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FORMATION AND GROWTH OF SCALES IN JUVENILE VIMBA *Vimba vimba* (L.) UNDER EXPERIMENTAL CONDITIONS

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A B S T R A C T. Body-scale relationship was analyzed for two groups of vimba juveniles: fed with nauplii (AN group), and with decapsulated cysts of brine shrimp (*Artemia* sp.) (AC group), at 25°C. A curvilinear body-scale relationship was developed and described with an exponential function. Fish lengths at the beginning of scale formation were 24.34 mm and 23.12 mm in AN and AC groups, respectively. Formation of scales in vimba was related to the growth conditions of fish. Body growth and scale growth were unequal (allometric), and related to stadial type of development.

Key words: *VIMBA VIMBA*, SCALES, FORMATION, GROWTH, BODY-SCALE RELATIONSHIP.

INTRODUCTION

An accurate back-calculation of fish length requires knowledge of details of scale formation and initial growth of scales. In many papers body length of fish during scale formation is mentioned, especially for cyprinid fishes such as: asp, orfe, crucian carp, white bream, bream, roach, bleak, rudd, and for percid and centrarchid fishes (Konstantinov 1957, Balon 1956, Lange 1960, Gerking 1966, Rider 1968, Hile 1970, Koblickaja 1981, Heese 1992). Time of scale formation was also stated for larval development of common carp, tench, chub, and nase (Prawocheński 1963, Penaz 1974, Penaz et al. 1983, Economiou et al. 1991, Pyka 1995). Data concerning vimba are scarce. Pliszka (1953), in the study of vimba development described postembryonic stage of scale formation. Iwaszkiewicz (1959) found that the scales in vimba appear in eighth week of postembryonic development. Both authors stated that scale formation takes place at the end of larval stage, when fin folds disappear, especially preanal fold.

The aim of the present study was observation of scale formation and their subsequent growth in first weeks of vimba life, under controlled conditions, at constant temperature and various feeding. Presented relationship between scale size and fish length in time refers to stadial allometry and methods of back-calculation of fish length.

MATERIAL AND METHODS

Larvae of vimba of the same origin were divided into two groups: fed from the 5th day after hatching with brine shrimp youngest nauplii (AN group), and with decapsulated cysts of that crustacean (AC group). Both groups, 25 fish each, were reared in two aquaria ($V = 3\ dm^3$) continuously supplied with heated and aerated recirculating water, purified using diatomite bio-mechanical filter. Temperature in both aquaria was maintained at 25°C (±0.5°C). Observations were carried out for 27 days, beginning from the 20th day after hatching. Fish were sampled daily, one at a time, at random.

Fish were measured (total length - l.t.) with 0.1 mm accuracy, and examined using binocular microscope at 10-25x magnification. Scales were sampled using preparatory needle, from central body part, between first rays of dorsal fin and lateral line (Steinmetz, Müller 1991). For comparison, also scales from caudal region were taken, above anal fin. Scales were placed on the object slide, in a drop of distilled water, oral zone up, and viewed at 40x magnification. Scale growth was measured as a number of circuli, basing on highly significant correlation between circuli number and length of scale radius (Tuszyńska, Sych 1983). Fish length in AN and AC groups was compared using t-Student's test.

Body-scale relationship was calculated from the data on fish that already developed scales. Number of fish were: $N_{AN} = 19$, and $N_{AC} = 17$. Body-scale relationship was described with an exponential function developed using Statistical Graphics System 2.0. From that function, fish length at the moment of scale formation was estimated, and mean fish body increment per unit of scale increment was calculated. Relationship scale-time (fish age in days) was also taken into consideration, and mean rate of one circulus formation was calculated. Statistic power of each relationship was expressed as the coefficient of determination.

RESULTS AND DISCUSSION

Fish fed with brine shrimp larvae were longer than those fed with decapsulated cysts (fig. 1). The difference of mean fish length between the groups (31.9±6.33 mm l.t. in AN, and 28.23±6.44 mm l.t. in AC) was statistically significant ($p<0.05$). Thus, it was assumed that fish of AN group grew and developed faster than those of AC gro-

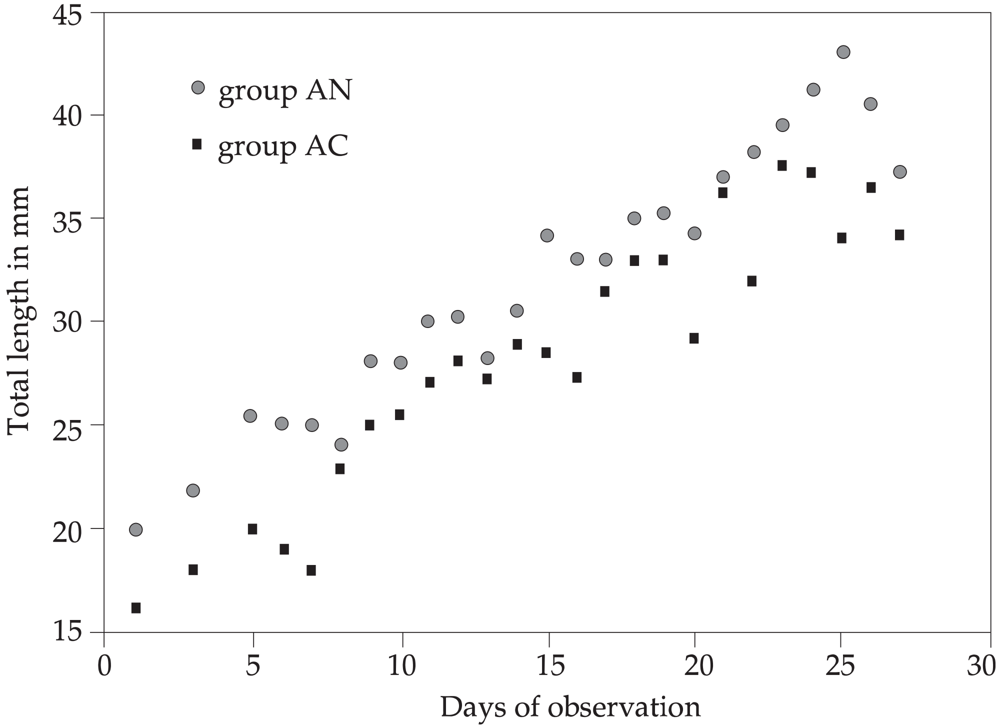

Fig. 1. Growth of vimba in AN and AC groups.

up, which was taken into consideration in further evaluations, and interpretation of the results.

First signs of scale formation were observed on the ninth day of observations in AN group, and on the eleventh day in AC group (fifth week of larval development). In both groups, at that moment, scales consisted of two complete circuli. Simultaneously with scale appearance, fin folds disappeared. Beginning from that moment, scales were present in all examined individuals.

Fish which developed scales first, at that moment were already completely scaled. Scales of oral and caudal parts of the body consisted of equal numbers of circuli (fig. 2) which seems to be an interesting observation. Usually it is stated that scale formation takes place at different time in various body regions (Balon 1956, Tesch 1968, Koblickaja 1981, Steinmetz, Müller 1991). However, it should be stressed that our results were obtained at high temperature, at which development was accelerated, so it seemed to be more equal.

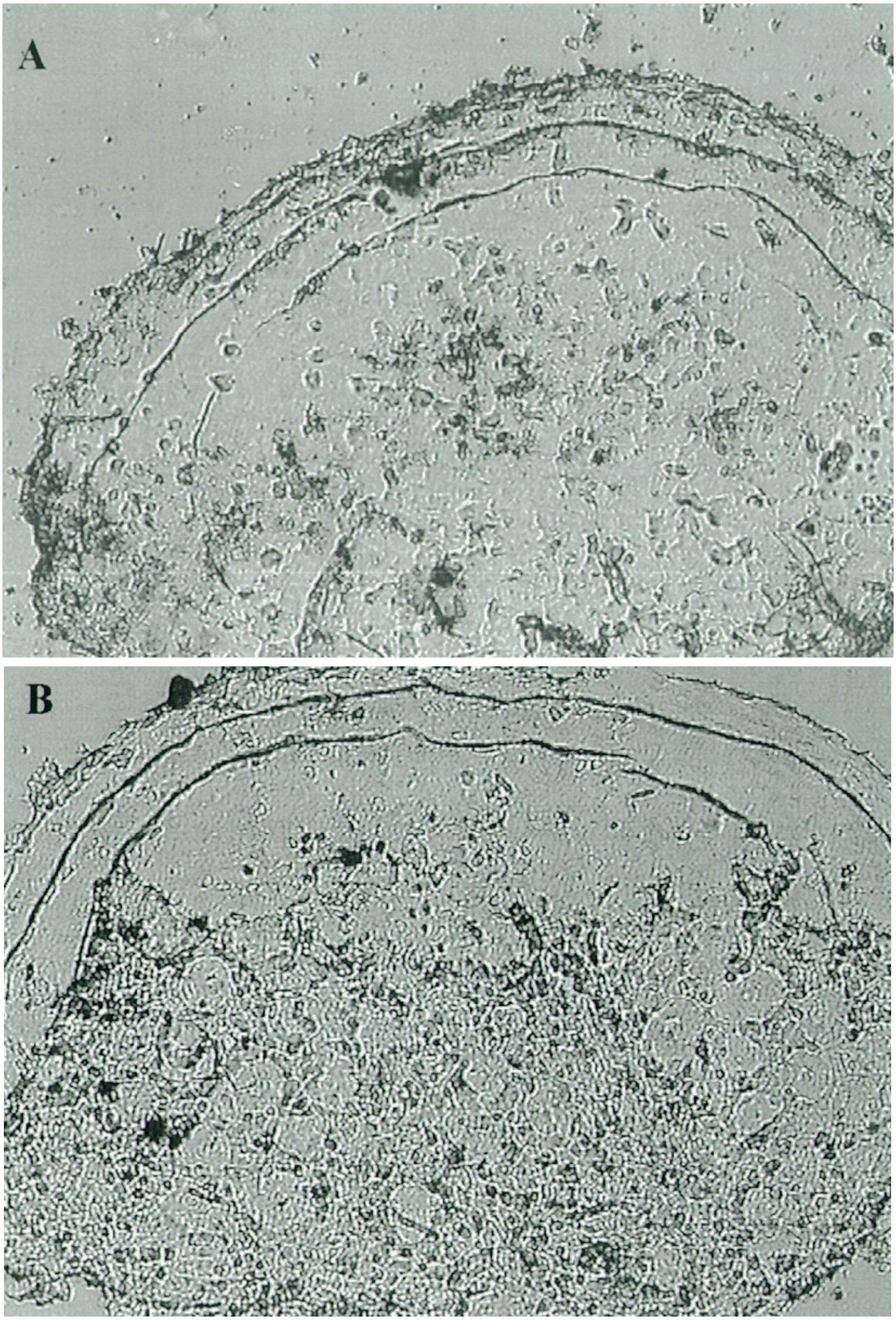

Fig. 2. Scale from central (A) and caudal (B) body regions of the same fish on the same day.

Maximum number of circuli observed during the experiment was 9 in AN group, and 8 in AC group. In both groups fish length-circuli number correlation was statistically significant at confidence level 95%. The values of the coefficient of determination for AN and AC groups were 92.02%, and 88.67%, respectively. The relationship was curvilinear for both groups (fig. 3) and described by the following equations:

for AN group: $L_{AN} = 24.34484 \cdot 1.063154^{C}$ (1),

where:

L_{AN} - total length (l.t.) of fish of AN group,

C - scale size expressed in number of circuli

for AC group: $L_{AC} = 23.115653 \cdot 1.062487^{C}$ (2),

where:

L_{AC} - total length (l.t.) of fish of AC group,

C - see above.

Mean individual body increment per unit of scale increment (one circulus) was 2.06 mm in AN group, and 1.93 mm in AC group. General relations, taking into consideration curvilinear character of the function, changed in the stipulated sections of scale size (fig. 3). In AN group individual body increment for first section from the nucleus to the third circulus was equal to 1.64 mm, for the second section - from third to seventh circulus - 2.03 mm, and for the third section - from seventh to tenth circulus - 2.51 mm. In AC group the values were: 1.54 mm, 1.90 mm, and 2.35 mm, respectively. Mean body length of fish at the moment of scale formation were obtained by extrapolation of the equations (1) and (2) to the number of circuli C = 0. Following values were obtained:

from equation (1), for $C = 0$, $L_{AN} = 24.34$ mm (AN group),

from equation (2), for $C = 0$, $L_{AC} = 23.12$ mm (AC group).

The values show that differences of length and body increment of vimba between AN and AC groups did not exceed 7%. The differences are apparently negligible but body-scale relationship was clearly related to the growth conditions. In better growing group AN body length of fish at the moment of scale formation was bigger. Also in further phase of the experiment body length versus scale size increased faster in AN, comparing to AC group (fig. 3). It means that neither body length at which scale formation starts, nor the values of parameters of the equation of body-scale relationship may be considered constant for a species.

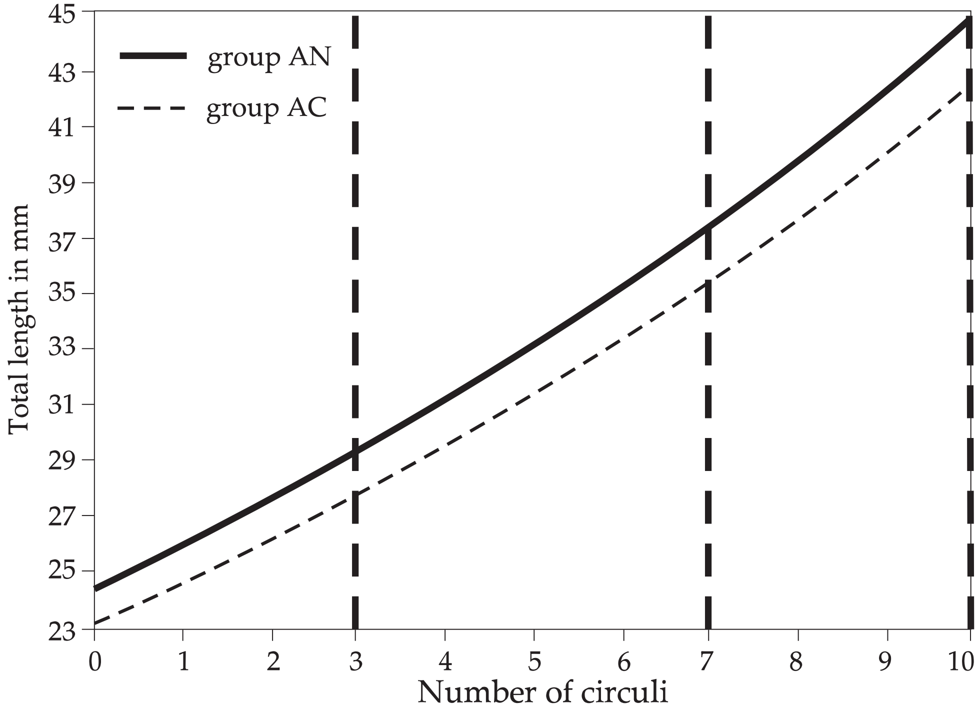

Fig. 3. Relationship between fish body length and scale growth in AN and AC groups. Section limits marked with a discontinuous line.

Pyka (1995) reared 3 groups of tench larvae under the same pond conditions, and body length at which scale formation started was even for all 3 groups, equal to 16.0 mm. Our results show that body length of vimba changed according to growth rate related to the diet. It is obvious that body lenght at the beginning of scale formation is a population characteristic related to the environmental conditions (Czugunova 1959, Brjuzgin 1961, after Heese 1992).

Body-scale relationship is expressed by a classic Lee formula (1920):

$$L_n = a + \frac{S_n}{S}(L - a) \qquad (3)$$

where:

Ln - fish length at age n,

a - intercept expression calculated from regression equation,

Sn - length of a section of scale radius to the next annual ring, *S* - total length of scale radius,

L - length of a fish at harvest.

Heese (1992) suggested to substitute expression "a" with fish length at the moment of beginning of scale formation (L_0):

$$L_n = L_0 + \frac{S_n}{S}(L - L_0) \qquad (4)$$

where L_0 is assumed as a standard value for a species.

It is contradictory to the results of our experiment, which indicate that Lo is modified within a species by growth conditions, and that body-scale relationship is curvilinear (exponential) for fish juveniles, so:

$$L_0 > a$$

That inequality shows that fish length back-calculated according to the formula (4) would be overestimated comparing to the formula (3), where "*a*" expression is adequately determined from regression for a scale sample of fish population under study. Growth of body and scales in juvenile vimba was unequal, which is shown by the calculated individual body increments for scale sections. Similar allometry of scale and body growth was described by Vaganov (1978) for roach in first year of life, for which parabolic growth curve was developed. Changes of the body-scale relationship were also reported for salmon and trout smolts (Lindroth 1963, Sych 1967). Thus, this phenomenon seems to reflect different conditions of growth and body proportions connected with stadial type of fish growth.

Allometry of body-scale relationship in juvenile vimba did not change a characteristic of scale growth upon time. In AN and AC groups new circulus appeared on average every two days. Relationship between fish age in days and number of circuli was statistically sigtificant at the 95% confidence level. Power of the relationship, expressed with the coefficient of determination, was for AN and AC groups equal to 90.9% and 87.4%, respectively.

CONCLUSIONS

The results presented in the study concern only juvenile developmental stages of vimba so the samples were non-numerous. However, they allow to formulate conclusions which may be extrapolated to other species and life stages.

1. The age of fish (in days) and body length at the beginning of scale formation are not constant for a species but depend on the environmental conditions.
2. Body-scale relationship in juvenile vimba is unequal (allometric) and can be described with an exponential function. Such type of allometry seems to reflect stadial type of development and is common in fish.
3. Allometry of body and scale growth and unequality of fish length at the beginning of scale formation (L_0) result in methodic consequences for back-calculation of fish growth. Especially empirically determined L_0 for a fish species should not be considered a substitute for the intercept expression "*a*" in Lee formula.
4. Allometry of body and scales may not affect a pattern of scale growth versus time. In juvenile vimba new circulus appeared on average every two days, with no respect to the growth rate difference between AN and AC groups.

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STRESZCZENIE

FORMOWANIE SIĘ I WZROST ŁUSEK U MŁODOCIANEJ CERTY *Vimba vimba* (L.) W WARUNKACH DOŚWIADCZALNYCH

Analizowano zależność ciało-łuska w dwóch istotnie różniących się tempem wzrostu grupach młodocianej certy - w szybciej rosnącej grupie AN, karmionej żywymi naupliusami *Artemia sp.* oraz w rosnącej wolniej grupie AC, żywionej zdekapsułowanymi cystami tego skorupiaka, przy stałej temperaturze wody 25°C (±0,5°C).

Wielkość łuski wyrażono liczbą sklerytów. Zależność ciało-łuska była statystycznie istotna i opisana została funkcją wykładniczą. Z funkcji tej wyznaczono średnie długości certy w czasie formowania się pierwszych łusek (grupa AN=24,34 mm; grupa AC=23,12 mm) oraz wykreślono krzywe wzrostu ryb i łusek. Stwierdzono, że długość ryb w czasie formowania się łusek nie jest stałą gatunkową, ale podlega warunkom wzrostu. Z funkcji wyliczono, że średni jednostkowy przyrost ryby na jeden skleryt wynosił w grupach AN i AC odpowiednio 2,06 i 1,93 mm. Jednostkowe przyrosty zmieniały się w sektorach łusek utworzonych według liczby sklerytów. Wzrost ciała i łuski był nierównomierny (alometryczny). Alometria wzrostu ciała i łuski zdaje się tu wiązać ze stadialnością rozwoju ryb. Stwierdzono ostotną zależność między wielkością łuski a czasem, tj. wiekiem ryb w dniach: w obydwu grupach jeden skleryt pojawiał się średnio co 2 dni.

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