

CADDISFLIES *STENOPSYCHE MARMORATA* (TRICHOPTERA: HYDROPSYCHIDAE) EXPLOIT RIVER MUSSELS AS ANCHORS FOR THEIR NETS

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Summary. In the foothill rivers of the south of Primorsky Krai (Russian Federation), during the abnormally hot summer-autumn season of 2021, the number of net-spinning larvae of the caddisflies *Stenopsyche marmorata* Navas, 1920 (Stenopsychidae) sharply increased. Here we describe the phenomenon of widespread use by these caddisfly larvae of the shells of live bivalves *Middendorffinaia* Moskvicheva et Starobogatov, 1973 (Unionidae) to attach their feeding nets. As a result, the immobilized river mussels could not move to the deeper sites for wintering, and in the coming winter season they died due to freezing into ice. The described phenomenon illustrates the indirect negative impact of climate change on vulnerable species of river biota.

Key words: net-spinning caddisflies larvae, *Stenopsyche marmorata*, river mussels, *Middendorffinaia mongolica*, threat to the survival, vulnerable species, climate change.

В. В. Богатов, Л. А. Прозорова. Ручейники *Stenopsyche marmorata* (Trichoptera: Hydropsychidae) используют речных двустворок в качестве якоря для своих сетей // Дальневосточный энтомолог. 2022. N 461. С. 31-36.

Резюме. В предгорных реках юга Приморского края (Российская Федерация) в период аномально жаркого летне-осеннего сезона 2021 г. резко возросла численность личинок сетеплетущих ручейников *Stenopsyche marmorata* Navas, 1920 (Stenopsychidae). Здесь мы описываем феномен повсеместного использования этими личинками раковин живых двустворчатых моллюсков *Middendorffinaia* Moskvicheva et Starobogatov, 1973 (Unionidae) для фиксации своих ловчих сетей. В результате обездвиженные речные двустворки не смогли переместиться в более глубокие места на зимовку и в наступивший зимний сезон погибли из-за вмерзания в лед. Описанное явление иллюстрирует опосредованное негативное воздействие климатических изменений на уязвимые виды организмов речной биоты.

INTRODUCTION

Net-spinning caddisflies in the Southern Russian Far East are represented by the families Stenopsychidae, Arctopsychidae and Hydropsychidae. Their larvae, living on gravel-pebble

bottom, secrete strong adhesives to construct retreats with capture nets, weaving between stones (Levanidova, 1982). Constructions made by net-spinning caddisfly larvae help to strengthen the river bed, substratum stability and reduce soil mobility during floods (Takao *et al.*, 2006; Bogatov & Fedorovsky, 2017).

Caddisflies *Stenopsyche marmorata* Navas, 1920 from the family Stenopsychidae inhabit southern part of East Palaearctic from Altai Mt. to Japan. Aquatic larvae of the species, living in clear and cold streams with stony bottoms, are important component of mountainous and foothill streams food web as a filter-feeding detritivores (Kocharina, 1999). Larvae of *S. marmorata* are the largest in size among other caddisflies in the Russian Far East. In the foothill rivers of Primorsky Krai, the average biomass of the species is up to 77% of the biomass of the order Trichoptera and up to 35% of the biomass of all river benthos (Kocharina, 1989, 1999).

Unionids of the genus *Middendorffinaia* Moskvicheva et Starobogatov, 1973 are endemic dwellers of foothill rivers of continental part of the southern Russian Far East within the Amur River system and riverine basins of Southern Primorsky Krai (Starobogatov *et al.*, 2004; Bogatov & Prozorova, 2017, and others). These large bivalves, like caddisflies *S. marmorata*, tend to live in clear, cold streams with hard bottoms and, like caddisflies, are filter feeders. In winter, *Middendorffinaia* mussels move to deeper sections of the river, burrow into the bottom sediments and hibernate.

Due to the similarity of ecological preferences, river mussels *M. mongolica* (Middendorff, 1851) and caddisflies *S. marmorata* dwell similar habitats in the same rivers. Living in the neighborhood, these organisms are not rigidly connected to each other by food web. Moreover, no ecological interactions between them have ever been reported. In the abnormally hot and dry summer–autumn season of 2021, we observed for the first time a close relationship between *S. marmorata* and *M. mongolica*, which consisted in the use of river mussels by caddisfly larvae as anchors for their feeding nets.

The studies were carried out in late October and in November 2021 on the foothill middle part of the Komarovka River near the settlement of Kondratyionovka (Ussuriysky District, Primorsky Krai). We also used observational data on unpolluted sections of the Knevichanka River (Artyom town). These rivers are subject to regular monitoring in terms of aquatic ecology and biodiversity due to the presence of populations of federally protected endemic pearl mussels *Margaritifera dahurica* (Middendorff, 1850), and river mussels *Middendorffinaia mongolica* (Red Data Book..., 2021).

In the Komarovka, we examined a riffle about 8 m wide, with an average depth of 0.2–0.3 m, a current speed of up to 0.3–0.4 m/s, gravel-pebble ground with boulders. The water in the river was clear and the bottom of the riffle was very clearly visible throughout, the water pH was 7.0 and an almost complete absence of NH₄ (pH value and ammonium content were determined using pH Value-Test and Ammonium/Ammonia-Test, respectively, manufacturer - Sera Werke Borsigstr 49, D-52525 Heinsberg, Germany).

DESCRIPTION OF OBSERVED PHENOMENON

In late October, pearl mussels *M. dahurica*, river mussels *M. mongolica*, and larvae of net-spinning caddisflies lived together on the studied site of the Komarovka River. All recorded 11 pearl mussels were located exclusively in the deep-water section of the channel, almost completely submerged in the ground. The river mussels *M. mongolica* were found in shallow part of the rift, with an average density of 2–4 specimens per 1 m². Among the caddisflies, *S. marmorata* (Fig. 1) prevailed, whose feeding nets in the absence of floods covered a significant part of the space between the stones.

Stenopsychid larvae typically form cone-shaped irregular silky nets that connect to their retreats between submerged stones; the primary role of these feeding net is to capture drifting detritus (Nishimura, 1984). Both capture nets and retreats are necessarily attached to stones by adhesives of silk glands, in most cases, they form bridges between multiple particles. As such peculiar anchors, net-spinning caddisflies use stones of various sizes, from which the bottom of foothill rivers is composed.

In 2021 we first observed the use of live river mussels *M. mongolica* by caddisflies instead of stones in the construction of capture nets (Fig. 2). This was not a single random event, as it was recorded by us many times in the rivers of southern Primorye, Komarovka and Knevichanka. In the Komarovka River, some mussels served as feeding net anchors for several caddisflies (Fig. 2 A). All river mussels *M. mongolica* used by stenopsychids were mature, their length did not exceed 7–8 cm. The unusual position of the mussels on the bottom attracted our attention. About 70% of the bivalves lay on their side with their legs extended outward (Fig. 2 B), and about 10% lay on the dorsal margin with open valves. Upon closer examination, it was found that the reason for this was the rigid attachment of the mollusks to the stones. The remaining 20% of the mussels in the area of the riffle were in a natural position, but they were also attached to the stones (Fig. 2 A). Only single specimens of *M. mongolica* remained free outside the riffle at a deeper site. A similar picture we observed in the Upper Knevichanka River, where some live *M. mongolica* were entangled in *S. marmorata* feeding nets as well.



Fig. 1. Last instar larva of the caddisfly *Stenopsyche marmorata* from Komarovka River. (Photo by V.V. Bogatov, 29 October 2021).

Both *M. mongolica* and *M. dahurica* are included in the Red Data Book of the Russian Federation (2021) as vulnerable and endangered species correspondingly. These filter feeders settle only in the cleanest foothill streams on hard substrate and extremely demand on the quality of water and its saturation with oxygen. Pearl mussels live in deeper sites than more active moving *M. mongolica*. By the end of summer 2021, due to a long period of dry and hot weather, the water level in the rivers of southern Primorye dropped significantly, and its temperature increased. This forced the *M. mongolica* to move to the most flowing shallow

sections of rivers in the area of riffles. At the same time, the environmental conditions in 2021 contributed to an increase in the abundance of the *S. marmorata*, widely distributed in small foothill rivers of southern Primorsky Krai. As a result, the ecological niches of the insect larvae and the *Middendorffinaia* mussels in both Komarovka and Knevichanka rivers completely overlapped.

Caught in close proximity to large larvae of caddisflies, bivalves became the object of their construction activity, serving as anchors for their feeding nets (Fig. 2 A). The caddisfly larvae are known to secrete adhesives which are proteins homologous to the silk of caterpillars (Tsukada *et al.*, 2010). Tensile bonding and compressive shear strength of the silk gland proteins from Japanese stenopsychids in spring were measured as 14.0 and 12.0 kg cm² for the iron substrata, respectively, and 2.7 (x 1/5) and 2.4 kg cm² (x 1/5) in autumn (Yamamoto *et al.*, 1990). The dimensions of feeding nets formed by the final-instar larvae of *S. marmorata* are generally larger than the nets of any other net-spinning species; these nets are 5–10 cm long, and about 10 cm wide (Tanida, 2002)).

Such large and strong nets built by *S. marmorata* larvae, completely immobile river mussels, but leave them alive during warm period, allowing them to breathe and feed on filtered particles (Fig. 2). In this case, caddysflies *S. marmorata* benefit from bivalves *M. mongolica* by obtaining shelter and food without significant harming mollusks during the warm period, but inevitably leading to their death during the onset of winter. Thus, here we see how close ecological interactions arose in previously ecologically unrelated organisms with a sharp change in external conditions.

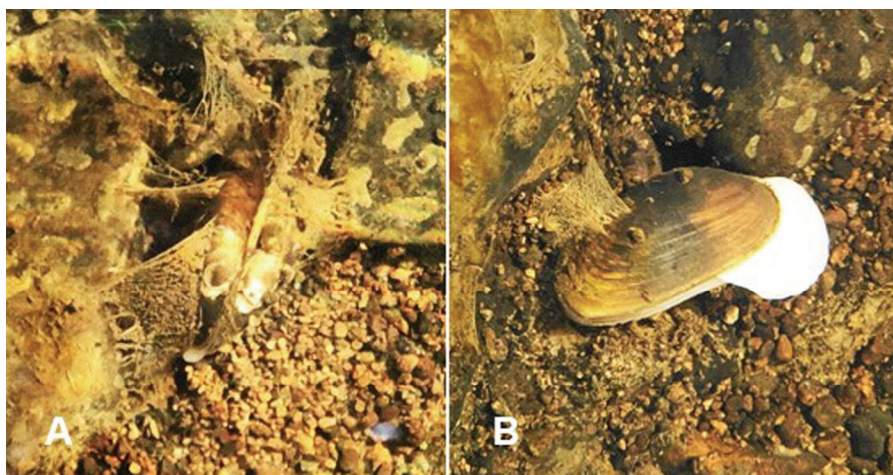


Fig. 2. Live specimens of *Middendorffinaia mongolica* used as anchor by net-spinning caddysfly larvae *Stenopsyche marmorata* to construct their capture nets. (Photo by V.V. Bogatov, 29 October 2021).

Despite the fact that in autumn the strength of the silk gland proteins of caddysflies decreases by 5 times (Tanida, 2002), the mussels are not able to break their fetters before the onset of the freezing period. Therefore, most likely, all bivalves that remained in the shallow water of riffles, glued to the stones with caddysfly nets, were doomed to death from freezing and predators.

DISCUSSION AND CONSLUSION

In recent years, in the context of global climate change, a significant change in the influence of monsoons on natural flood cycles has been increasingly observed. At the same time, the strength of floods increases, but the probability of precipitation during the dry season decreases, i.e., there are more climatic extremes (Strayer & Dudgeon, 2010; Bogatov & Fedorovskiy, 2016; and many others). For example, within the south of the Russian Far East in August-September 2020, heavy rains occurred in Primorsky Krai, including those caused by two typhoons, and there were no typhoons in the summer-autumn season of 2021. Moreover, such a long dry period has not been observed in the region since 2010.

The increase in abnormal weather events contributes to unusual ecological interspecies relationships in river ecosystems. In particular, this article describes how the larvae of net-spinning caddisfly *S. marmorata* temporarily become commensals of river mussels *M. mongolica*. The main trigger of the phenomenon was abnormally hot and low-water conditions in southern Primorsky Krai during the summer and autumn of 2021. In ordinary years, constructions of net-spinning caddisflies are destroyed during rain floods and typhoons common for Primorsky Krai. In 2021, there was very little precipitation during the warm period and therefore the *Middendorffinaia* mussels remained firmly attached to large stones, despite ongoing efforts to release (Fig. 2 B). They did not lose their vital functions, continuing their filtration activity till late November, but could not move to the deeper sites for wintering, and then they died due to freezing into ice or being eaten by predators. The described phenomenon illustrates the indirect negative impact of climate change on vulnerable species of river biota.

As we can see, under conditions of a long low water period, the activity of net-spun caddisflies can lead to immobilization and, ultimately, to a sharp decrease in the survival of unionids *M. mongolica*, which prefer shallow river riffles during warm period. This danger does not threaten less mobile pearl mussels *M. dahurica* dwelling deeper habitats.

Considering that under conditions of long low water, the activity of net-spinning caddisflies can cause high mortality of federally protected rare bivalves *Middendorffinaia*, it is necessary to adjust the strategy for their conservation. In particular, the pre-winter collection of specimens glued to stones in shallow water and their transfer to deep-water sections of the river channel can be effective to reduce the threats to their survival. During the low water period, it is necessary to exclude as much as possible any forms of anthropogenic pollution from entering small rivers, especially mountain and foothill ones, where large bivalves *Middendorffinaia* and *Margaritifera*, as well as other endemic stenoecic organisms live.

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