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RESPIRATORY MOVEMENTS OF TROUT (*SALMO TRUTTA* L.) LARVAE DURING EXPOSURE TO MAGNETIC FIELD*

RUCHY ODDECHOWE LARW TROCI (*SALMO TRUTTA* L.) PODCZAS EKSPOZYCJI W POLU MAGNETYCZNYM

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The effect of steady magnetic field on movement velocity of pectoral fins in trout (*Salmo trutta* L.) larvae was determined. Newly hatched trout larvae were exposed to magnetic field (51–70 mT). Steady magnetic field was found to cause an increase in movement velocity of pectoral fins of larvae. The number of movements increased significantly until the 6th min after magnetic field application, whereupon – beginning from the 9th min – it gradually dropped.

INTRODUCTION

During their embryonic development fish lack specialized respiratory organs and therefore initially they respire through the whole body surface. In fish this way of respiration is maintained throughout their whole life; its importance decreases, however, in parallel with the development. In the larval period when the hemopoietic system is already present, the functions of the respiratory system are fulfilled by a network of yolk sac vessels, "germs" of unpaired fins, pectoral fins and subsequently by the developing gills. Pectoral fins of larvae contribute in an essential manuer to the respiration process; namely, their movements cause inflow of water to the yolk sac system and to the developing gills. Therefore, the pectoral fins remain in steady movement, this allowing for better oxygenation of circulating blood, whereas the "germs" of other gills display no such a motility.

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Studies of the effect of magnetic field on living organisms have confirmed that animals, including fish, are sensitive to magnetic field (Kalmijn, 1978; Quinn, 1980; Kirschvink et al., 1985; Lindauer and Martin, 1985; Maret et al., 1986; Carstensen, 1987).

In studies of the sensitivity of salmonids to magnetic field we have found that a field of an induction between 51–70 mT caused an increase in the number of myocardial contractions in trout larvae (Winnicki and Formicki, 1990); this was accompanied by disturbances in the motor activity of the pectoral fin muscles. In this connection we resolved to observe in detail the effect of magnetic field on the motor activity of pectoral fins in trout larvae.

MATERIAL AND METHOD

The material comprised Baltic trout (*Salmo trutta* L.) larvae. Fertilized eggs were incubated in miniincubators at a constant temperature of 7 ± 1°C.

The hatched larvae (11 individuals) were placed singly in a cylinder-shaped chamber (internal ϕ 15 mm) on a microscope table cooled with water (9°C). The larva placed in the chamber could change its position.

After preliminary adaptation of the larva (30 min), on both sides of the chamber bar-shaped permanent magnets were applied. With a distance of 18 mm between magnet poles, the induction of the magnetic field was 51–70 mT (Fig. 1). Field intensity was measured with a TH-26 Hall generator meter. In the control test magnet dummies were applied. The microscope was connected with a TV-camera, and the movements of the pectoral fins of larvae were recorded on a video-recorder tape.

The recorded movements of the pectoral fins of larvae were reproduced at a slowed-down speed. This allowed for counting all movements of the pectoral fins prior to and after application of the magnetic field, and permitted their detailed analysis.

For statistical treatment we applied two-way analysis of variance (ANOVA, LSD), where 1-min time intervals were the first factor and the individuals studied – the

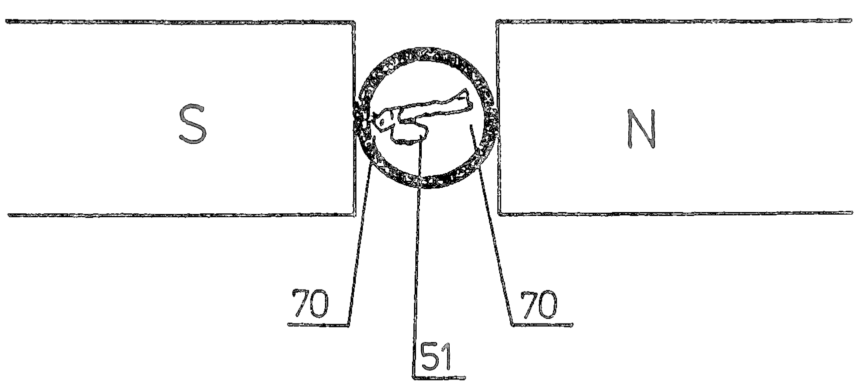

Fig. 1. Position of the chamber between magnet poles (description in text)

second factor; the replications consisted in each minute of 5-sec time intervals, from which the total number of larval fin movements was counted. Moreover, the regression analysis was carried out (Elandt, 1964).

RESULTS

The numbers of pectoral fin movements in trout larvae, found after application of magnetic field, are illustrated in Fig. 2. The results indicate that immediately after application of magnetic field the number of these movements increases significantly. The significance ($p < 0.001$) of the differences in the pectoral fin movements between control and larva exposed to magnetic field was proved by two-way analysis of variance (ANOVA, LSD). The motor activity of fins rises significantly until the 6th min of the experiment whereupon – from the 9th min – it slowly decreases. To account for the effect of individual differences on the final results of the experiment, the changes in the pectoral fin motor activity were referred to control (accepted as zero level), whereupon the analysis of variance was calculated once again; the differences were found to be significant ($p < 0.001$) (Elandt, 1964).

Changes in the numbers of pectoral fin movements over time were described in the form of a function, using regression analysis. The model best describing the dynamics of changes was formulated by the function:

$$y = -0.69\,t^2 + 9.07\,t + 257.88$$

the coefficient of determination was 6%; the model was significant.

When the results were referred to control accepted as zero level, the model best describing the dynamics of changes was formulated by the function:

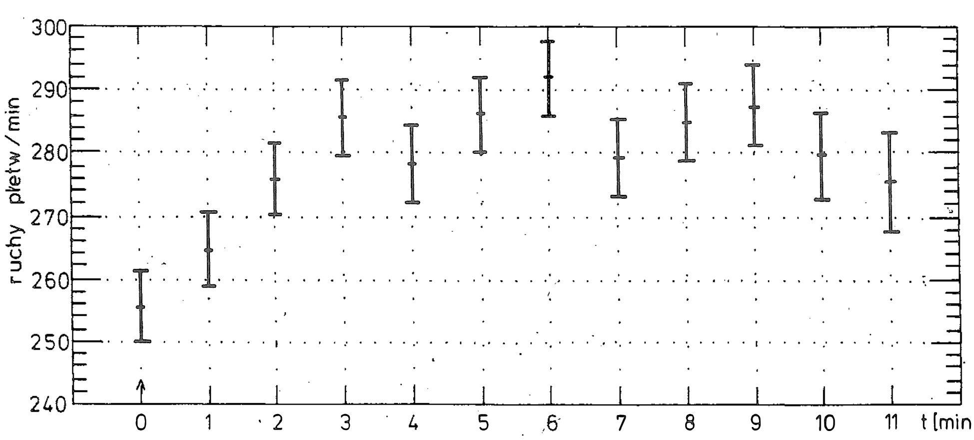

Fig. 2. Movement velocity of pectoral fins of trout larvae in control and the applied magnetic field; ↑ – arrow denotes moment of magnetic field application

$$y = -0.33\,t^2 + 4.01\,t + 0.59$$

the coefficient of determination was 32%; the model was significant.

DISCUSSION

According to the present results, larvae of salmonids are sensitive to magnetic fields stronger than the Earth's magnetic field. Artificially produced magnetic field induces in trout larvae an increase in the motility of pectoral fins, correlated in time with a periodic rise of the myocardial activity (Winnicki and Formicki, 1990).

This phenomenon caused by application of magnetic field could possibly result from acceleration of the metabolic processes in the organism of the larva, leading to an increase in oxygen requirement. This is hardly possible, because there is no rise of the motor acitivty of the larva, forcing a higher oxygen requirement; moreover, the occurrence of such an instantaneous, short-lasting enhancement of the biochemical processes in the organism of the larva is unlikely.

It seems most probable that magnetic field causes a decrease in the permeability of limit membranes in capillary vessels and respiratory epithelium. This is followed by a drop in the oxygen diffusion rate, and thus in the amount of oxygen penetrating into blood and tissues per time unit. Maintenance of this state could lead to asphyxia. This is prevented by a compensatory action of the organism, initiated by the first link, i.e.mycocardial muscle. After a short latent period, cardiac action is enhanced; the number of myocardial contractions is highest between the 2nd and 7th min of exposure to magnetic field (Winnicki and Formicki, 1990). Acceleration ot cardiac action causes an increase in the blood circulation rate, this leading to relatively normal gas exchange in the respiration proces. The heart cannot, however, work under such stress loading conditions for too long a time. The organism tends to restore the physiological conditions; thus, during cardiac action acceleration, there is intervention of the second link of the compensatory proces in the form of an enhanced motor activity of the pectoral fins driving greater amounts of oxygenated water into the respiratory apparatus of the larva.

The number of pectoral fin movements is greatest between the 3rd and 9th min after magnetic field application (Fig. 2). The slight drop in this number in the 4th min is probably related to stabilization of blood oxygen content.

The increase in the inflow of oxygenated water to the respiratory apparatus of the larva allows for survival of the difficult conditions induced by exposure to magnetic field and for gradual adaptation to the changed environmental conditions.

In this connection, the need arises to elucidate the character of the effect of magnetic field on the young organism of the larva. It probably involves an instantaneous spontaneous effect manifesting itself by "tightening" of cell membranes and reduction

of their permeability, reflecting the reaction of liquid crystals present in the membranes to external magnetic field (Lösche, 1973; Rościszewski, 1973; Wadas, 1978). In the later period this permeability is, however, increased owing to adaptative mechanisms. Therefore, the observed overall reaction of the larva may be considered as stress reaction which permits survival until adaptation to the changed environmental condition.

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STRESZCZENIE

Badano wpływ stałego pola magnetycznego na szybkość ruchu płetw piersiowych larwy troci (*Salmo trutta* L.) Świeżo wylęgnięte larwy troci, umieszczone w okrągłej komorze, poddano działaniu stałego pola magnetycznego o wartości 51–70 mT (Rys. 1). Szybkość ruchów płetw piersiowych larwy rejestrowano przy użyciu techniki video. Odtworzenie obrazu w zwolnionym tempie umożliwiło policzenie wszystkich ruchów płetw piersiowych larwy przed i po przyłożeniu pola magnetycznego. Stwierdzono, że stałe pole magnetyczne powoduje zwiększenie szybkości ruchów płetw piersiowych larwy. Ilość ruchów istotnie zwiększała się do szóstej

minuty od momentu przyłożenia pola, a następnie, począwszy od dziewiątej minuty, stopniowo się obniżała (Rys. 2).

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