Henault, J. and Westwood, R. Endangered *Oarisma poweshiek* larvae vary their graminoid forage in Manitoba, Canada

**Supplementary material, Tables S1–S6**

**Table S1.** Direction which the dorsal surface of an *Oarisma poweshiek* immature’s body faced while feeding and resting (mean ± angular deviation). Direction not recorded for Immature 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Immature** | **Behaviour (*n*)** | **Direction (°)** | ***r*** | **Rayleigh test (*P*)** |
| 2 | Feeding (3) | 0 ± 32 | 0.846 | Not permitted. |
|  | Resting (12) | 347 ± 63 | 0.404 | 0.147 |
| 3 | Feeding (5) | 307 ± 35 | 0.815 | 0.026 |
|  | Resting (7) | 357 ± 34 | 0.827 | 0.004 |

**Table S2**. Locations on shoots where *Oarisma poweshiek* Immatures (as larvae) were observed feeding and resting (distance in cm from the apex of the head capsule). We recorded only the tip or ground distance when we the risk of disturbing larvae was higher (please see methods).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Feeding** | | |  | **Resting** | | |
| **Stage** | **Distance to the leaf tip (mean (range) )** | **Distance to the ground (mean (95 % C. I.) )** |  | **Stage** | **Distance to the leaf tip (mean (range) )** | **Distance to the ground (mean (95 % C. I.) )** |
| **Immature 1** |  |  |  | **Immature 1** |  |  |
| Instar 1 | 0.00 (0.00 to 0.00) (n = 3) | (n = 0) |  | Instar 1 | 1.01 (0.93 to 1.09) (n = 2) | 9.9 (3.8 to 16.0) (n = 2) |
| **Immature 2** |  |  |  | **Immature 2** |  |  |
| Instar 1 | 0.00 (0.00 to 0.00) (n = 6) | 16.7 (16.4 to 17.0) (n = 3) |  | Instar 1 | 1.28 (0.90 to 1.72) (n = 4) | 15.8 (15.3 to 16.3) (n = 3) |
| 2 | 0.17 (0.00 to 0.85) (n = 5) | 13.4 (7.1 to 19.8) (n = 3) |  | 2 | 5.56 (3.40 to 10.56) (n = 4) | 11.1 (7.0 to 15.2) (n = 6) |
| 3 | 0.14 (0.00 to 0.86) (n = 8) | 12.4 (9.3 to 15.4) (n = 7) |  | 3 | 7.15 (3.67 to 11.18) (n = 6) | 8.4 (5.7 to 11.2) (n = 6) |
| 4 | 0.13 (0.00 to 0.54) (n = 8) | 9.3 (7.5 to 11.1) (n = 8) |  | 4 | 15.29 (n = 1) | 5.2 (n = 1) |
| **Immature 3** |  |  |  | **Immature 3** |  |  |
| Instar 1 | 0.11 (0.00 to 0.35) (n = 6) | 25.8 (21.6 to 30.0) (n = 6) |  | Instar 1 | 2.94 (2.29 to 5.10) (n = 5) | 23.4 (21.8 to 25.0) (n = 5) |
| 2 | 0.00 (0.00 to 0.00) (n = 3) | 27.8 (25.3 to 30.3) (n = 4) |  | 2 | 7.69 (1.26 to 17.52) (n = 5) | 19.0 (12.1 to 25.8) (n = 5) |
| 3 | 0.31 (0.00 to 0.61) (n = 2) | 9.1 (8.5 to 9.7) (n = 2) |  | 3 | 1.68 (1.39 to 1.95) (n = 3) | 8.4 (8.2 to 8.6) (n = 3) |

**Table S3.** Degree-day accumulations in egg enclosures (each plot type: *n* = 4) and comparison plots calculated using two models (mean (95% confidence interval)).

|  |  |  |  |
| --- | --- | --- | --- |
| Plot | Active larval | Diapause | Break of diapause to adult eclosion |
| Egg enclosure |  |  |  |
| Standard | 1050.1 (1011.7–1088.4) | 107.3 (93.0–121.7) | 542.6 (526.9–558.3) |
| Double sine | 976.7 (909.5–1043.8) | 211.3 (202.1–220.4) | 535.9 (522.1–549.8) |
| Comparison |  |  |  |
| standard | 1017.5 (971.6–1063.3) | 111.6 (70.8–152.4) | 564.3 (540.2–588.4) |
| Double sine | 980.9 (954.0–1007.8) | 205.3 (138.3–272.3) | 535.7 (508.2–563.3) |

**Table S4.** The temperature (ºC), relative humidity (%), and dewpoint (ºC) during *Oarisma poweshiek* development periods (mean (95% confidence interval)) recorded in egg enclosures and comparison plots. Bolded values are significantly different from the values of at least 3 data loggers of the other plot type.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Plot** | **Temperaturemean** | **Temperaturemin** | **Temperaturemax** | **Relative Humiditymean** | **Relative Humiditymin** | **Relative Humiditymax** | **Dewpointmean** | **Dewpointmin** | **Dewpointmax** |
|  |  |  |  |  |  |  |  |  |  |
| **Active larval period** | | | | | | | | | |
| **Egg enclosure** |  |  |  |  |  |  |  |  |  |
| 1 | 16.6 (15.6 to 17.7) | 8.3 (7.3 to 9.3) | 25.5 (24.2 to 26.9) | **77.2 (75.3 to 79.1)** | **50.8 (47.9 to 53.8)** | 98.3 (97.6 to 99.1) | 12.1 (11.2 to 13.1) | 6.3 (5.3 to 7.4) | 16.4 (15.4 to 17.4) |
| 2 | 16.4 (15.4 to 17.4) | 8.1 (7.1 to 9.0) | 25.4 (24.0 to 26.8) | 81.1 (79.2 to 82.9) | 55.3 (52.2 to 58.5) | **100.3 (99.7 to 100.8)** | 12.7 (11.7 to 13.7) | 6.6 (5.5 to 7.6) | 17.4 (16.3 to 18.5) |
| 3 | 16.8 (15.7 to 17.9) | 7.0 (6.0 to 8.0) | **27.6 (26.0 to 29.1)** | **75.7 (74.0 to 77.4)** | **48.4 (45.5 to 51.3)** | 95.4 (94.9 to 95.9) | 11.9 (11.0 to 12.9) | 5.2 (4.2 to 6.2) | 16.8 (15.7 to 17.9) |
| 4 | 16.7 (15.7 to 17.7) | 8.0 (7.1 to 9.0) | 26.4 (25.0 to 27.8) | **76.6 (74.9 to 78.2)** | **52.7 (49.9 to 55.5)** | 94.7 (94.0 to 95.4) | 12.2 (11.3 to 13.2) | 5.8 (4.7 to 6.8) | 17.1 (16.1 to 18.2) |
| **Comparison** |  |  |  |  |  |  |  |  |  |
| 5 | 16.7 (15.7 to 17.7) | 8.7 (7.7 to 9.7) | 24.6 (23.3 to 25.9) | **82.9 (81.1 to 84.7)** | **64.0 (60.9 to 67.1)** | 97.7 (97.2 to 98.2) | 13.2 (12.2 to 14.1) | 6.4 (5.3 to 7.5) | 18.2 (17.2 to 19.2) |
| 6 | 16.6 (15.6 to 17.6) | 8.4 (7.4 to 9.4) | 25.7 (24.1 to 27.2) | **82.9 (81.2 to 84.6)** | **61.1 (57.7 to 64.4)** | 98.1 (97.7 to 98.4) | 13.0 (12.1 to 14.0) | 6.3 (5.2 to 7.4) | 18.6 (17.5 to 19.6) |
| 7 | 15.5 (14.2 to 16.9) | 8.5 (7.3 to 9.7) | 23.5 (21.6 to 25.4) | 76.9 (71.5 to 82.3) | 60.2 (54.9 to 65.5) | 89.7 (83.9 to 95.4) | 12.3 (11.2 to 13.5) | 5.8 (4.7 to 6.9) | 18.0 (16.5 to 19.4) |
| 8 | 16.3 (15.4 to 17.2) | 8.8 (7.9 to 9.7) | 24.2 (22.9 to 25.5) | **80.8 (79.4 to 82.3)** | **64.9 (62.4 to 67.3)** | **93.0 (92.3 to 93.7)** | 12.6 (11.7 to 13.5) | 5.8 (4.7 to 6.8) | 18.3 (17.2 to 19.3) |
|  |  |  |  |  |  |  |  |  |  |
| **Diapause** | | | | | | | | | |
| **Egg enclosure** |  |  |  |  |  |  |  |  |  |
| 1 | -1.0 (-1.7 to -0.3) | -4.9 (-5.4 to -4.4) | 3.0 (1.9 to 4.1) | 83.0 (81.3 to 84.7) | 69.6 (66.7 to 72.4) | 94.5 (93.6 to 95.3) | -3.9 (-4.5 to -3.3) | -7.4 (-8.1 to -6.7) | -1.2 (-1.8 to -0.5) |
| 2 | -1.0 (-1.7 to -0.3) | -4.6 (-5.1 to -4.2) | 2.7 (1.6 to 3.8) | 87.4 (85.9 to 89.0) | 75.6 (72.6 to 78.5) | **97.0 (96.4 to 97.7)** | -3.3 (-3.8 to -2.7) | -6.3 (-6.9 to -5.7) | -0.8 (-1.5 to -0.2) |
| 3 | -0.7 (-1.4 to -0.1) | -4.4 (-4.9 to -3.9) | 3.1 (2.0 to 4.2) | 82.1 (80.7 to 83.6) | 70.4 (67.7 to 73.1) | **91.3 (90.7 to 91.9)** | -3.6 (-4.1 to -3.0) | -6.8 (-7.5 to -6.1) | -1.1 (-1.7 to -0.5) |
| 4 | 0.0 (-0.6 to 0.6) | -3.0 (-3.4 to -2.5) | 3.3 (2.3 to 4.3) | 82.2 (80.6 to 83.8) | 72.7 (70.0 to 75.4) | **90.0 (89.2 to 90.8)** | -2.7 (-3.3 to -2.2) | **-5.5 (-6.2 to -4.9)** | -0.6 (-1.2 to 0.0) |
| **Comparison** |  |  |  |  |  |  |  |  |  |
| 5 | -0.5 (-1.2 to 0.2) | -4.1 (-4.6 to -3.7) | 3.3 (2.2 to 4.5) | 84.6 (83.0 to 86.1) | 72.5 (69.7 to 75.3) | 94.1 (93.4 to 94.8) | -3.6 (-4.2 to -3.0) | -7.3 (-8.0 to -6.7) | -0.5 (-1.3 to 0.2) |
| 6 | -0.8 (-1.6 to -0.1) | -4.8 (-5.3 to -4.3) | 3.1 (2.0 to 4.3) | 85.6 (84.0 to 87.1) | 73.4 (70.6 to 76.2) | 95.0 (94.3 to 95.6) | -3.8 (-4.4 to -3.2) | **-7.7 (-8.4 to -7.0)** | -0.7 (-1.4 to 0.1) |
| 7 | -0.1 (-0.7 to 0.4) | **-2.9 (-3.4 to -2.5)** | 2.8 (1.8 to 3.7) | **89.0 (87.7 to 90.2)** | 79.0 (76.7 to 81.3) | 95.9 (95.3 to 96.5) | -2.4 (-3.0 to -1.9) | -5.8 (-6.4 to -5.2) | 0.3 (-0.4 to 1.0) |
| 8 | -0.6 (-1.2 to 0.1) | -3.6 (-4.2 to -3.1) | 2.5 (1.5 to 3.5) | 80.1 (78.8 to 81.4) | 70.7 (68.4 to 72.9) | **86.9 (86.1 to 87.6)** | -4.0 (-4.6 to -3.3) | -7.6 (-8.4 to -6.9) | -1.2 (-1.9 to -0.4) |
|  |  |  |  |  |  |  |  |  |  |
| **Break of diapause to adult emergence** | | | | | | | | | |
| **Egg enclosure** |  |  |  |  |  |  |  |  |  |
| 1 | 16.7 (15.6 to 17.7) | 8.0 (6.8 to 9.2) | 25.7 (24.1 to 27.3) | 71.6 (68.3 to 75.0) | **42.8 (38.5 to 47.1)** | 97.5 (96.0 to 99.0) | 10.6 (9.4 to 11.8) | 5.9 (4.5 to 7.2) | **14.4 (13.2 to 15.7)** |
| 2 | 16.8 (15.7 to 17.8) | 7.3 (6.0 to 8.6) | 26.3 (24.7 to 27.9) | 75.8 (72.6 to 79.1) | 47.5 (42.8 to 52.2) | **100.0 (99.1 to 100.9)** | 11.6 (10.4 to 12.9) | 5.9 (4.5 to 7.2) | 15.8 (14.5 to 17.2) |
| 3 | 16.7 (15.6 to 17.8) | 7.8 (6.6 to 9.0) | 25.6 (24.0 to 27.1) | 73.0 (70.2 to 75.9) | 49.2 (45.1 to 53.2) | **94.3 (93.2 to 95.5)** | 11.3 (10.1 to 12.5) | 5.6 (4.3 to 6.9) | 15.6 (14.3 to 16.9) |
| 4 | 16.5 (15.6 to 17.5) | 8.8 (7.7 to 9.8) | 25.3 (23.9 to 26.8) | 74.6 (71.6 to 77.6) | 51.2 (46.8 to 55.6) | **93.4 (92.4 to 94.5)** | 11.5 (10.3 to 12.7) | 6.2 (5.0 to 7.5) | 15.8 (14.4 to 17.1) |
| **Comparison** |  |  |  |  |  |  |  |  |  |
| 5 | 17.2 (16.2 to 18.3) | 7.8 (6.5 to 9.1) | 26.7 (25.0 to 28.4) | 76.2 (72.5 to 80.0) | 53.2 (47.6 to 58.9) | 96.9 (95.9 to 97.9) | 12.0 (10.8 to 13.2) | 5.1 (3.6 to 6.5) | 17.5 (16.2 to 18.7) |
| 6 | 17.3 (16.2 to 18.4) | 7.6 (6.3 to 8.9) | 27.6 (25.7 to 29.4) | 75.0 (71.4 to 78.6) | 48.5 (43.0 to 54.0) | 97.4 (96.5 to 98.3) | 11.8 (10.6 to 12.9) | 5.1 (3.7 to 6.5) | 17.1 (15.8 to 18.5) |
| 7 | 16.6 (15.6 to 17.5) | 8.7 (7.5 to 9.8) | 25.3 (23.8 to 26.8) | 79.6 (76.5 to 82.7) | 56.0 (51.1 to 60.9) | 98.2 (97.5 to 98.8) | 12.3 (11.1 to 13.4) | 5.6 (4.2 to 7.0) | 17.7 (16.5 to 18.9) |
| 8 | 16.7 (15.7 to 17.7) | 8.5 (7.4 to 9.6) | 26.1 (24.6 to 27.7) | 74.9 (72.1 to 77.7) | 53.7 (49.2 to 58.1) | 91.5 (90.7 to 92.3) | 11.6 (10.4 to 12.7) | 4.9 (3.6 to 6.2) | 17.6 (16.2 to 18.9) |

**Table S5.** The standardised number of shoots of *Oarisma poweshiek* host food plant species (0.19 m2) in 2018 and 2019 (mean ± standard deviation).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Date** | ***A. gerardi*** | ***M. richardsonis*** | ***S. heterolepis*** | ***S. scoparium*** |
| 3 August 2018 |  |  |  |  |
| Egg enclosure | 43.2 ± 20.2 | 17.0 ± 20.5 | 57.3 ± 53.3 | 5.0 ± 9.3 |
| Target plot | 35.7 ± 25.6 | 37.1 ± 49.0 | 82.8 ± 29.2 | 7.2 ± 12.3 |
| 9 May 2019 |  |  |  |  |
| Egg enclosure | 0.8 ± 1.3 | 0.2 ± 0.4 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| Comparison plot | 0.1 ± 0.3 | 0.1 ± 0.3 | 0.0 ± 0.0 | 0.0 ± 0.0 |
| 30 May 2019 |  |  |  |  |
| Egg enclosure | 0.2 ± 0.4 | 10.8 ± 12.1 | 27.3 ± 18.5 | 0.0 ± 0.0 |
| Comparison plot | 0.0 ± 0.0 | 2.8 ± 2.5 | 16.1 ± 12.2 | 0.0 ± 0.0 |
| 11 June 2019 |  |  |  |  |
| Egg enclosure | 9.0 ± 7.2 | 10.7 ± 13.8 | 37.2 ± 31.4 | 3.5 ± 7.2 |
| Comparison plot | 12.4 ± 6.6 | 2.1 ± 1.6 | 29.4 ± 18.9 | 1.1 ± 1.2 |
| 5 July 2019 |  |  |  |  |
| Egg enclosure | 21.3 ± 11.3 | 2.8 ± 1.9 | 33.7 ± 35.0 | 7.3 ± 10.5 |
| Comparison plot | 41.2 ± 21.7 | 1.3 ± 1.9 | 30.7 ± 17.6 | 5.8 ± 11.9 |

**Table S6.** Species enumerated during 2018 and 2019 research ("+" = observed, "-" = not observed, empty = not evaluated; fonts of observed hosts bolded). We use the most recent nomenclature and common names from Looman and Best (1987), Leighton and Harms (2014), and Tropicos.org (Missouri Botanical Garden 2021).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scientific Name and Authority** | **Family** | **Common name** | **Egg enclosure** | **Target plot** | **Comparison plot** |
| *Achillea* Linnaeus spp.1 | Asteraceae | Yarrow | - | + |  |
| *Amelanchier alnifolia* (Nuttall) Nuttall ex M. Roemer | Rosaceae | Saskatoon berry | - | + |  |
| ***Andropogon gerardi* Vitman** | **Poaceae** | **Big bluestem** | **+** | **+** | **+** |
| *Antennaria* Gaertner spp. | Asteraceae | Everlasting genus | - | + |  |
| Asteraceae Berchtold and J. Presl spp.2 |  | Aster family | + | + |  |
| *Beckmannia syzigachne* (Steudel) Fernald | Poaceae | Slough grass | - | + |  |
| *Bromus* Linnaeus spp. | Poaceae | Brome grass | + | + |  |
| *Caltha palustris* Linnaeus | Ranunculaceae | Marsh-marigold | - | + |  |
| *Campanula rotundifolia* Linnaeus | Campanulaceae | Harebell | - | + |  |
| Cyperaceae Jussieu spp. |  | Sedge family | + | + |  |
| *Dalea purpurea* Ventenat | Fabaceae | Purple prairie-clover | + | + |  |
| *Deschampsia cespitosa* (Linnaeus) Palisot de Beauvois | Poaceae | Tufted hairgrass | + | + |  |
| *Eleocharis* R. Brown spp. | Cyperaceae | Spike rush genus | - | + |  |
| *Equisetum* Linnaeus sp.3 | Equisetaceae | Horse-tail sp. 1 | + | + |  |
| *Equisetum* Linnaeus sp.4 | Equisetaceae | Horse-tail sp. 2 | + | + |  |
| *Fragaria virginiana* Miller | Rosaceae | Strawberry | + | + |  |
| *Geum triflorum* Pursh | Rosaceae | Three-flowered avens | + | + |  |
| *Glycyrrhiza lepidota* Pursh | Fabaceae | Wild licorice | + | + |  |
| *Helianthus maximiliani* Schrader | Asteraceae | Maximillian's sunflower | + | + |  |
| *Hesperostipa spartea* (Trinius) Barkworth | Poaceae | *H. spartea* grass | + | + |  |
| ***Hypoxis hirsuta* (Linnaeus) Coville** | **Hypoxidaceae** | **Star-grass** | **+** | **+** | **+** |
| Juncaceae Jussieu spp. |  | Rush family | + | + |  |
| *Lathyrus* Linnaeus spp. | Fabaceae | Wild pea genus | - | + |  |
| *Liatris ligulistylis* (A. Nelson) K. Schumann | Asteraceae | Meadow blazingstar | + | + |  |
| *Lithospermum canescens* (Michaux) Lehmann | Boraginaceae | Hoary puccoon | + | + |  |
| *Lysimachia quadriflora* Sims | Primulaceae | *L. quadriflora* forb | - | + |  |
| ***Muhlenbergia richardsonis* (Trinius) Rydberg** | **Poaceae** | **Mat muhly** | **+** | **+** | **+** |
| *Muhlenbergia* Schreber spp.5 | Poaceae | Muhly | + | + | + |
| *Parnassia* Linnaeus spp. | Celastraceae | Grass-of-Parnassus genus | + | + |  |
| Poaceae Barnhart spp. |  | Grass family | - | + |  |
| *Populus tremuloides* Michaux | Salicaceae | Trembling aspen | - | + |  |
| *Potentilla fruticosa* Linnaeus | Rosaceae | Shrubby cinquefoil | + | + |  |
| *Rudbeckia hirta* Linnaeus | Asteraceae | Black-eyed susan | + | + |  |
| *Salix* Linnaeus spp. | Salicaceae | Willow genus | - | + |  |
| ***Schizachyrium scoparium* (Michaux) Nash** | **Poaceae** | **Little bluestem** | **+** | **+** | **+** |
| *Solidago ptarmicoides* (Torrey and A. Gray) B. Boivin | Asteraceae | Upland white goldenrod | + | + |  |
| *Solidago rigida* Linnaeus | Asteraceae | Rigid goldenrod | + | + |  |
| *Solidago* Linnaeus sp. | Asteraceae | *Solidago* sp. 1 | + | + |  |
| *Solidago* Linnaeus spp.6 | Asteraceae | Goldenrod genus | + | + |  |
| *Sorghastrum nutans* (Linnaeus) Nash | Poaceae | *S. nutans* grass | + | + | + |
| ***Sporobolus heterolepis* (A. Gray) A. Gray** | **Poaceae** | **Prairie dropseed** | **+** | **+** | **+** |
| *Sporobolus michauxianus* (Hitchcock) P.M. Peterson and Saarela | Poaceae | Prairie cordgrass | + | + |  |
| *Thalictrum dasycarpum* Fischer and Avé-Lallemant | Ranunculaceae | Tall meadow-rue | + | + |  |
| *Toxicodendron radicans* (Linnaeus) Kuntze | Anacardiaceae | Poison-ivy | - | + |  |
| *Viola* Linnaeus spp. | Violaceae | Violet | + | - |  |
| *Zizia* W.D.J. Koch spp.7 | Apiaceae | *Zizia* spp. | + | + |  |

1. Most likely *A. millefolium* Linnaeus.  
2. Not including other species in the Asteraceae family which were enumerated.  
3. Most likely *E. laevigatum* A. Braun.  
4. Most likely *E. pratense* Ehrhart.  
5. *Muhlenbergia* spp. other than *M. richardsonis* (Trinius) Rydberg. A mixture of most likely *M. glomerata* (Willdenow) Trinius and *M. racemosa* (Michaux) Britton, Sterns and Poggenburg.  
6. *Solidago* Linnaeus spp. other than *S. ptarmicoides, S. rigida* and *Solidago* Linnaeus sp. 1.  
7. Mixture of *Z. aptera* (A. Gray) Fernald and *Z. aurea* (Linnaeus) W.D.J. Koch.