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INFLUENCE OF THE MINERAL SUBSTRATE GRAIN SIZE ON THE COMPLETION OF THE *HYDROPSYCHE PELLUCIDULA* (*TRICHOPTERA*) LIFE CYCLE[*] [**]

Mariusz Tszydel, Maria Grzybkowska, Eliza Szczerkowska, Małgorzata Dukowska

Department of Ecology and Vertebrate Zoology, University of Łódź
ul. Banacha 12/16, 0-237 Łódź, Poland
e-mail: mtszydel@biol.uni.lodz.pl

A b s t a r c t. Pre-pupation selectivity of inorganic substrate grain size for case building by trichopteran larvae, *Hydropsyche pellucidula,* was estimated on the basis of laboratory experiment and field data. Among four inorganic substrate fractions (fine and coarse sand, fine and coarse gravel) individuals of *H. pellucidula* that had inhabited in coarse sand and fine gravel were able to complete their life cycle.

K e y w o r d s: *Hydropsyche pellucidula,* case building, mineral particles, life cycle

INTRODUCTION

Local current velocity, water depth, substratum composition and availability of food resources are known to influence the microdistribution of lotic macroinvertebrates [10]. But for some insects, such as trichopteran species, the grain size of inorganic substrate is especially important and it may be a key factor for completing their life cycle, because larvae of some genera, including *Hydropsyche* build their pupal cases with mineral grains collected in their neighbourhood. These cases are usually attached to coarse grains. The given development stages usually prefer one size of mineral material grains, so the architecture of caddis fly cases can be used for the identification of taxa [12].

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Trichopteran larvae, represented mainly by Psychomidae (scrapers) and Hydropsychidae (filtering collectors), were very numerous and diverse (the latter family) in the lowland Drzewiczka River below the dam reservoir [16,17]. But the reach of this river changed very much after the complete emptying of the reservoir in order to dredge it; a step increase in fine sediment load to downstream reach (colmation) was noted during that period. Thus the main aim of this study (and experiment) is to learn the reasons of the abundance decrease of many insects including one of the most important in this biocoenosis, Trichoptera, in the post impoundment period. It is possible that limited availability of the preferred fraction of mineral grains for case building may be one of them.

STUDY AREA

The Drzewiczka River is the biggest right tributary of the Pilica River; it is 81.3 km long and its catchment area is ca. 1.083 km^2. The study area (20º28'E and 51º27'N) was established in a fourth order stream section of this river, 53 km downstream of the spring and 1.5 km below the dam reservoir called Lake Drzewieckie, with an area of 0.84 km^2. The research materials was sampled in a straightened river bed section with high-flow area and fast current velocity of 0.6 ms^{-1} (0.3-0.9), and with substrate index (SI) of particulate inorganic matter of 6.6 mm. According to Quinn and Hickey [11], this single index was made on a weight basis by summing the mid point values of size classes weighed by their percentage cover (29% 0.25-0.5 mm size, 22% of 0.5-1 mm size, 6% of 2-4 mm size, 6% of 4-8 mm size and 24% of 16-32 mm size).

Further details of the habitats of the investigated site are given by Szczerkowska *et al*. [14], Tszydel *et al*. [16,17], Dukowska *et al*. [4].

MATERIALS NAD METHODS

Mature larvae (fifth instar) of *Hydropsyche pellucidula* (Curtis, 1834), before their pupation, were taken from the Drzewiczka River in April 2005. Pupal cases (167 pieces), as a control group, were gathered in July of the same year. In the laboratory, each of the specimens was reared separately in a plastic box (500 ml in capacity) filled up with the riverine water and one of the four grain-size fractions [1]: fine (0.125-0.25 mm) and coarse (0.5-2 mm) sand, fine (2-4 mm) and coarse gravel (4-16 mm). The plastic boxes were kept in thermostatic refrigerator at variable temperature (14-23°C), imitating natural conditions and aerated. In the presented experiment, 40 mature larvae were reared in each of the selected fractions.

The time that larvae needed to make cases of given inorganic substrate was measured and also the success of metamorphosis in laboratory raising was estimated. Each pupal case was also measured (its length and diameter to the nearest

0.01 mm) and its mass was determined (to 0.0001 g). The same procedure was followed for empty pupal cases collected from the Drzewiczka River.

All statistical analyses were carried out using CCS Statistica (StatSoft 2000). We used two-way ANOVA test in comparisons concerning the length, diameter and mass of cases built when one of the four grain size fractions of minerals was available and collected in the Drzewiczka River.

RESULTS

Throughout our study covering a period of about 3 months (from 18 April to 5 July) we observed that pupal cases were constructed with various speed depending on size of grain. The construction time was the longest when fine sand was used. In our research period the number of larvae that tried to close their life cycles in coarse sand as well as fine gravel displayed the same trend. In both these fractions the proportion of larvae mortality and the appearance of pupae and imagines were similar, too (Fig. 1). The highest percentages of adult stages were noted for fine gravel (42%) and coarse sand (38%). A significant percentage of larvae were not capable of building pupal cases in gravel substrate, which resulted in 75% mortality, while the larval metamorphosis in fine sand attained limited success, because although many larvae (51%) managed to build their "pupal shelter", yet 33% of them were capable of left cocoons or could not transform to mature (Fig. 1).

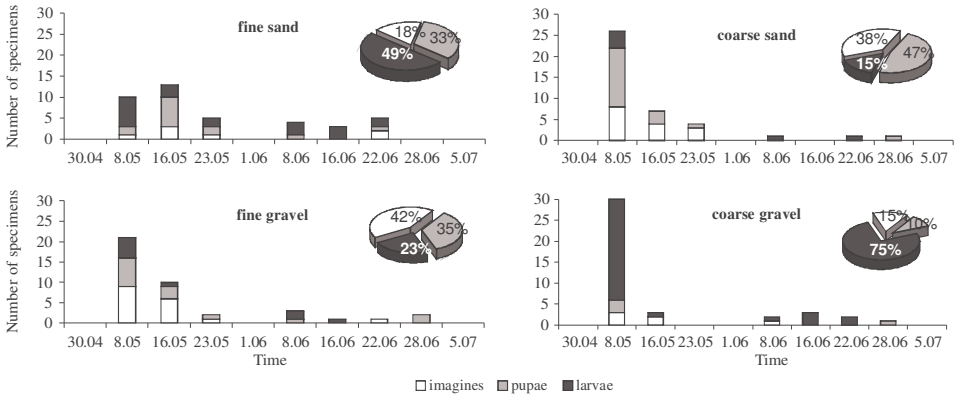

Fig. 1. The number of larvae, pupae and imagines obtained in the entire laboratory rearing with each of the available four grain-size fractions on given sampling dates (histograms) and cumulative data (pie charts). Larvae – percent mortality, pupae – pupal case building and death at prepupal and pupal stage, imagines – success in completion of life cycle (metamorphosis)

Differences were also observed in the recorded parameters of pupal cases: length, diameter and mass. ANOVA II (two-way) test showed that differences be-

tween the examined parameters of pupal cases produced from each of the fractions were highly significant at p=0.0 (Fig. 2). The post hoc Tukey test revealed that case mass did not differ significantly between cases made of fine sand and those that came from the river (p=0.098) nor did case diameter between coarse sand case and river bed (p=0.154).

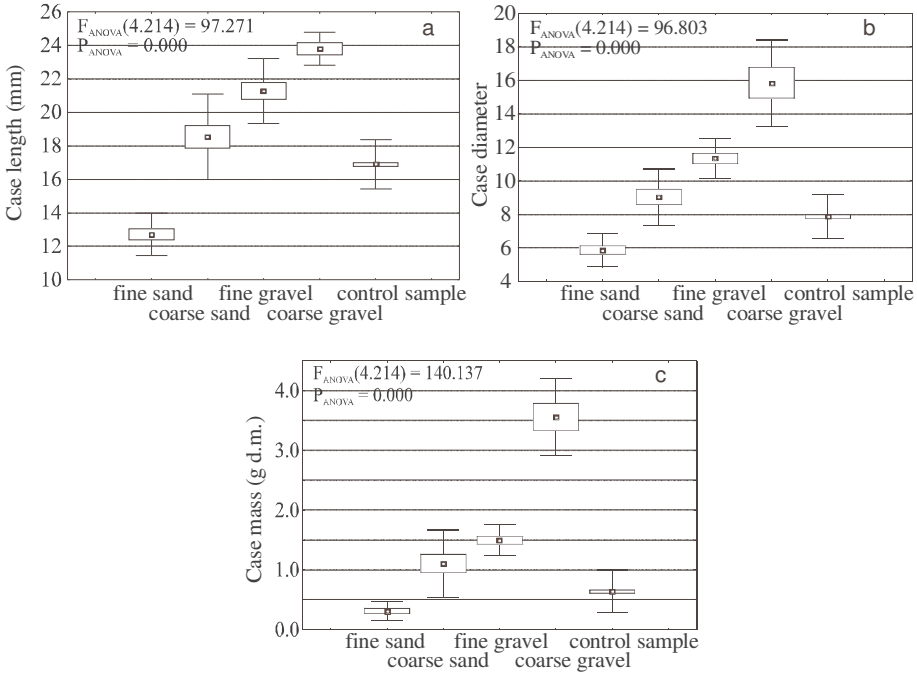

Fig. 2. Mean with standard error and standard deviation of the length, diameter and mass of cases obtained with each of the four available grain-size fractions in the laboratory experiment and of those collected in the river (control sample). F_{ANOVA} – ANOVA test value, p_{ANOVA} – significance level of ANOVA test

DISCUSSION

According to Mackay and Wiggins [9] building cases from mineral or organic particles cemented with silk threads is considered crucial for the evolutionary success of Trichoptera. But such behaviour causes some problems. Caddies flies need available fine mineral grains for their case building, coarser material (like cobbles and stones) to attach these cases in rapidly flowing streams, and high oxygen renewal rates [3,12]. This conflict of resource requirements in natural lotic ecosystems is usually resolved by a shortage in mineral grain size that is in or near the grain-size range preferably used by caddies flies [5]. This problem may be more important for inverte-

brate builder in impounded rivers, where the riverbed may be covered by finer mineral particles which keep on sedimenting from loads from the upper reaches, dam reservoirs, or as a result of dam removal [2] and reservoir dredging as in case of our investigated site of the river [16].

In our laboratory experiments mature larvae of *Hydropsyche* collected from the altered river-bed were reared separately (thus permitting the exclusion of aggressive interactions between individuals), had a lot of space to attach their cases and enough of oxygen (saturation), thus only the availability of preferred mineral grains should be the main limitation of case construction. Our results showed that the case building was successful if the mineral fraction consisted of both 2-4 mm and 0.5-2 mm particles, and they were similar to these obtained by Statzner *et al*. [13] for *H. siltalai* (2.5-3.15 mm) in the Furan River. In those experiments the dominant fraction constituted over 50% mass of the cases. Note that, contrary to our investigations, larvae before pupation in Statzner *et al*. [12] experiments had the choice of particle sizes but with either high or low availability of each of them. However, the use of various grain-size fractions when the preferred ones are unavailable may lead to changes in case architecture (mainly mass) and have further consequences for case stability, e.g. the resistance of the case to damage resulting from floods [12], and in particular to changes of materials for building [6,7,15].

The lack of preferred materials for case building may also have another biological consequence for the animals – the energetic cost of the silk-thread production. As Huryn and Wallace [8] stated, the silk threads produced by *Hydropsyche* larvae can energetically consume up to about 20% of their body tissue production (mainly for building of filter nets). Before pupation silk is required to cement particles in case construction and its amounts increase with decreasing particle size. According to Stevens *et al*. [13], forcing caddis flies to use plenty of silk prior to pupation causes only minor, though significant, decreases in the mass of adults. Thus the presence of various particles, including low availability of preferred ones, needs high production of silk that reduces the gap among grains to a minimum but enables to finish the construction while the presence of only one, the non-preferred, may lead to their death, as in our experiments with fine sand and coarse gravel.

CONCLUSIONS

1. Our results provide support for the hypothesis that the main reason of the sharp decrease in *Hydropsyche* abundance in our investigated site during the post impoundment period was fine sand deposition on a large area of the riverbed.

2. This phenomenon limited larval feeding activity throughout their entire life (the finding of places to attach the nets) and strictly before pupation, causing difficulty with arranging preferred mineral grains for case-building.

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REFERENCES

1. **Cummins K.W.:** An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Am. Mid. Nat., 67, 477-504, 1962.
2. **Doyle M. W., Stanley E.H., Harbor J.M.:** Channel adjustments following two dam removal in Wisconsin. Water Resour. Res., 39, 1-15, 2003.
3. **Dudgeon D.:** Functional significance of selection of particles and their use by aquatic animals in the construction of external structures, 263-288. [In:] R. S. Wotton (ed.): The biology of particles in aquatic systems. CRC, 1990.
4. **Dukowska M., Szczerkowska E., Grzybkowska M., Tszydel M., Penczak T.:** Effects of discharge changes caused by dam and sport canoeing track on a macrobenthic community in a lowland river (mscr).
5. **Gorter F.J.:** Köcherbauversuche an Trichopterenlarven. Z. Morph. kol. Tiere, 20, 443-532, 1931.
6. **Haller P.H.:** Morphologische, biologische und histologische Beiträge zur Kenntnis der Metamorphose der Trichopteren (*Hydropsyche*). Mitt. Schweiz. Entomol. Ges., 21, 301-359, 1948.
7. **Hanna H.H.:** Selection of materials for case-building by larvae of caddis flies (Trichoptera). Proc. R. Entomol. Soc. Lond., (A) 36, 37-47, 1961.
8. **Huryn A.D., Wallace J.B.:** Community structure of Trichoptera in a mountain stream: Spatial patterns of production and functional organization. Freshw. Biol., 20, 141-155, 1988.
9. **Mackay R.J., Wiggins G.B.:** Ecological diversity in Trichoptera. Annu. Rev. Entomol., 24, 185-208, 1979.
10. **Matthaei C.D., Townsend C.R.:** Inundate floodplain gravels in a stream with an unstable bed: temporary shelter or true invertebrate refugium? New Zealand Journal of Marine and Freshwater Research., 34, 147-156, 2000.
11. **Quinn J.M., Hickey C.W.:** Magnitude of effects of substrate particle size, recent flooding, and catchment development on benthic invertebrates in New Zealand rivers. N.Z. J. Mar. Freshwat. Res., 24, 387-409, 1990.
12. **Szczerkowska E., Grzybkowska M., Dukowska M, Tszydel M.:** Organic matter in a lowland river of strongly modified discharge. 2. Discharge volume and "resistance" of habitats. Acta Agrophysica, 88, 557-568, 2003.
13. **Statzner B., Mérigoux S., Leichtfried M.:** Mineral grains in caddis fly pupal cases and streambed sediments: Resource use and its limitation through conflicting resource requirements. Limnol. Oceanogr., 50(2), 713-721, 2005.
14. **Stevens D.J., Hansell M.H, Freel J.A., Monaghan P.:** Developmental trade-offs in caddis flies: Increased investment in larval defence alters adult resource allocation. Proc. R. Soc. Lond., (B) 266, 1049-1054, 1999.
15. **Tolkamp H.H.:** Organism-substrate relationships in lowland streams. Agric. Res. Rep. Wageningen, 907, 1-211, 1980.
16. **Tszydel M., Szczerkowska E., Grzybkowska M., Dukowska M.:** Population parameters of trichopterans (Trichoptera) in dominant habitats of a permanently disturbed lowland river. Acta Agrophysica, 88, 585-593, 2003.
17. **Tszydel M., Grzybkowska M., Szczerkowska E., Dukowska M.:** Dam and canoeing track – induced modifications to the lowland river flow patterns and their caddis biodiversity implications. Teka Kom. Ochr. Kszt. Środ. Przyr., 1, 282-292, 2004.

MIGRACJA LARW V-STADIUM CHRUŚCIKOW BEZDOMKOWYCH *HYDROPSYCHE PELLUCIDULA* (*TRICHOPTERA*) WYMUSZONA POSZUKIWANIEM PODŁOŻA NIEORGANICZNEGO O ODPOWIEDNIEJ GRANULACJI DO BUDOWY DOMKU POCZWARKOWEGO

Mariusz Tszydel, Maria Grzybkowska, Eliza Szczerkowska, Małgorzata Dukowska

Katedra Ekologii i Zoologii Kręgowców, Uniwersytet Łódzki
ul. Banacha 12/16, 0-237 Łódź
e-mail: mtszydel@biol.uni.lodz.pl

S t r e s z c z e n i e. Praca prezentuje eksperyment laboratoryjny dotyczący wybiórczości odpowiedniej średnicy ziaren potrzebnych do budowy domku poczwarkowego przez larwy *Hydropsyche pellucidula* znajdujące się w ostatnim stadium rozwojowym. Badano zdolność budowlaną dla czterech frakcji ziaren oraz sukces w zamknięciu cyklu życiowego

S ł o w a k l u c z o w e: *Hydropsyche pellucidula*, domek poczwarkowy, uziarnienie podłoża, cykl życiowy