LED elements rise smoothly. The maximum heating of R-, G-, B-crystals is close to 80°C and corresponds to air temperature of 26°C (Figure 3) [7].

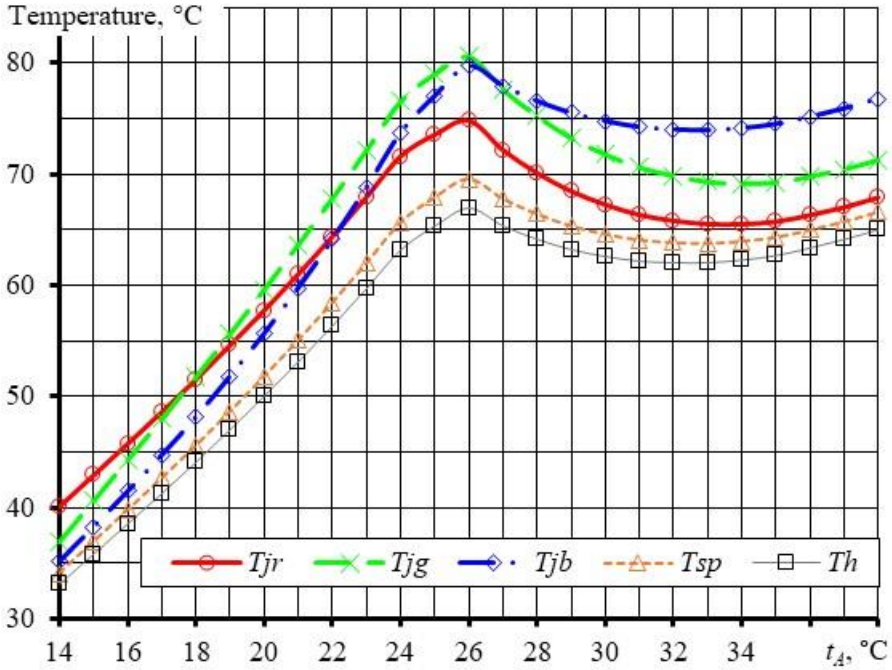


Figure 3. Dependences of changes in temperatures *Tjr*, *Tjg*, *Tjb* (corresponding to R-, G-, B- crystals LED) *Tsp* (LED solder point) and *Th* (heatsink) on air temperature

Apart from the increase in the number of larvae laid by mosquitoes, which are used as food for fish, adult insects (at the stage of development of imago) can also be used to increase the proportion of live food. In electro-optical converters used to attract flying insects for feeding fish, a rotating unit (flexible line, fan, etc.) is mainly used as a means of destruction. The operation of these installations is associated with the need for regular cleaning of fishing line, fan, emitter, replacement, cleaning the storage for caught insects, etc.

The shading of emission source by insects reduces the efficiency of installation. The use of attractant source submerged in water in an electro-optical converter for feeding fish [1] allows simplifying the operation of this installation, making only seasonal cleaning of tight RGB-LED strip.

Under the influence of optical emission from a source-attractant immersed in water, insects are forced to change their flight path to the surface of the reservoir. Insects of various species, caught on the water or flying close to its surface, become prey for fish. This solution made it possible to significantly simplify the design of the installation and improve the practicality of its use in the conditions of inland fisheries [1].

During the use of sources-attractants immersed in water, it is necessary to take into account the distortion of the color of their light due to the selectivity of water and the impurities contained in it for the absorption of optical emission. Water most effectively absorbs optical emission with wavelengths of 365-405 nm and over 650 nm. The smallest effect is at a wavelength of 435-540 nm. A high content of impurities in water significantly increases the absorption of emission in blue-green and yellow-red spectral regions [1].

A fan is often used as a damaging unit in electro-optical converters [9]. Figure 4 shows a block diagram of an electrical installation with a fan for feeding fish with mosquitoes. Three RGB LEDs generate optical emission with optimal color index (Figure 1), attracting insects to the converter. A fan installed under the lighting module draws in attracted mosquitoes and damages them with its blades. All this insects' mass nutrient for fish falls on the surface of the reservoir and fish eaten it.

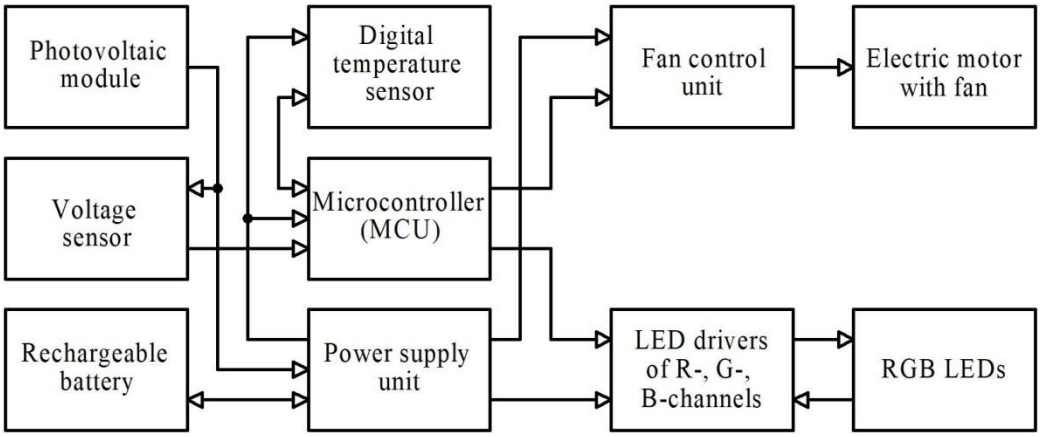


Figure 4. Block diagram of electro-optical converter for feeding fish with mosquitoes

The power supply of the electro-optical converter for feeding fish with mosquitoes (Figure 4) is carried out from a storage battery, charged during the day from a photovoltaic module. This ensures the autonomy of the electrical installation. LEDs and a fan turn on during the active summer of mosquitoes to light in evening and morning hours. The level of natural light is controlled by the voltage at the output of the photovoltaic module.

3. Conclusion

Nowadays the difficulties in the provision of fodder to artificial inland fisheries slow down the development of fish farming industry. The increase in the proportion of live food obtained from the natural food base around water bodies can improve the quality of fish feeding. For this purpose, it is advisable to use electro-optical converters for feeding fish with flying insects.

During the development of these electrical installations, RGB LEDs are used as attractant sources, which allow creating optical radiation of various colors. The use of a color stimulus during phototaxis increases the efficiency of attracting flying insects. It was found that the optimal color of emission

attracting insects can vary depending on air temperature. The use of electro-optical converters for feeding fish makes it possible to increase the content of live feed in the diet of fish, which has a beneficial effect on its health and development, reduces the cost of artificial feed, increases the productivity of ponds and increases the profitability of fish production.

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