

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

A little story about river pollution, predation, and leg regeneration in *Serratella ignita* (Poda, 1761) (Ephemeroptera: Ephemerellidae)

This is a pre print version of the following article:

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1907596> since 2023-09-13T07:45:10Z

Published version:

DOI:10.1080/01650424.2023.2211972

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)



A little story about river pollution, predation, and leg regeneration in *Serratella ignita* (Ephemeroptera: Ephemerellidae)

Journal:	<i>Aquatic Insects</i>
Manuscript ID	NAQI-2023-0004.R1
Manuscript Type:	Research Article
Date Submitted by the Author:	10-Mar-2023
Complete List of Authors:	Fenoglio, Stefano; Universita degli Studi di Torino, DBIOS Marino, Anna; Universita degli Studi di Torino, dbios Bona, Francesca; Universita degli Studi di Torino, dbios Ricaldone, Daniele; Universita degli Studi di Torino, dbios Mina, Federico; Universita degli Studi di Torino, DBIOS Conrado, Isabella; Universita degli Studi di Torino, dbios
Keywords:	environmental pollution, autotomy, feeding functional groups, trophic interactions, behaviour

SCHOLARONE™
Manuscripts

1
2
3 *A little story about river pollution, predation, and leg regeneration in*

4
5 *Serratella ignita* (Ephemeroptera: Ephemerellidae)

6
7 A. Marino, F. Mina, D. Ricaldone, F. Bona, I. Conrado, S. Fenoglio

8
9 Department of Life Sciences and Systems Biology, Università degli Studi di Torino, Via A.
10 Albertina, 13, 10123 Torino, Italy and ALPSTREAM – Alpine Stream Research Center/Parco
11 del Monviso, 12030 Ostana (CN), Italy

12
13
14
15 Corresponding author: stefano.fenoglio@unito.it

16
17
18 **Abstract:**

19
20 We found significantly different percentages of malformed nymphs in two contiguous
21 populations of *Serratella ignita* in a NW Italy stream. We suggest that this may be due to a
22 marked difference in the environmental conditions and especially to the effect of pollution
23 on the functional structure of the insect community.

24
25
26
27
28
29 **Keywords:** environmental pollution; autotomy; feeding functional groups; trophic
30 interactions

31
32
33 **Introduction**

34
35 Among Insecta the regeneration of a lost body part is an interesting phenomenon that,
36 contrary to what happens in some other invertebrate groups, typically concerns limbs and
37 not parts of the trunk, tissues, or other organs (Maruzzo and Bortolin 2013). Even if most of
38 the studies focused on terrestrial insects, the capacity to regenerate a limb lost during the
39 immature stage has also been documented in a few aquatic insects, including Odonata and
40 Ephemeroptera (Saxton et al. 2020). In some mayflies, limbs seem to show a “breakage point”
41 (Almudi et al. 2019), which allows the easy detachment of the leg when subject to pressure,
42 a self-defense mechanism called autotomy that facilitates escape when attacked. The
43 capacity to break off legs and then regenerate them likely allows these insects to survive
44 predators better (Bely and Nyberg 2010). In this study, we report and discuss the different
45 occurrences of *Serratella ignita* (Poda, 1761) (Ephemeroptera: Ephemerellidae) nymphs with
46 malformed/regenerated legs in two reaches of the same stream characterized by contrasting
47 environmental conditions.

48
49
50
51
52
53
54
55
56
57
58
59
60 **Materials and Methods**

In the frame of an extensive study about the combined impact of climate change and wastewater treatment discharge (WWT) on the environmental quality of lotic systems, we monthly collected quantitative aquatic insect samples from the Malone stream (NW Italy). We sampled two stations, the first located 100 m upstream of a WWT (45° 16' 54.0" N, 7° 40' 20.0" E) and the second located 150 m downstream. Up- and downstream sections had similar streambed and channel characteristics. Using a Surber net (22 x 23 cm; 500 micron mesh), we collected five samples/month in each station to assess the taxa presence and abundance of the natural population of benthic insects. In this study, we focused on the samples collected in April and March 2022 (N = 20 surber), as in this period, the nymphs of *S. ignita* reach their largest size before emerging. To evaluate environmental quality we employed the widely used BMWP and ASPTe assessment methods (Buss et al. 2015; Monge-Salazar 2021).

Results

Analyzing the samples, we found several *S. ignita* specimens with not regularly developed, malformed legs (Fig. 1). Interestingly, specimens with regenerating legs were almost exclusively found in the upstream section. Here, on a total number of 494 specimens, 99 reported malformed legs. Among them, 7 nymphs showed a malformation in the first right leg, 14 the first left leg, 22 in the second left leg, 28 in the second right leg, 14 in the third left leg, and 14 in the third right leg. In the downstream section, we found 314 *S. ignita* nymphs, among which only one showed a malformed leg (the mesothoracic right one). In general, no missing or torn structures are noted; this suggests that the limb has been completely detached, and the one found is in its regrowth phase. No organism belonging to another species reported similar malformations.

We detected a marked difference in the environmental quality between the two stream reaches. In the upstream section, BMWP values reached 185, corresponding to a first ecological class (excellent quality, with an ASPT value equal to 5.1). In contrast, in the downstream section, the BMWP reached a 69 score, corresponding to an impacted environment (ASPT = 1.76). We also detected a marked difference in the functional structure of the two benthic communities. While the upstream community was characterized by a more balanced presence of Functional Feeding Groups (Collectors Cg = 56.1%, Filterers F =

1
2
3 40.1 %, Scrapers Sc = 1.15 %, Predators P = 1.92 %, Shredders Sh = 0.71), downstream the
4 community was dominated by taxa feeding on fine particulate organic matter (Cg = 78.7%,
5 F =19.8 %, Sc = 0.40 %, P = 0.40 %, Sh = 0.50). In particular, for predators (represented in
6 this stream mainly by *Rhyacophyla* sp., *Chloroperla* sp., and *Onychogomphus forcipatus*
7 immature stages), we highlighted a significant reduction in the polluted reach (t-test among
8 quantitative Up and Downstream samples = - 2.31, p < 0.05).
9
10
11
12
13



14 Discussion

15
16 This study suggests that the presence of predators could influence the frequency of prey
17 with limb regenerating, highlighting still little-known effects of pollution on the features of
18 aquatic insect populations. According to Nilson (1986), we hypothesized that the highest
19 presence of nymphs with regenerating legs might be linked to higher predation pressure in
20 the upstream station; in the downstream station, the deteriorated environmental quality led
21 to a reduction of predator presence and then limited this phenomenon. The study of trophic
22 interactions between species is a fundamental component of aquatic entomology. Predators
23 are found in nearly all major aquatic insect groups (Fenoglio et al. 2009; Fukuoka 2023). They
24 are known to play an important role in freshwater communities, for example conditioning
25 prey abundance and their distribution within microhabitats (Bo et al. 2010), influencing
26 community composition and trophic cascades (Start and Gilbert 2017) and, as in this case,
27 determining the occurrence of malformations in preys. It is well known that pollution can
28 alter the functional structure of stream insect communities (Merritt et al. 2017), also
29 influencing prey availability and predator diet (Bo et al. 2020) but our findings suggest that
30 pollution can indirectly also affect the frequency of malformations in a prey population.
31 Finally, this study highlights how the ability to regenerate legs among mayflies can be more
32 widespread than what has been known so far.
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

50 References

- 51
52 Almudi, I., Martín-Blanco, C.A., García-Fernandez, I.M., Lopez-Catalina, A., Davie, K.,
53 Aerts, S., and Casares, F. (2019), 'Establishment of the mayfly *Cloeon dipterum* as a new model
54 system to investigate insect evolution', *EvoDevo*, 10(1), 1-10.
55
56
57 Bely, A.E., and Nyberg, K.G. (2010), 'Evolution of animal regeneration: re-emergence of a
58 field', *Trends Ecology Evolution*, 25(3), 161-70.
59
60

Bo, T., Fenoglio, S., López-Rodríguez, M.J., Tierno de Figueroa, J.M., Grenna, M., and Cucco, M. (2010), 'Do predators condition the distribution of prey within micro habitats? An experiment with stoneflies (Plecoptera)', *International review of hydrobiology*, 95(3), 285-295.

Bo, T., Cammarata, M., Doretto, A., and Fenoglio, S. (2020), 'How organic pollution and habitat alteration influence the trophic habits of *Perlodes intricatus* (Pictet, 1841) in alpine rivers?', *Aquatic Insects*, 41(1), 67-75.

Buss, D.F., Carlisle, D.M., Chon, T.S., Culp, J., Harding, J.S., and Hughes, R.M. (2015), 'Stream biomonitoring using macroinvertebrates around the globe: a comparison of large-scale programs', *Environmental monitoring and assessment*, 187, 1-21.

Fenoglio, S., Bo, T., López-Rodríguez, M.J., Tierno de Figueroa, J.M., and Malacarne, G. (2009), 'Preimaginal feeding habits of *Isoperla carbonaria* Aubert, 1953 (Plecoptera: Perlodidae)', *Aquatic Insects*, 31, 401-407.

Fukuoka, T., Tamura, R., Yamasaki, S., and Ohbac, S. (2023), 'Effects of different prey on larval growth in the diving beetle *Cybister sugillatus* Erichson, 1834 (Coleoptera: Dytiscidae)', *Aquatic Insects*, 1-9.

Maruzzo, D., and Bortolin, F. (2013), 'Arthropod regeneration', in *Arthropod biology and evolution*, eds. A. Minelli, G. Boxshall and G. Fusco, Springer.

Merritt, R.W., Fenoglio, S., and Cummins, K.W. (2017), 'Promoting a functional macroinvertebrate approach in the biomonitoring of Italian lotic systems', *Journal of Limnology*, 76, 5-8.

Monge-Salazar, M.J. (2021), 'The effect of artisanal gold mining on aquatic insect communities: a case study in Costa Rica', *Aquatic Insects*, 42(2), 160-178.

Nilsson, C. (1986), 'The occurrence of lost and malformed legs in mayfly nymphs as a result of predator attacks', *Annales Zoologici Fennici*, 23, 57-60.

Poda, N. (1761), 'Insecta Musaei Graecensis, Graecii, quae in ordines, genera et especies juxta Systema Naturae Caroli Linnaei digessit: Haeredes Widmanstadii, pp 18-127.

Saxton, N.A., Powell, G.S., and Bybee, S.M. (2020), 'Prevalence of leg regeneration in damselflies reevaluated: A case study in Coenagrionidae', *Arthropod structure and development*, 59, 100995.

Start, D., and Gilbert, B. (2017), 'Predator personality structures prey communities and trophic cascades' *Ecology letters*, 20, 366-374.

Caption to figure

Figure 1. Three *Serratella ignita* nymphs from Malone stream (NW Italy) showing regenerating legs.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



176x191mm (300 x 300 DPI)