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A NEW COEFFICIENT FOR EVALUATION OF CONDITION OF FISH LARVAE

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Abstract: We propose a new coefficient for evaluation of condition of fish larvae, based on fish body measurements in photographs, as an alternative to Fulton's coefficient. The study was done on young stages of common carp kept under laboratory conditions. The obtained results show that in the first period after hatching, carp larvae grow mostly in length, and adverse environmental factors such as water contamination with copper may reduce their growth. The new coefficient is calculated according to the formula: $S=2Pa\times l^{-2}$, where Pa – body perimeter area, l – body length. The values of this new coefficient increase with fish age, and are always higher for the control larvae (0.26-0.43) than for the copper-exposed ones (0.24-0.36). Having body perimeter area, it is also possible to calculate the regression equation for the area/mass relationship, and to estimate the value of Fulton's coefficient.

Keywords: Fulton's coefficient, fish, condition, growth, copper

Introduction

Growth of fish larvae and juveniles is very fast. Many environmental factors influence growth: temperature, accessible alimentary base and presence of toxicants belong to the most important. Under optimum conditions – at appropriate temperature and at sufficient quantities of food, the fish increase in both: body length and mass (Park and Zhang 1998; Keckeis et al. 2001; Korwin-Kossakowski and Ostaszewska 2003; Rowe 2003; Vosylienè et al. 2003). On the other hand, in the water polluted with toxicants, e.g. heavy metals fish growth may be inhibited (Alabaster and Lloyd 1980; Hellawell 1989; Jezierska and Witeska 2001). Inhibition of growth is one of the most distinct symptoms of toxic action of metals on fish larvae (Woltering 1984; Norberg-King 1989). Therefore, fish body length and mass are indicators of environmental conditions. Another good indicator is condition coefficient. Weighing of fish, necessary for Fulton's coefficient calculation is very difficult in fish larvae, because drying them to obtain accurate weight often results in their death. Nowadays, evaluation of fish growth using photographs and computer image analysis system is possible. We propose a new coefficient for evaluation of condition of fish larvae, based on fish body measurements, as an alternative to Fulton's coefficient.

Material and Methods

Larvae and juveniles of common carp kept under laboratory conditions were used in the experiment. The fish were placed in tanks with dechlorinated clean tap water (temperature 22ºC, dissolved oxygen saturation about 90%, hardness 210 mgL^{-1} as $CaCO_3$, pH 6.7) at the density of 300 fish per 180 L. Water was changed every 3 days. The fish were fed brine shrimp nauplii ad libitum, three times a day, and from the twentieth day, additionally with dry feed. Immediately after hatching, the larvae were divided into two groups: control reared in clean dechlorinated tap water, and Cu-exposed (Cu) reared in tap water + 0.2 mgL^{-1} Cu (as $CuSO_4*5H_2O$).

The fish were weighed (with 0.01 mg accuracy) and photographed using digital camera connected with stereoscopic microscope, and the computer image analysis system MultiScan. Body length and body perimeter area of larvae were measured in the photographs. In series I, measurements were done from the 20 to 45 day after hatching, (in 20 fish randomly sampled from each group every 5 days), and in series II from the 20 to 30 day after hatching (25 fish were randomly sampled daily from each group). The fish of series II were only photographed, and not weighed. For series I, the Fulton's coefficient $K=W\times l^{-3}\times 100$ was calculated using the obtained results of body mass (mg) and lengths (mm). The results were subjected to statistical analysis (one-way ANOVA, and post-hoc Duncan's test $p\leq 0.05$) using Statistica program.

Results and Discussion

The influence of metal exposure on growth of carp larvae under laboratory conditions is shown in Fig. 1 (A, B, C). The increase rate of fish body length was quite steady but faster in the control. The average length of 45 days old control larvae was 18.32 mm which was almost twice higher in comparison to the average length of larvae on the 20 day after hatching. The Cu-exposed larvae after 20 days of exposure were shorter than the control ones, and after 45 days reached only 13.91 mm, which was equal to 76 % of body length of the control larvae. They were significantly shorter than the control fish, begining from the 25 day after hatching (with exception of the 40 day) (Figure 1 A). The increase in body perimeter area of larvae was slow until the 30 day of life, but later became much faster, especially in the control. After 45 days of the experiment it was over six times higher than on the 20 day. The average perimeter areas of 20 days old larvae from the control and Cu groups were 11.88 and 9.13 mm^2, respectively, of the 30 days old ones – 21.95 and 14.29 mm^2, while of the 45 days old fish – 74.32 and 34.75 mm^2. After the end of the experiment, perimeter area of Cu-exposed larvae comprised only 48% of perimeter area of control fish. The values significantly differed on the 25, 30, 35 and 45 day after hatching (Figure 1 B).

Even greater differences in fish growth are visible in Figure 1C, representing changes in fish body mass. The average value of body mass of the control fish increased from the 20 day after hatching about nine times, and reached after 45 days of experiment 91 mg. The copper-exposed fish grew considerably slower and reached only 32 mg which was equal to 37% of mass of control fish. The statistically significant differences occurred on the 30, 35 and 45 of day after hatching.

The obtained results show that in the first period after hatching, carp larvae grow mostly in length, and adverse environmental factors such as water contamination with copper may reduce their growth. Reduction of fish growth by copper was reported by e.g. Buckley et al. (1982), Collvin (1984), Vosylienè and Petrauskienè (1995), Marr et al. (1996), Słomińska and Jezierska (2000). The perimeter area and body mass were similarly but even more affected by toxic action of metal, especially after the 30 day of carp life.

The obtained results were used for calculations of condition coefficients of the fish. The coefficient K calculated using the

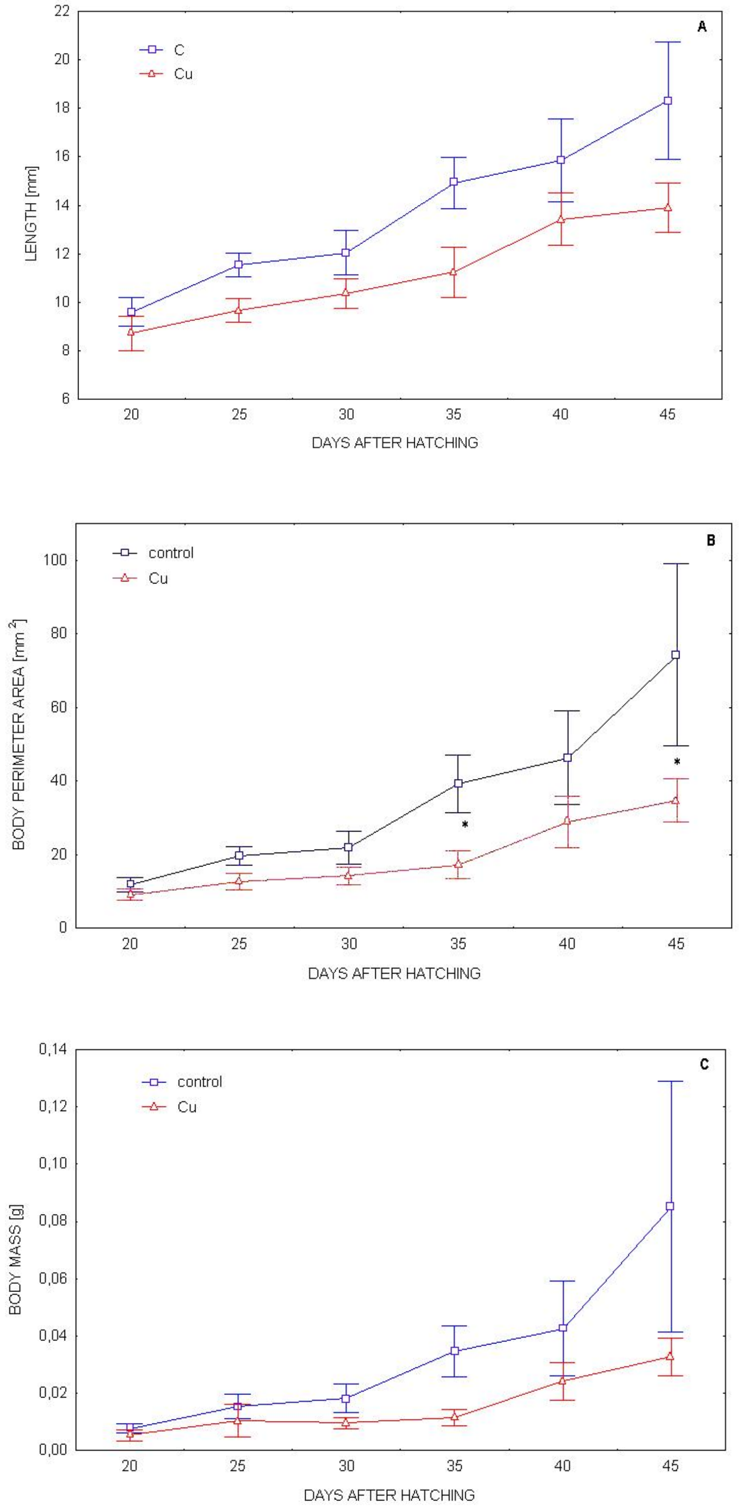

Figure 1. Growth of common carp larvae under laboratory conditions (series I, n=20 mean±S.D.
A – length, B - perimeter area, C - mass, (* - significantly different from the control)

values of larval body length and mass (Figure 2) shows considerable variability. The average value of condition coefficient of control fish at the age of 20-40 days was about 1.0, and increased after the 45 day after hatching. The average value for the Cu-treated fish was lower, (except for the 25 day after hatching) but the differences were not statistically significant. These results are similar to those obtained by the other authors, cited by Jezierska and Witeska (2001), that indicate higher efect of metal exposures on body mass than on the length. Changes of body mass are closely related to fish condition. Vosylienè and Petrauskienè (1995) reported greater toxic influence of metals on rainbow trout weight than on length, and additionally obtained lower Fulton's coefficient for the metal-exposed fish.

Basing on the value of body area of fish calculated as 2×Pa (instead of body mass), where Pa – perimeter area (neglecting body thickness) we propose a new condition coefficient:

$S = 2Pa \times L^{-2}$.

The values of this coefficient increase with fish age (Figure 3), and are always higher for the control larvae (0.26-0.43) than for the copper-exposed ones (0.24-0.36). The significant differences occurred on the 35 and 45 day after hatching. The values of S coefficient are also considerably less variable comparing to the Fulton's coefficient. It seems that S coefficient is better than Fulton's coefficient for evaluation of fish condition at early developmental stages.

Comparison of the relationship between the body perimeter area and mass for the control and Cu-exposed fish (Fig. 4 AB) shows a distinct correlation between these parameters. For the control fish, correlation coefficient was r=0.94853, and for Cu-treated ones r=0.93896 ($p<0.05$). The obtained results show that metal affects more body mass than the area. Relationship between the body perimeter area and mass of fish is expressed with the equation $y=-11.274+0.636\times x$ for control fish, and $y=-3.609+0.493\times x$ for Cu-exposed ones (x – body perimeter area, y – body mass).

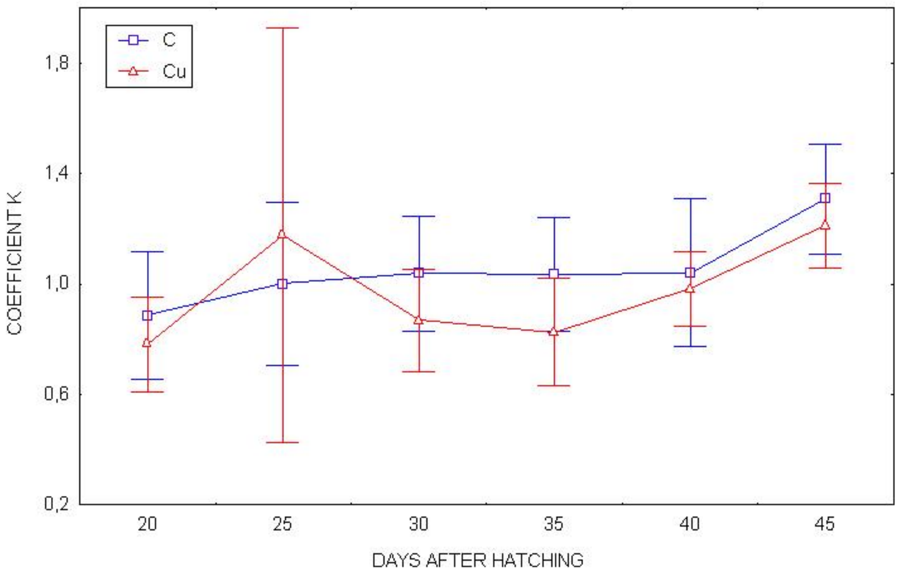

Figure 2. The changes of Fulton's coefficient K (series I, n=20),

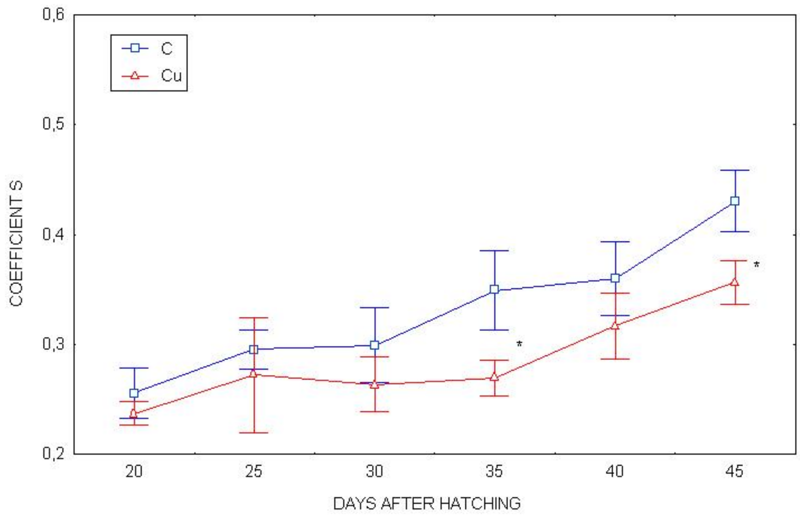

Figure 3. The changes of S coefficient during experimental rearing of common carp larvae (series I, n= 20 * - significantly different from the control)

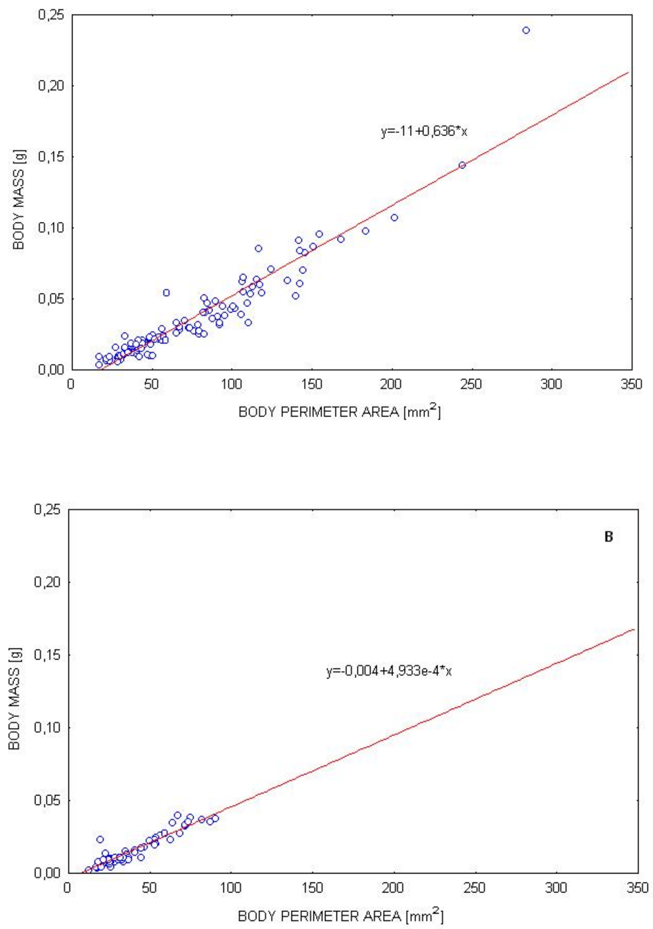

Figure 4. Relationship between the body area and mass of common carp larvae (series I, n=20 A – control, B - Cu).

These equations were used for calculation of body mass from perimeter area, and the obtained values were used for estimation of the Fulton's coefficient K* (Figure 5). The values of this coefficient fit within the range 0.89-1.31 for the control fish, and 0.72-1.12 for Cu-exposed ones. Similar calculations were done for the fish from series II, which were not weighed. In Figure 6 the changes of coefficient S are shown. These results confirm those obtained for series I, the value of coefficient for the control fish ranged from 0.27 to 0.33 and for Cu-treated ones - from 0.23-0.27, showing lower condition of fish subjected to copper. Figure 7 shows the changes of coefficient K* estimated using the values of body mass calculated from the relationship between the body perimeter area and mass of fishes in series I. The values of this coefficient for the control fish was within the range of 0.94-1.04, and for Cu-exposed ones 0.87-0.94. This way of estimation of Fulton's coefficient allows to compare the results obtained in the studies of fish larvae with the data obtained by the other authors. Our results indicate that:

1. Body measurements done in the photographs, and simultaneous weighing of representative sample of each experimental group allows for calculation of Fulton's condition coefficient, and of a new condition coefficient S the calculation of which does not require weighing of the fish. Having body perimeter area, it is also possible to calculate the regression equation for the area/mass relationship, and to estimate the value of Fulton's coefficient.

2. The equations of area/mass relationship may be used for estimation of Fulton's coefficient to:

a) evaluate condition of individually observed larvae that cannot be weighed because of the risk of death,

b) evaluate condition of large groups of larvae if there is no enough time for detailed measurements during the experiment, and only the photographs may be taken in order to make measurements later.

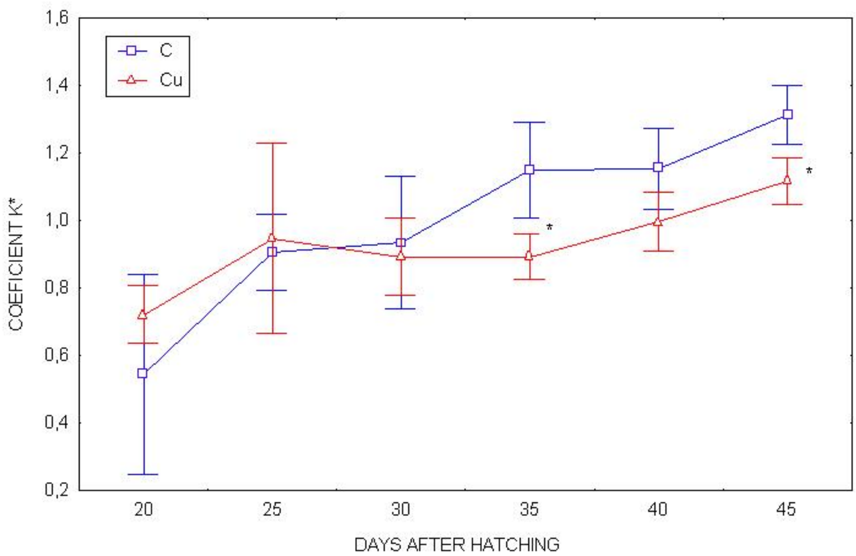

Figure 5. The changes of Fulton's coefficient K* (series I, n=20)

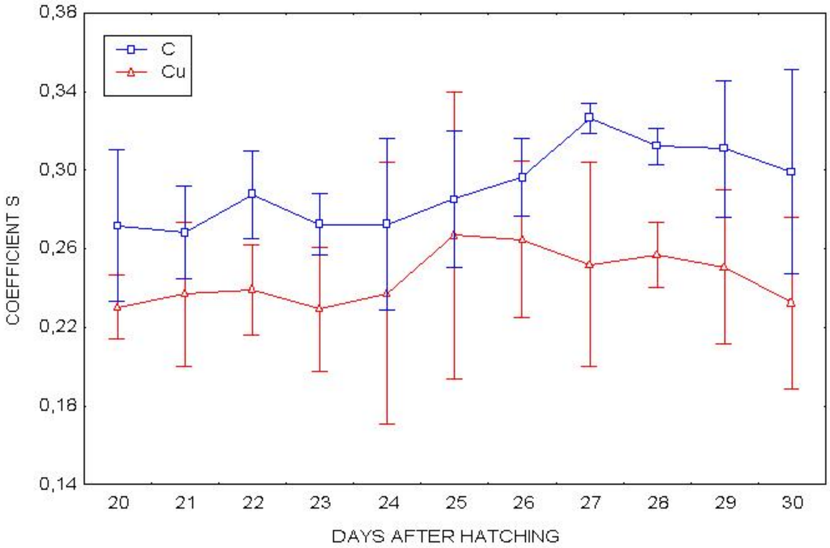

Figure 6. The changes of S coefficient (series II, n=25)

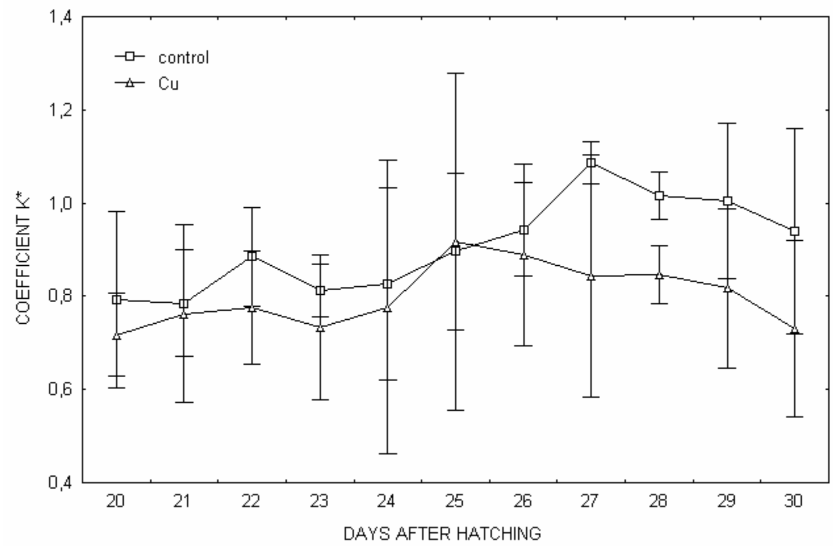

Figure 7. The changes of Fulton's coefficient K* (series II, n=25)

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