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LIFE CYCLE AND GROWTH OF *METRELETUS OMELKOI* TIUNOVA, 2010 (EPHEMEROPTERA: AMELETIDAE) IN A TEMPORARY STREAM IN PRIMORSKII KRAI, RUSSIA

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Summary. Data are presented on the life cycle and growth of *Metreletus omelkoi* Tiunova, 2010 (Ephemeroptera: Ameletidae) from a temporary stream on the western slope of the Przhevalsky Mountains in the valley of the River Komarovka (Primorskii krai). *M. omelkoi* has a univoltine summer life cycle (Us). Larvae hatch in April and adults, emerge in June. The watercourse dries up in the second half of June. The population winters in the egg stage. Larvae of *M. omelkoi* are characterized by an exponential growth type. The growth rate and body weight of the larvae during the life cycle are in direct relationship.

Key words: mayfly, life history, growth rates, stream, Primorye, Russian Far East.

Т. М. Тиунова. Жизненный цикл и рост веснянки *Metreletus omelkoi* Tiunova, 2010 (Ephemeroptera: Ameletidae) из временного ручья в Приморском крае // Дальневосточный энтомолог. 2019. N 388. С. 23-32.

Резюме. Приводятся данные по жизненному циклу и росту *Metreletus omelkoi* Tiunova, 2010 (Ephemeroptera: Ameletidae) из временного ручья восточных склонов хребта Пржевальского в долине реки Комаровка, Приморский край. *M. omelkoi* имеет унивольтинный летний жизненный цикл (Us). Отрождение личинок происходит в апреле, появление имаго – в июне. Во второй половине июня водоток пересыхает. Популяция зимует в стадии яйца. Для личинок *M. omelkoi* характерен экспоненциальный тип роста. Скорость роста и масса тела личинок в течение жизненного цикла находятся в прямой зависимости.

INTRODUCTION

Currently, the genus *Metreletus* Demoulin, 1951 having a trans-Palearctic distribution includes three species: the West-European mountain species, *M. balcanicus* (Ulmer, 1920), and the Far-Eastern species, *M. micus* (Bajkova, 1976) and *M. omelkoi* Tiunova, 2010 (Tiunova, 2010). *Metreletus micus* is known as a single specimen from Far-Eastern Russia.

Of the above types, life cycles data are available only for *M. balcanicus*. The species demonstrates two types of univoltine life cycle within the nearby European countries (Poland, Czech Republic and East Ukraine): overwintering only as the stage of egg (Us) and overwintering as the larvae and eggs (Us-Uw) (Soldan, 1978; Jaždžewska & Wojcieszek, 1997; Soldan & Jaždžewska, 2000; Martynov, 2016).

This work is devoted to the study of the life cycle and growth of larvae of *M. omelkoi*, known only from the typical habitat in the Russian Far East.

STUDY AREA

The investigation was carried out in the temporary stream which flows along the road in Gornotaezhnoe village (Mountain-Taiga Station, Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far East Branch of the Russian Academy of Sciences) and into the Bolshoi Krivoi stream on the western slope of the Przhevalsky Mountains, in the valley of the River Komarovka. The village of Gornotaezhnoe is located 25 km north of Ussuriysk City, Primorskiy Kray (43°41'45'' N, 132°9'23'' E). The bottom of the stream is swampy with a lot of silt and residues of half-rotten plants (Fig. 1). The depth ranged from 5 to 25 cm. The water temperature during the period material was collected was follows:

Data	4.VI.2011	24.IV.2012	7.V.2012	16.V.2012	23.V.2012	30.V.2012	15.VI.2012
t°C	11.0	1.9	8.6	11.1	12.4	12.2	10.7

Conductivity was in the range 72–106 μs during the period of study; pH range was 7.0–7.8. The larvae were noted only in a 100 m section of the stream only.

METHODS

Samples of *M. omelkoi* were taken in 4 June 2011 and from April to June 2012 (24 April, 7, 16, 24 and 30 May and 15 June). Samples were taken with a Petersen dredger (Fig. 2) and a simple net of gas number 25. All samples were preserved in 75 % ethanol. A total of 1100 specimens was measured and weighed. The width of the head capsule and length of the body was measured for all larvae: total length was measured from the anterior edge of the head to the edge of abdominal tergitum X and the width of the head capsule was measured between the outer edges of the eyes. Measurements were made under a binocular microscope at magnifications of x16 and x32. Tarsal balances WT-20 with accuracy of 0.01 mg were used. To estimate the growth rates of *M. omelkoi* seasonal differences in the size-frequency distribution were analyzed and histograms were constructed from measurements of the larvae at intervals from 7 to 16 days.

Absolute growth rate (dW/dt, mg day^{-1}) was estimated for larvae using the following equation (Winberg, 1968):

$dW/dt = (\ln W_2 - \ln W_1)/ (t_2 - t_1)$,   (1)

where: $(t_2 - t_1)$ was the duration of the interval of the measurement, W_1 and W_2 is body wet weight before and after of the duration of the interval.

Mean exponential weight of a larva was found using the equation:

$W = (W_2 - W_1)/ (\ln W_2 - \ln W_1)$,   (2)

Empiric data were processed using the equation (Winberg, 1966):

$dW/dt = NW^m$,   (3)

where: W, mean exponential body wet weight (mg) and N and m are constants.

The allometric growth equation was used to describe the relationship between body wet weight and body length, body wet weight and width of the head capsule (Simpson et al., 1960; Winberg, 1971):

$W = a L^b$,   (4)

where W is body wet weight (mg), L is body length (mm) and a and b are coefficients.

$W = c D_k f$,   (5)

where: W is body wet weight (mg), D_k is width of the head capsule (mm); c and f are constants.

Statistical processing of the material was carried out using the program STATISTICS 14.

Figs 1–4. *Metreletus omelkoi*. 1 – biotope: temporary stream flowing along the road of the Gornotaezhnoe village; 2 – sampling using Petersen dredger; 3 – the mass emergence subimago; 4 – females floating after laying of eggs.

RESULTS AND DISCUSSION

Life cycle

On 4 June 2011, larvae of *M. omelkoi* were collected. These were mainly mature individuals (i.e., with dark wing pads). The quantity of the larvae was very high. From 4 June till 11 June, there was a mass emergence of subimago from the larvae, and they remained on the grass near the stream (Fig. 3), and the male imagines mass swarmed over the grass and small scrub at a height of not more than 1 meter. The swarming usually began after 4:00 pm and lasted until 8:00 pm. Males in the vertical position slowly rose and fell over the vegetation.

The swarming lasted 15–20 minutes; thereafter, the males rested on nearby leaves. After some time, the males took off again. We found a small extension stream nearby and found dead females floating after laying their eggs (Fig. 4). At the beginning of July, the water in the stream disappeared, and the bottom was overgrown with grass.

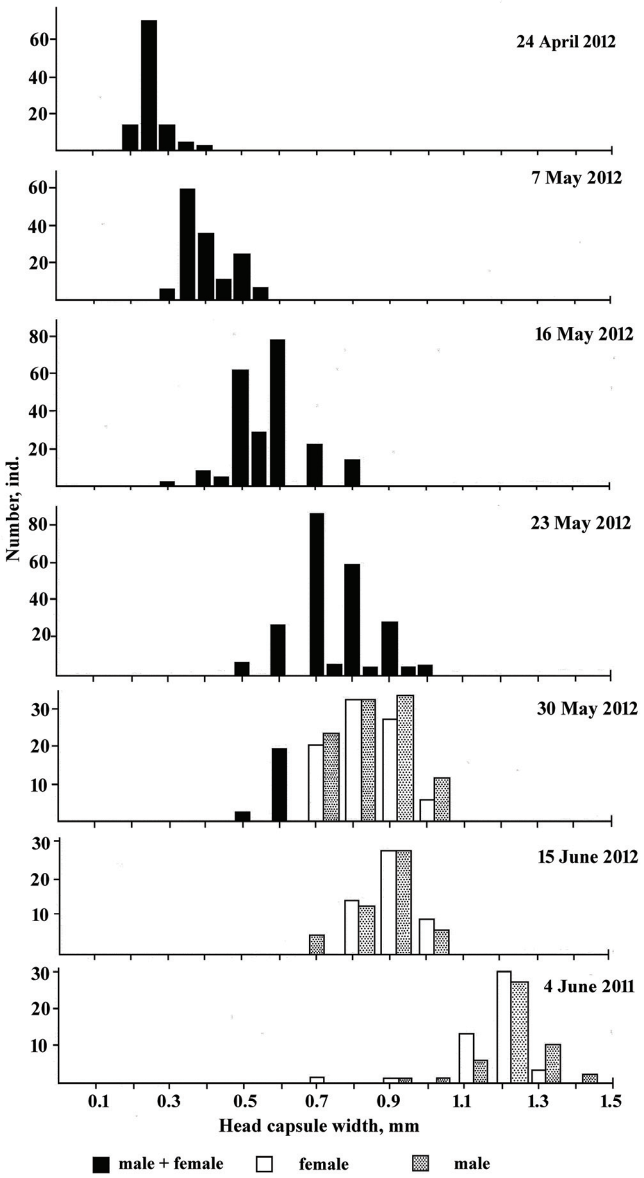

Fig. 5. Size frequency histogram for *Metreletus omelkoi* larvae.

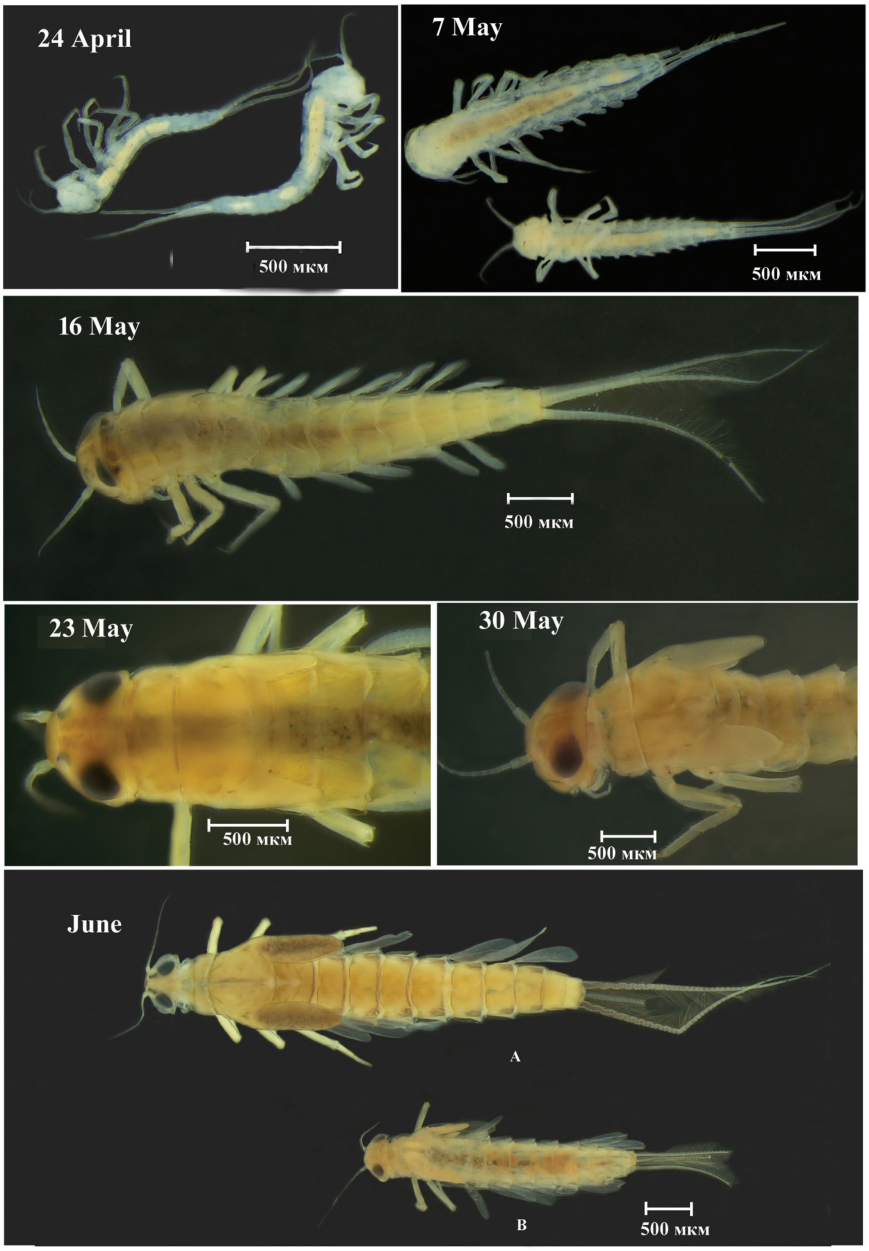

Fig. 6. Dynamics of development of larvae of *Metreletus omelkoi* during April – June 2012. A – larvae for 4 June 2011, B – larvae for 15 June 2012.

Table 1. Growth data for *Metreletus omelkoi* in the temporary stream in Gornotaezhnoe village. All data are in 2012 except for those marked with * which are in 2011.

Data	Width head capsule, mm min – max (mean)	Length, mm min – max (mean)	Wet weight, mg min – max (mean)	Number of individuals
24 April	0,2 – 0,4 (0,25 ± 0,004)	0,9 – 1,9 (1,2 ± 0,02)	0,023 – 0,038 (0,030 ± 0,004)	101
7 May	0,3 – 0,55 (0,4 ± 0,006)	1,3 – 2,9 (1,8 ± 0,03)	0,048 – 0,173 (0,097 ± 0,03)	138
16 May	0,3 – 0,8 (0,6 ± 0,007)	1,4 – 4,9 (3,0 ± 0,04)	0,21 – 1,58 (0,38 ±0,03)	198
23 May	0,5 – 1,0 (0,7 ± 0,007)	2,3 – 5,8 (4,0 ± 0,04)	0,22 – 2,15 (0,89 ± 0,03)	212
30 May	0,5 – 1,0 (0,8 ± 0,008)	2,5 – 6,8 (4,4 ± 0,05)	0,25 – 4,1 (1,29 ± 0,04)	204
15 June	0,7 – 1,0 (0,9 ± 0,007)	3,2 – 6,0 (4,7 ± 0,05)	0,52 – 3,64 (1,65 ± 0,06)	101
4 June*	0,9 – 1,4 (1,2 ± 0,008)	6,0 – 9,8 (7,5 ± 0,09)	3,3 – 12,1 7,5 ± 0,20)	95

The life cycle of *M. omelkoi* according to the histograms of size-frequency composition, univoltine summer (Us) (Fig. 5). The population is represented by one a fast growing cohort, the development of which occurs within 57 days from mid-April to the second decade of June. The flight of adults and egg laying were noted in the second decade of June. The first larvae of the new generation, with a length from 0.9 mm to 1.2 mm (mean 1.2 mm) and a head capsule width from 0.2 to 0.4 mm (mean 0.25 mm), were present in samples from 24 April 2012. Considering that it is 2.5 times the diameter of the egg (286–320 μm) the newly hatching larva is approximately, the length of the newly-hatched larva will be 0.7–0.8 mm, indicating that hatching had started somewhat earlier than the sampling date. Hatching larvae had a milky colour and poorly-developed gills (Fig. 6). Newly-hatched larvae began to grow very quickly and the gills became noticeable by 7 May, although the color was still milky. The average body length was 1.86 mm (1.3 – 2.9 mm) and head capsule 0.40 mm (0.3 – 0.55 mm) wide (Table 1) y the time of sampling on 16 May the larvae had acquired a brown color and the pads of fore wings started to appear, body length reached 1.8 – 4.4 mm (mean 3.0 mm), and the width of the head capsule 0.3 – 0.8 mm (mean 0.55 mm). In the samples collected on 23 May, the wing pads of the larvae were already well expressed. In the same sample, the range of linear dimensions of the larvae was quite wide: so, body length varied from 2.3 to 5.8 mm (mean 4.0 mm), with the width of the head capsule ranging from 0.5 to 1.0 mm (mean 0.75 mm). During this period, most individuals showed differentiation by sex. However, in terms of linear size, no sharp differences were found between males and females. By 30 May, the wing pads of the larvae extended to the middle of first tergite and body length averaged 4.4 mm (2.5 – 6.0 mm) with a head capsule width of 0.8 mm (0.5 – 1.0 mm). In this period, a decrease in the amount of water in the stream was noted. The larvae were observed only in areas where the depth was at least 5 cm.

By 15 June, water only remained in certain areas of the stream, where it was oozing between the remains of vegetation. The average parameters of the body length and width of the head capsule were 4.6 mm (3.2 – 6.0 mm) and 0.9 (0.7 – 1.0 mm), respectively. However, wing pads extended to the middle of the third tergite and in 10 % of individuals (both males and females) were ready to move to the emergence of the subimago.

Thus, by 15 June 2012 only 10% of the larvae had dark wing pads, in contrast to 4 June 2011, when almost all the larvae were ready for emergence, which started at the end of May and continued until 11 June. In 2012, the emergence began on 19 June, and many individuals could not leave the watercourse due to its having dried out. In addition, mature larvae collected on 4 June 2011 were much larger (mean body length 7.5 mm, and width of the head capsule 1.2 mm) than the larvae collected on 15 June 2012 (Fig. 6), due to the fact that the spring of 2012 was late and dry so the water regime was not favorable, which led to the rapid shallowing and drying of the stream.

Thus, the duration of larval development of *M. omelkoi* can consist from 56 to 67 days.

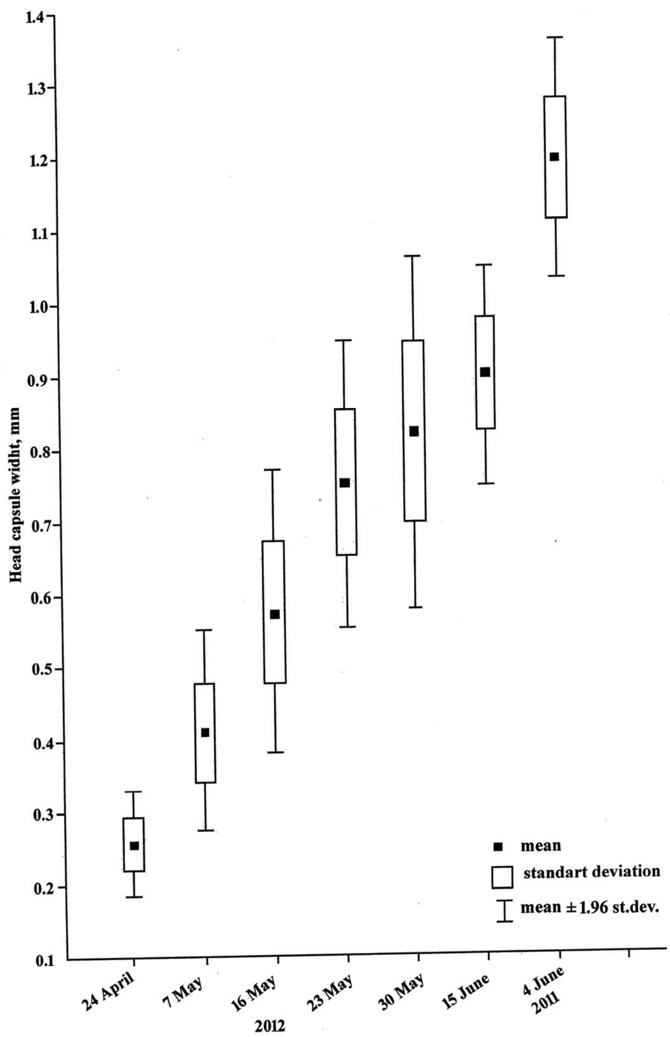

Fig. 7. The growth of the head capsule width of larvae of *Metreletus omelkoi*.

Larval growth

The allometric growth equation in most cases is used for the relation between the linear parameters and the body weight of animals of different systematic rank. Based on this, the parameters were calculated for body length–body weight and width of the head capsule–body weight relationship equations for *M. omelkoi*, which can be expressed by as following:

$W = (0.028 \pm 0.002)\ L^{(2.727 \pm 0.052)}$ (6)

The correlation coefficient is equal to 0.95 (n = 33).

$W = (2.644 \pm 0.074)\ D_k^{(3.526 \pm 0.068)}$ (7)

The correlation coefficient is equal to 0.99 (n = 24).

Thus, the values of the exponent indicate the presence of negative allometry (b<3) in *M. omelkoi* larvae. As is known, negative allometry is most pronounced in representatives of the family Baetidae (b=2.652), it is connected with an appreciable body extension during the growth process (Tiunova, 1997).

The growth rates of *M. omelkoi* were analyzed on the basis of the size-age structure of the larval population (Fig. 5). The growth rates of *M. omelkoi* differed somewhat between different stages of the life cycle. Larvae grew rapidly until the 23 May then the growth rate declined (Table 1, Fig. 7). Using our results on the growth rates over the period of observations, we obtained the equation for dW/dt as a function of W (Fig. 8), which can be expressed by as following:

$dW/dt = (0.103 \pm 0.057)\ W^{(1.06 \pm 0.004)}$ (8)

The correlation coefficient is equal to 0.98.

Thus, the larvae of *M. omelkoi* exhibit an exponential type of growth, and since the coefficient "m" is equal to unity, the dependence of the growth rate of the larvae on their body mass is described by the equation $dW/dt = (0.103 \pm 0.057)\ W$.

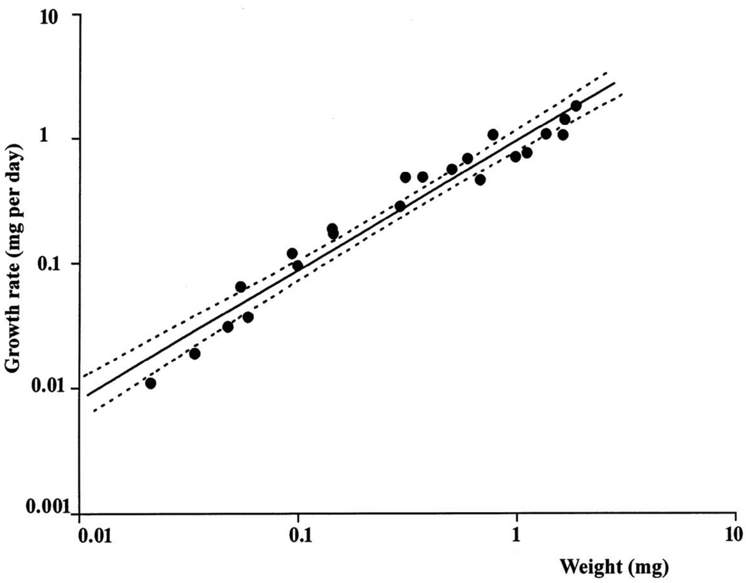

Fig. 8. A relationship between growth rate (dW/dt, mg day^{-1}) and body weight (W, mg) in *Metreletus omelkoi* on log/log scale. Dotted lines indicate confidence intervals at the 95% significance level.

DISCUSSION

According to Clifford's classification (Clifford, 1982), the *M. omelkoi* studied in our research has a univoltine summer life cycle (Us). The hatching of larvae, their growth, and the emergence of the imago occurs in late spring or early summer; the population overwinters in the egg stage. A similar life cycle was also noted in another representative of the *Metreletus* genus, *M. balcanicus* (Ulmer, 1920). In Eastern Ukraine the species has one generation per year and overwinters as the egg stage (Us) and larvae begin to hatch in March; larvae of middle and older ages are recorded in the middle of April (Martynov, 2016). In other European countries (Poland and Czech Republic) the species demonstrates two types of univoltine life cycles: overwintering only as the stage of egg (Us) or overwintering as larvae and eggs (Us-Uw) (Soldan, 1978; Jażdżewska & Wojcieszek, 1997; Soldan & Zahradkova, 2000).

As is well known (Golubkov, 2000), the type of life cycle that determines the periods of growth and the timing of reproduction in insects are closely related to the adaptive strategy of development (succession) of the community. A univoltine summer life cycle with synchronous development can be considered as an adaptation to life in biotopes with relatively constant environmental conditions during the period of larval development. Animals with this type of life cycle have embryonic diapauses. In addition, the synchronization of development and departure can reduce the mortality of imago mayflies. As a result, the growth and reproduction of insects occur in a relatively short time and in the most favorable period for a particular year. During the rest of the year, animals do not participate in community activities. Mayflies with such a life cycle are common in temporary waterbodies. So, in our case, the most favorable period of development for *M. omelkoi* is the period from April to mid-June as, after June 20, the stream dries up. Thus, in our case, larval development is more dependent on the presence of water and its level in the stream, as the water temperature does not rise above 13°C, even at high water levels.

Larvae of *M. omelkoi* are characterized by exponential growth type. The growth rate and body weight of the larvae during the life cycle are directly related. Of the 16 mayfly species found in the Far East of Russia, in which growth rate depends on body weight, the highest level of growth rate was noted for *Baetis fuscatus* L. (Tiunova, 1997):

$$dW / dt = (0.141)\ W^{0.841} \qquad (9)$$

The growth rate of the larvae of *M. omelkoi* was lower than the growth rate of *B. fuscatus* (a factor of 0.6 times) but 1.7–1.9 times higher than other species of mayfly. The life cycle of *B. fuscatus* in the Far East of Russia displays a bivoltine summer development cycle with two summer generations (MBss). The development of the second generation occurs very quickly – from July to September (Tiunova, 2014). At the same time, the larvae of the second generation are much smaller in terms of size than those of the first generation, before their flight as the imago. Thus, the acceleration of the development of animals can occur not only due to an increase in the growth rate, but also due to a decrease in their definitive sizes. This is clearly seen in the larval population of *M. omelkoi* in 2011 and 2012.

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