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THE LIFE HISTORY OF *SOYEDINA PRODUCTA* (CLAASSEN) (PLECOPTERA:NEMOURIDAE) IN AN OREGON SUMMER-DRY STREAM, WITH NOTES ON ITS LARVAL GENERIC CHARACTER DEVELOPMENT

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ABSTRACT
Voltinism and life history of the low, but sustained, population of *Soyedina producta* were determined from monthly collections of larvae, and adults from emergence traps, over a 15-year period. Monthly numbers from the 5 best years, 2003-2007, and selected months from 1994 to 2002 were used for determination of larval growth. Emergence phenology was determined from numbers of adults taken from emergence traps over the period 1994 to 2008. Head capsule widths of 180 larvae were measured. The life cycle was univoltine and greatly adapted to the physical conditions of the summer-dry stream. Adult emergence peaked in March. The incubation time for eggs was not determined, but early-instar larvae were first recorded in July. There was little growth through September and then a steady growth from October until the early spring emergence. No larvae were found in benthos samples from April through June. The larval generic diagnostic character of lateral pronotal notch was present in the smallest 0.33mm head-capsule width larvae collected, and all larvae had a distinctive dark pigment pattern. First wingpad development occurred at 0.81-0.84mm head capsule width, and they grew to an inside forewingpad length of up to 1.41mm. Number of cercal segments increased during development from 16-18 to 24-28.

Keywords: Plecoptera, *Soyedina producta*, Nemouridae, Life History, Oregon

INTRODUCTION

Stewart & Anderson (2008) described the larvae of three Nemouridae species from two summer-dry streams on the outskirts of Corvallis, Oregon, and determined the life histories of two of them, *Malenka bifurcata* (Claassen) (Stewart & Anderson 2009a) and *Ostrocerca dimicki* (Frison) (Stewart & Anderson 2010). The larva of the third species described, *Soyedina producta* (Claassen), occurred at low, but sustained population levels in the stream, Oak Burn, over a 15-year period from 1994 to 2008. This report of the life history and larval generic character development of *S. producta* is from the population in Oak Burn where its congener *Soyedina interrupta* (Claassen) does not co-exist.

As with most Nemouridae species, few biological studies have been reported for *Soyedina* (Stewart & Stark 2002). The eastern species *Soyedina vallicularia* (Wu) was found to have a univoltine, slow cycle in permanent southeastern Canadian streams, with adult emergence in May, early-instar larvae appearing in June, and steady and complete growth to penultimate instars for most larvae by winter (Mackay 1969; Harper 1973). The only study of *S. producta* was by Kerst & Anderson (1975) from a small Oregon stream; they were unable to distinguish between the co-occurring larvae of *S. producta* and *S. interrupta*, so the univoltine, fast cycle they proposed for both species was from combined larval growth data. *Soyedina producta* emerged from March to May, and *S. interrupta* emerged over the longer period September through May. Dieterich & Anderson (1995) further clarified the *S. interrupta* life cycle as univoltine, but extremely variable, since early-instar larvae were most abundant in May and June, but also occurred from April to December. Emergence also was extended, including a major spring emergence and a minor autumnal one. Their field observations suggested that larvae survived the summer drought in moist seeps in the non-flowing channels of two high-gradient study streams in McDonald Forest.

STUDY STREAM AND METHODS

Anderson (1997) and Stewart & Anderson (2008, 2009a, b) gave detailed descriptions of the study stream, Oak Burn. It is located in a remnant of oak savanna near 60th Street less than 1km north of the Corvallis, Oregon, city limits at an elevation of 150m. The flow interval varies from about late October or early December to mid-July or late August, depending on annual precipitation that averaged 122cm from 1992 to 2007. The stream is typically without surface flow, or with a trickle and a few seep areas remaining wetted during summer and into fall. Anderson (1997) and Stewart & Anderson (2009a) illustrated the stream in summer-dry, mid-winter flow, and spate conditions.

Larval collections were made monthly during wet and dry seasons, and were recovered from substrates by the same methods reported by Stewart & Anderson (2009a, b). Because of the sustained low population levels and low monthly numbers of larvae recovered, numbers from the samples of the 5 best years, 2003-2007, and selected months from 1994 to 2002, were pooled to obtain average monthly head capsule width (hcw) measurements of 180 larvae for determining growth phenology. Larvae were preserved in 70-80% ethanol and later measured with a calibrated ocular micrometer on a Wild M-5 stereomicroscope.

Adults were collected from emergence traps described by Dieterich & Anderson (1995) and Stewart & Anderson (2009a,b, 2010) over the same period as the larvae that were taken in the benthos collections (1994-2007). These low numbers were supplemented by adults collected in 2008 in a further study of longitudinal distribution of the insect fauna in Oak Burn. This provided an additional 26 adults that were pooled with those in the long-term collections for monthly totals in determining emergence phenology.

Data from the longitudinal study were used to compare the relative abundance and emergence timing of *S. producta* with that of the other nemourid species in Oak Burn. Five pyramidal traps, each 0.5m^2, were placed in two sections: (1) upstream section on Anderson property (A); and (2) downstream section on Christianson property (C). These were larger than the elongate (0.3m^2) traps that were used in the long-term study. It is not clear whether the adults captured in the pyramidal traps were actually emerging from the benthos beneath the traps or if some portion were attracted to the site and captured after crawling into the trap. The square design meant that some were perched, rather than below the water surface allowing continuous access to and egress from the trap. In the entire reach of 400m, both gradient and substrate particle size decreased in a downstream direction. In addition, the upper reach (A) was somewhat more shaded than the downstream area (C) and the latter dried up earlier in the summer.

The first appearance and change (development) of diagnostic generic and other morphological characters were determined by microscopic study of the 180 larvae measured. Characters studied were: (1) the marginal fringe of bristles and lateral notch of the pronotum (the major diagnostic character of late-instar *Soyedina*; Stewart & Stark 2002); (2) progression of wingpad development (measured as length of the inside margin of the mesonotal wingpads); (3) pigment pattern; and (4) number of cercal segments.

RESULTS AND DISCUSSION

Voltinism and life history. Only 23 males and 38

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Adults				
♂	4	19	0	0
♀	3	17	15	3

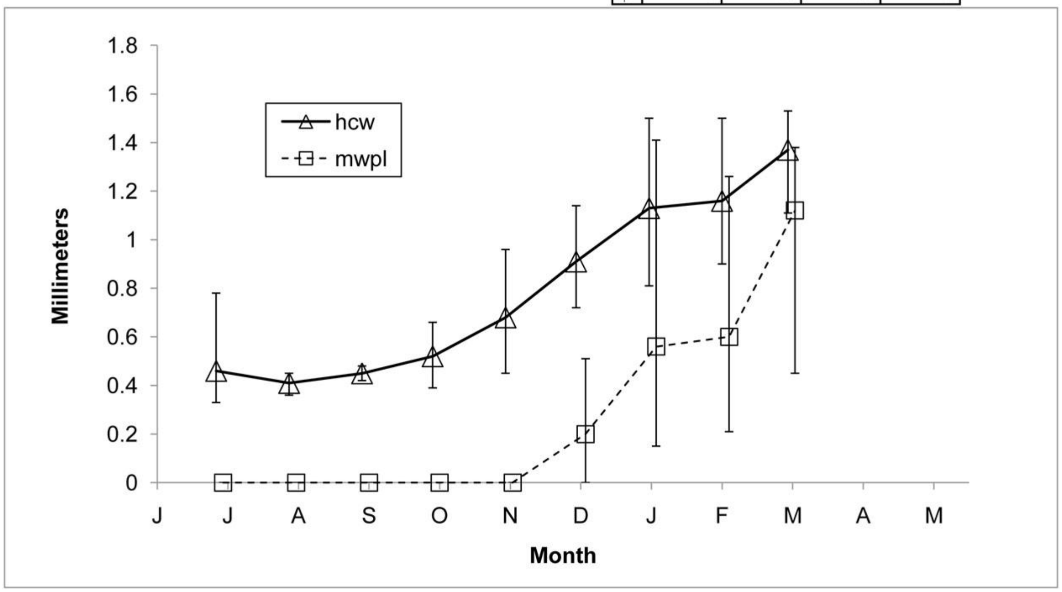


Fig. 1. Emergence and growth of *Soyedina producta.* Emergence numbers pooled by month (1994-2008) from Table 2. Monthly plots of average larval head capsule widths (hcw) and mesosternal wingpad lengths (mwpl) are from pooled numbers of 1994 to 2007 larval collections measured (Table 1). Vertical lines are ranges of measurements.

Table 1. *S. producta* larval head capsule widths and wingpad lengths, pooled all years 1994-2007; n=180.

	Head capsule width (mm)				**Inside front wingpad length (mm)**		
Months	n	max.	min.	average	max.	min.	average
January	31	1.50	0.81	1.13	1.41	0.15	0.56
February	17	1.50	0.90	1.16	1.26	0.21	0.60
March	16	1.53	1.11	1.37	1.38	0.45	1.12
Apr.-Jun.	none recorded						
July	8	0.78	0.33	0.46	0.0	0.0	0.0
August	18	0.45	0.36	0.41	0.0	0.0	0.0
September	4	0.48	0.42	0.45	0.0	0.0	0.0
October	42	0.66	0.39	0.52	0.0	0.0	0.0
November	27	0.96	0.45	0.68	0.0	0.0	0.0
December	17	1.14	0.72	0.91	0.51	0.0	0.20

Table 2. Pooled emergence numbers of *S. producta* by month, 1994-2008.

Month	Males	Females	Total
February	4	3	7
March	19	17	36
April	--	15	15
May	--	3	3

females were taken in the Oak Burn emergence traps over the 1994-2008 study period (Table 2, Fig. 1). This, and the 180 larvae recovered from the benthos samples (Table 1) mainly from 2003-2007, showed that Oak Burn supported a low, but sustained population of *S. producta.* It was less common than *Sweltsa adamantea* Surdick (Stewart & Anderson 2009b) or *Malenka bifurcata* (Stewart & Anderson 2009a). In the 2008 longitudinal study, two other nemourid species also were more abundant than *S. producta* (Fig. 2). Emergence began in late February (Table 2, Fig. 1), peaked in March, and only females were recovered in April and May, similar to the report by Kerst & Anderson (1975) in a nearby permanent stream. The 23 males taken from emergence traps in late February-March, the 20 females from that same period, and only 18 females and no males in April-May (Table 2) suggested an emergence protandry. No emergers were taken in traps from June through January in the 1994-2007 or 2008 trapping periods.

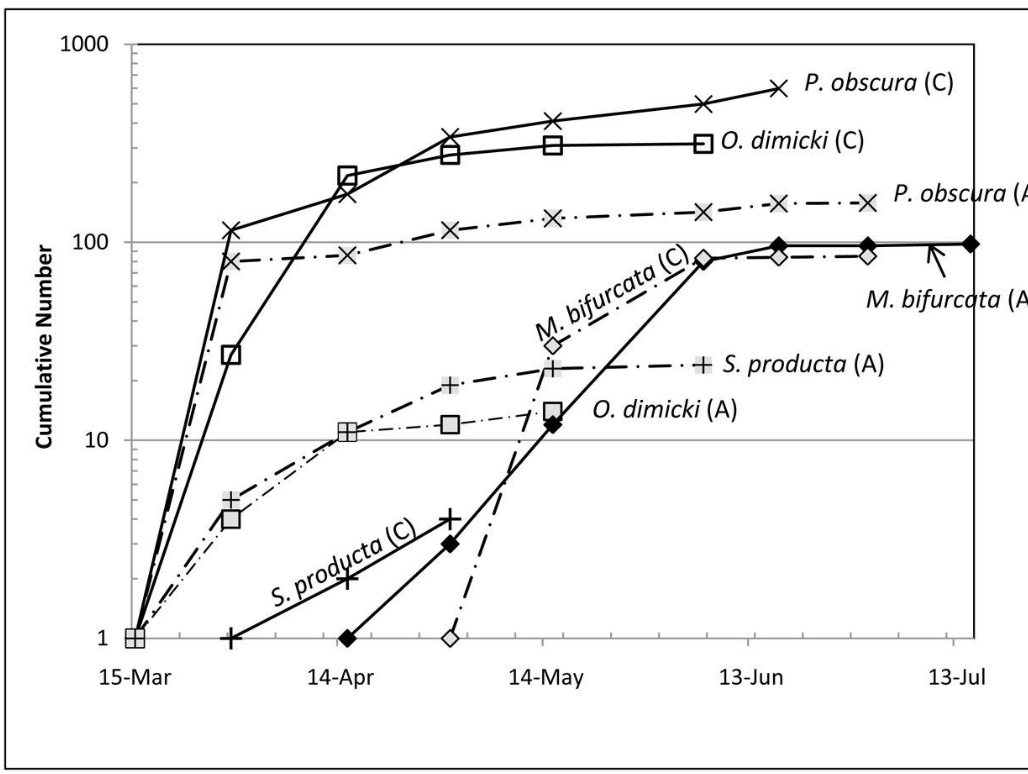


Fig. 2. Log scale comparison of cumulative numbers of nemourid stoneflies recovered from 10 emergence traps in upstream (A= Anderson, 5 traps) and downstream (C= Christianson, 5 traps) sections of Oak Burn in 2008. *Malenka bifurcata, Ostrocerca dimicki, Podmosta obscura, and S. producta.*

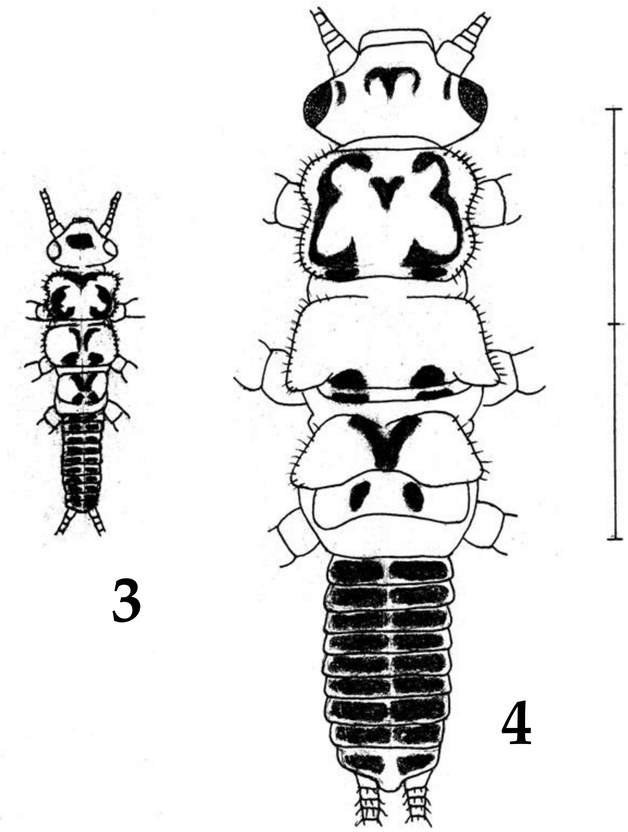
Head-capsule measurements of the 180 field sampled larvae ranged from 0.33 to 1.53mm, and average monthly hcw ranged from 0.41 to 1.37mm (Table 1). Interestingly, the range of *S. producta* hcw corresponded closely with those of the Oak Burn nemourid *Malenka bifurcata* (0.36 to 1.47mm; Stewart & Anderson 2009a) and *Ostrocerca dimicki* (0.33 to 1.32mm) from the input tributary to Oak Burn, Outgate Beck (Stewart & Anderson 2010).

The smallest larvae were first collected in benthos samples in July, near the end of the annual flow interval of Oak Burn (Table 1, Fig. 1). Little growth then occurred through September, became accelerated in October (with declining temperature and in some years resumption of flow), and then steadily increased during the winter-spring flow period when food for shredders is most available. Pre-emergent sized larvae were present from January to March just prior to peak emergence, and no larvae were found from April through June (Table 1, Fig. 1).

This emergence and growth pattern indicated a univoltine cycle greatly adapted to the physical conditions of Oak Burn, with: (1) a peak March emergence of both sexes; (2) an approximate 3-4 month (March-June) unaccounted for period of egg maturation-incubation-hatch (possibly a short term egg diapause? with larvae not present); (3) a larval aestivation July-September in the moist substrates and trickles of the summer-dry flow period; and (4) sustained growth from October to pre-emergent size from January to March. The life cycle is generally similar to that of the eastern *S. vallicularia* (Mackay 1969; Harper 1973), except that direct egg hatch was not indicated soon after peak emergence as was the case for *S. vallicularia.* The late February-May emergence timing of *S. producta* in Oak Burn was similar to the findings of Kerst & Anderson (1975) for the species in nearby McDonald Forest streams. Our findings demonstrate that the life cycle of *S. producta* in Oak Burn is not as variable or complex as that reported for *S. interrupta* in the Oak Creek catchment of McDonald Forest by Dieterich & Anderson (1995). They found that early-instar larvae of *S. interrupta* were most abundant in May and June but they also occurred from April to December, that spring hatchlings took 10-12 months to mature, and there was a major spring and minor autumnal emergence. In Oak Burn, there are no *S. producta* early-instar larvae from March to June, or in December (Table 1, Fig. 1), no autumnal emergence (Table 2, Fig. 1), and hatchlings recruited probably in June or July took 8 or 9 months to mature (Table 1, Fig. 1).

Table 3. Development of morphological characters in *S. producta larvae.*

Head capsule width (mm)	**Characters**
0.33-0.50	Marginal fringe of bristles and lateral notch of pronotum evident; distinctive pigment pattern (Fig. 3); no wingpad development; 16-18 cercal segments.
0.51-0.80	Addition of cercal segments to 19-26; continued presence of lateral pronotal notch; no wingpad development.
0.81-0.84	First wingpad development ("nub" to 0.21mm inside length of mesosternal wingpad); 22-24 cercal segments; distinctive pigment pattern (Fig. 4).
0.85-1.20	Inside mesosternal wingpad length 0.21-0.51mm; cercal segments 24-28.
1.21-1.50 (pre-emergent)	Major wingpad development (0.51-1.35mm inside mesosternal wingpad length; ♀ up to 1.20-1.35mm); cercal segments 24-28; sexual dimorphism evident (males with developing epiproct on tergum 10 and developing hypoproct on sternum 9).



Figs. 3,4. *S. producta* larval habitus. 3. At 0.33mm hcw and 1.35mm body length. 4. at 0.84mm hcw and 3.4mm body length. Scale line= 2mm.

Morphological character development. Table 3 summarizes morphological characters of the smallest field-sampled larvae (0.33 to 0.50mm hcw), and their appearance and change (development) until the pre-emergent size of 1.21-1.50mm hcw. The generic diagnostic characters of marginal fringe of bristles and shallow lateral notch of the pronotum (Stewart & Stark 2002) were present in the smallest larvae (Fig. 3), so they can be identified to genus at this small size; these characters persisted throughout development. These early-instar larvae also displayed a distinctive dark pigment pattern (Figs. 3-4) that enabled separation from all the other stonefly larvae present in the stream at the same time. The number of cercal segments increased progressively from the 16-18 at 0.33-0.50mm hcw to 24-28 at 0.85-1.20mm hcw size, then remained stable in number in the late instars of 1.21-1.50mm hcw size (Table 3). The first wingpad development occurred at the 0.81-0.84mm hcw size, gradually increased through 1.20mm hcw, and experienced major development after that size (Table 3). The distinctive dark pattern persisted throughout development; the typical pattern of middle instars is shown in Fig. 4. Male larvae could be distinguished by their developing epiproct on tergum 10 and developing hypoproct on sternum 9 in the pre-emergent instars.

Habitat occurrence of nemourid species. *S. producta* is only one of five nemourid species in this small, summer-dry headwater stream. In addition to the four species shown in Fig. 2, 12 *Ostrocerca foersteri* (Ricker) adults were identified from the 2008 longitudinal study. The two most abundant species, *Podmosta obscura* (Frison) and *O. dimicki,* were especially common in the lower reach (C) which was surface-dry before the end of June. Stewart & Anderson (2010) have shown that these species can exploit short-flow meadow streams where other stoneflies are absent. *Malenka bifurcata* has a complex life history, resulting in indeterminate voltinism (Stewart & Anderson 2009a). It had the latest emergence interval; the first adults were collected in mid-April and emergence continued until the sites were surface dry. Though the numbers of *S. producta* were always low, there was a sustainable population throughout this long-term study. Dieterich & Anderson (2000) characterized *S. producta* as an obligate of forested (shaded) streams and facultative in intermittent habitats. In the higher gradient sections of Oak Burn there are sustainable patches of habitat enabling this species to persist despite its low numbers.

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