

## Supplementary Information

### **Managing an endemic taxon at the verge of extinction: factors driving population persistence and larval microhabitat selection of *Zygaena angelicae elegans* (Lepidoptera, Zygaenidae)**

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Nora Dalüge<sup>#1</sup>, Axel Hofmann<sup>2</sup>, Gregor Markl<sup>3</sup>, Valerie Kiefer<sup>4</sup>, Veronika Braunisch<sup>1,5</sup>

<sup>1</sup> Forest Research Institute Baden-Württemberg FVA, Dpt. Forest Conservation, Wonnhaldestrasse 4, DE-79100 Freiburg im Breisgau, Germany; nora.m@gmx.net

<sup>2</sup> Am Hochgestade 5, D-76351 Linkenheim-Hochstetten, Germany

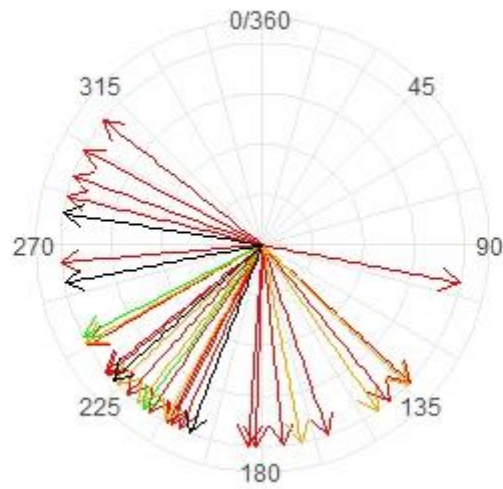
<sup>3</sup> Fachbereich Geowissenschaften, Schnarrenbergstrasse 94-96, Universität Tübingen, Germany

<sup>4</sup> endura kommunal, Emmy-Noether-Straße 2, 79110 Freiburg, Germany

<sup>5</sup> Division of Conservation Biology, Institute of Ecology and Evolution, University of Bern, Baltzerstrasse 6, CH-3012 Bern, Switzerland

## Supplementary Information

### Exposure of occupied patches [°]



**SI1** Exposure of the patches occupied by *Zygaena angelicae elegans*. The colors of the arrows indicate population size categories with red: very small populations (<10 individuals), yellow: small populations (10-99), green: medium populations (>100) and black: extinct populations.

## Supplementary Information

### Univariate analyses

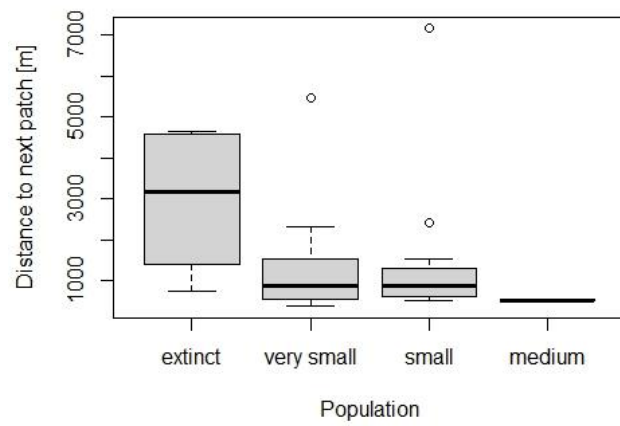
|                                                                                                                                  | Estimate | Standard<br>Error | z-value | p-value      | AIC   |
|----------------------------------------------------------------------------------------------------------------------------------|----------|-------------------|---------|--------------|-------|
| LS1 <sup>+</sup> Landscape scale: <i>Z. angelicae elegans</i> – population size (MAP2)                                           |          |                   |         |              |       |
| Distance                                                                                                                         | -1.8321  | 0.6688            | -2.739  | 0.006 **     | 277.5 |
| Northness                                                                                                                        | -1.3755  | 0.6896            | -1.995  | 0.046 *      | 280.0 |
| Eastness                                                                                                                         | -0.4784  | 0.4747            | -1.008  | 0.313 n.s.   | 282.3 |
| Slope                                                                                                                            | -0.0712  | 0.1005            | -0.709  | 0.479 n.s.   | 282.7 |
| Height a.s.l.                                                                                                                    | 0.0051   | 0.0025            | 2.007   | 0.045 *      | 279.9 |
| Number of visits                                                                                                                 | 0.2091   | 0.1232            | 1.697   | 0.089 n.s.   | 279.0 |
| Connectivity_1.5 <sup>1</sup>                                                                                                    | 0.4391   | 0.1890            | 2.323   | 0.020 *      | 277.9 |
| Connectivity_1.3 <sup>2</sup>                                                                                                    | 0.3351   | 0.1877            | 1.785   | 0.074 n.s.   | 279.8 |
| LS2 <sup>+</sup> Landscape scale: <i>Z. angelicae elegans</i> – population stability (MAP1 vs. MAP2)                             |          |                   |         |              |       |
| Distance                                                                                                                         | -45.17   | 19.82             | -2.279  | 0.023 *      | 330.5 |
| Northness                                                                                                                        | -18.849  | 16.359            | -1.152  | 0.249 n.s.   | 335.3 |
| Eastness                                                                                                                         | 11.549   | 16.613            | 0.695   | 0.487 n.s.   | 334.8 |
| Slope                                                                                                                            | -0.036   | 1.528             | -0.024  | 0.981 n.s.   | 335.3 |
| Height a.s.l.                                                                                                                    | 0.0074   | NaN               | NaN     | NaN          | 336.4 |
| Connectivity_1.5 <sup>1</sup>                                                                                                    | 10.062   | 4.618             | 2.179   | 0.029 *      | 330.9 |
| Connectivity_1.3 <sup>2</sup>                                                                                                    | 12.973   | 4.770             | 2.719   | 0.007 **     | 328.7 |
| LS2 Landscape scale: <i>Z. angelicae elegans</i> – population stability (MAP1 vs. MAP2), differing developmental stages excluded |          |                   |         |              |       |
| Distance                                                                                                                         | -0.0127  | 0.0055            | -2.330  | 0.019 *      | 271.4 |
| Northness                                                                                                                        | -15.531  | 18.962            | -0.819  | 0.413 n.s.   | 275.6 |
| Eastness                                                                                                                         | 7.123    | 22.584            | 0.315   | 0.752 n.s.   | 276.2 |
| Slope                                                                                                                            | -0.1125  | 1.7644            | -0.064  | 0.949 n.s.   | 276.3 |
| Height a.s.l.                                                                                                                    | 0.0200   | 0.1011            | 0.198   | 0.843 n.s.   | 276.3 |
| Connectivity_1.5 <sup>1</sup>                                                                                                    | 10.715   | 5.147             | 2.082   | 0.037 *      | 272.3 |
| Connectivity_1.3 <sup>2</sup>                                                                                                    | 13.907   | 5.456             | 2.549   | 0.011 *      | 270.5 |
| LS3 Landscape scale: <i>Z. angelicae elegans</i> – population persistence (MAP1 vs. MAP2)                                        |          |                   |         |              |       |
| Distance                                                                                                                         | -3.991   | 1.736             | -2.299  | 0.022 *      | 26.6  |
| Northness                                                                                                                        | -2.1638  | 1.1168            | -1.938  | 0.052 n.s.   | 27.6  |
| Eastness                                                                                                                         | 1.638    | 1.612             | 1.016   | 0.310 n.s.   | 30.4  |
| Slope                                                                                                                            | -0.0183  | 0.1099            | -0.166  | 0.868 n.s.   | 31.7  |
| Height a.s.l.                                                                                                                    | -0.0072  | 0.0085            | -0.853  | 0.394 n.s.   | 30.5  |
| Connectivity_1.5 <sup>1</sup>                                                                                                    | 1.5996   | 0.7761            | 2.061   | 0.039 *      | 28.2  |
| Connectivity_1.3 <sup>2</sup>                                                                                                    | 1.4033   | 0.8110            | 1.730   | 0.084 n.s.   | 28.1  |
| MS1 <sup>+</sup> Microhabitat scale: <i>Z. angelicae elegans</i> larvae - occurrence                                             |          |                   |         |              |       |
| Sun_day                                                                                                                          | 0.0055   | 0.0025            | 2.153   | 0.031 *      | 101.6 |
| Sun_morning                                                                                                                      | 0.0005   | 0.0038            | 0.138   | 0.890 n.s.   | 101.8 |
| Sun_afternoon                                                                                                                    | 0.0141   | 0.0043            | 3.260   | 0.001 **     | 87.1  |
| Canopy                                                                                                                           | -0.030   | 0.0111            | -2.661  | 0.007 **     | 107.2 |
| Shrub                                                                                                                            | -0.0359  | 0.0221            | -1.627  | 0.104 n.s.   | 112.5 |
| CC_cov                                                                                                                           | 0.1474   | 0.0423            | 3.485   | 0.0005 ***   | 94.8  |
| CC_height                                                                                                                        | 0.1151   | 0.0282            | 4.087   | 4.37e-05 *** | 79.2  |

## Supplementary Information

|                                                                                     |         |         |        |              |       |
|-------------------------------------------------------------------------------------|---------|---------|--------|--------------|-------|
| Grass                                                                               | 0.0144  | 0.0105  | 1.377  | 0.169 n.s.   | 113.8 |
| Plants                                                                              | -0.0131 | 0.0132  | -0.989 | 0.323 n.s.   | 114.6 |
| Litter                                                                              | -0.0150 | 0.0114  | -1.310 | 0.190 n.s.   | 113.9 |
| Bare_ground                                                                         | 0.0316  | 0.0118  | 2.669  | 0.007 **     | 107.7 |
| Nect_pl                                                                             | 0.1044  | 0.0533  | 1.959  | 0.051 n.s.   | 111.6 |
| MS2 <sup>+</sup> Microhabitat scale: <i>Z. angelicae elegans</i> larvae - abundance |         |         |        |              |       |
| Sun_day                                                                             | 0.0052  | 0.0026  | 1.963  | 0.049 *      | 215.0 |
| Sun_morning                                                                         | 0.0003  | 0.0040  | 0.083  | 0.934 n.s.   | 210.5 |
| Sun_afternoon                                                                       | 0.0089  | 0.0035  | 2.575  | 0.010 *      | 203.6 |
| Canopy                                                                              | -0.0304 | 0.0089  | -3.416 | 0.0006 ***   | 220.5 |
| Shrub                                                                               | -0.0311 | 0.0262  | -1.189 | 0.234 n.s.   | 230.0 |
| CC_cov                                                                              | 0.1089  | 0.0259  | 4.192  | 2.76e-05 *** | 209.9 |
| CC_height                                                                           | 0.0904  | 0.0197  | 4.594  | 4.35e-06 *** | 201.1 |
| Grass                                                                               | 0.0163  | 0.0143  | 1.142  | 0.254 n.s.   | 230.1 |
| Plants                                                                              | 0.0252  | 0.0141  | -1.782 | 0.075 n.s.   | 228.4 |
| Litter                                                                              | -0.0180 | 0.0141  | -1.277 | 0.202 n.s.   | 229.9 |
| Bare_ground                                                                         | 0.0247  | 0.0121  | 2.041  | 0.041 *      | 227.1 |
| Nect_pl                                                                             | 0.0887  | 0.0425  | 2.086  | 0.037 *      | 227.0 |
| MS3 Microhabitat scale: <i>Coronilla coronata</i> (larval host plant) - occurrence  |         |         |        |              |       |
| Sun_day                                                                             | 0.0048  | 0.0023  | 2.098  | 0.036 *      | 103.9 |
| Sun_morning                                                                         | 0.0024  | 0.0035  | 0.684  | 0.494 n.s.   | 105.5 |
| Sun_afternoon                                                                       | 0.0112  | 0.0038  | 2.979  | 0.003 **     | 94.9  |
| Canopy                                                                              | -0.0228 | 0.0097  | -2.338 | 0.019 *      | 110.5 |
| Shrub                                                                               | -0.0532 | 0.0204  | -2.606 | 0.009 **     | 108.2 |
| Grass                                                                               | 0.0229  | 0.0111  | 2.055  | 0.039 *      | 111.8 |
| Plants                                                                              | -0.0037 | 0.0113  | -0.332 | 0.740 n.s.   | 116.5 |
| Litter                                                                              | -0.0136 | 0.0099  | -1.379 | 0.168 n.s.   | 114.7 |
| Bare_ground                                                                         | 0.0145  | 0.01138 | 1.269  | 0.204 n.s.   | 114.9 |

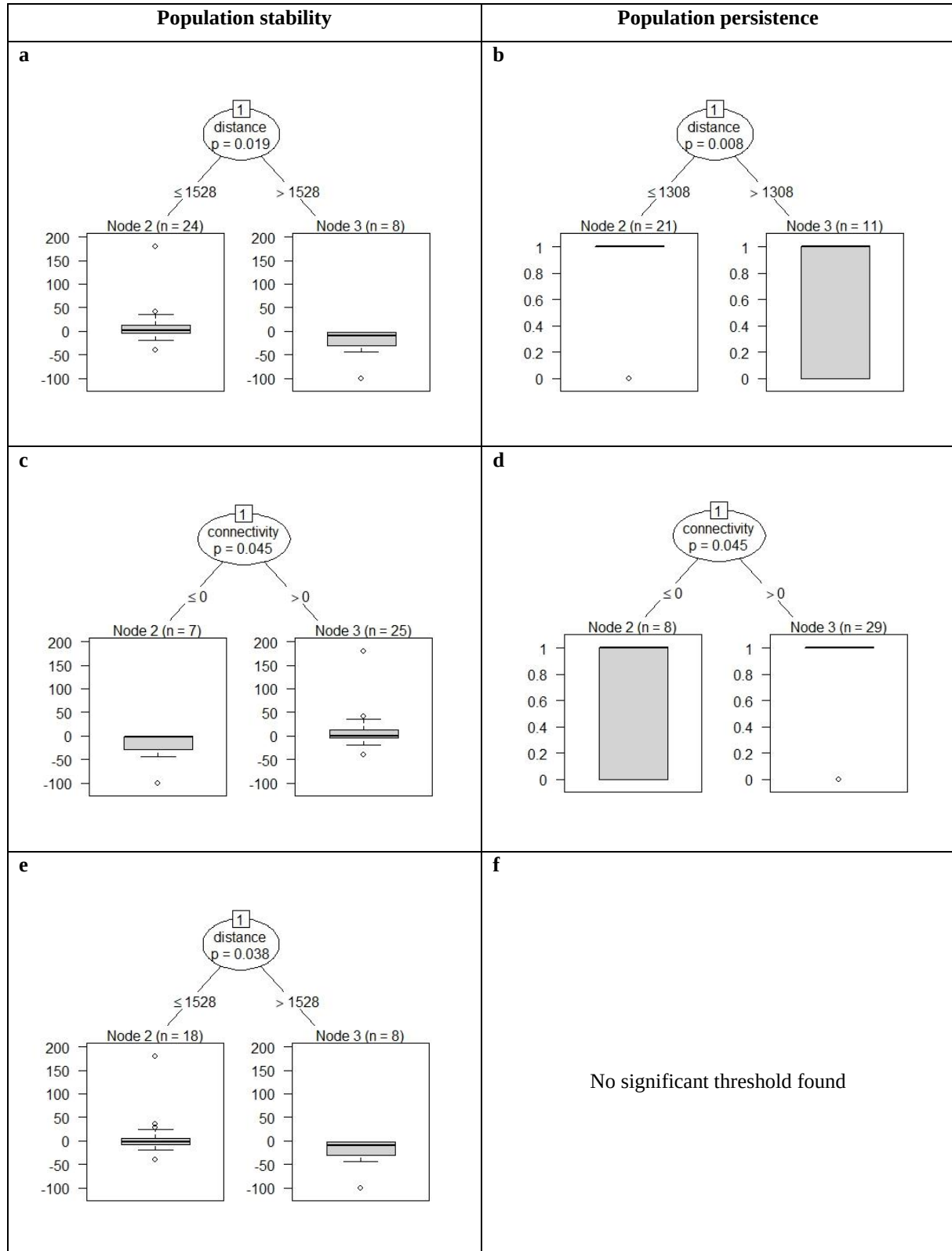
**SI2** Results of the variables that were tested in univariate generalized linear (mixed<sup>+</sup>) models for explaining population size (LS1) population stability (LS2) and population persistence (LS3) of *Z. angelicae elegans* at landscape scale, and the presence (MS1) and abundance (M2) of larvae as well as the presence of the larval host plant *Coronilla coronata* (MS3) at microhabitat scale. Asterisks indicate significance levels with \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ , n.s. = non-significant. <sup>1</sup>The variable “connectivity\_1.5” represents the number of populations within the distance threshold of 1528 m (SI4) calculated for population stability which was tested a-posteriori in a separate model. <sup>2</sup>The variable “connectivity\_1.3” represents the number of populations within the distance threshold of 1308 m (Online Resource SI4) calculated for population persistence, which was tested a-posteriori in a separate model.

## Supplementary Information



**SI3** Populations of different size categories in relation to their distance to the next occupied patch.

## Supplementary Information



**SI4** Conditional inference trees (CIT) for population stability and persistence between the two surveys (MAP1 and MAP 2) of *Z. angelicae elegans* in relation to the distance (a,b) to and the number (c,d) of connected patch(es) within the critical distance. (e and f) display population stability and persistence in relation to the distance, including solely patches for which data of the same larval development stages were available in both MAP1 and MAP2 (n = 26).

## Supplementary Information

| (1) Random effects (RE) and fixed effect (FE) intercepts of multivariate GLMMs                                   |                       |                |                     |             |      |      |
|------------------------------------------------------------------------------------------------------------------|-----------------------|----------------|---------------------|-------------|------|------|
|                                                                                                                  | RE standard deviation | FE intercept   | Random effect       |             |      |      |
| LS1 <sup>+</sup>                                                                                                 | 3.95x10-5             | 3.15           | Developmental stage |             |      |      |
| LS2 <sup>+</sup>                                                                                                 | 0.013                 | 137.78         | Developmental stage |             |      |      |
| MS1 <sup>+</sup>                                                                                                 | 1.786                 | -6.13          | Patch               |             |      |      |
| MS2 <sup>+</sup>                                                                                                 | 1.313                 | -3.02          | Patch               |             |      |      |
| (2) MS1 <sup>+</sup> Microhabitat scale: Z. angelicae elegans larvae – occurrence (multivariate models) 2nd best |                       |                |                     |             |      |      |
|                                                                                                                  | Estimate              | Standard Error | z-value             | p-value     | AIC  | AUC  |
| CC_height                                                                                                        | 0.089848              | 0.024578       | 3.656               | 0.000257*** | 68.1 | 0.85 |
| Sun_afternoon                                                                                                    | 0.009812              | 0.004209       | 2.331               | 0.019743*   |      |      |

**SI5** Additional results of multivariate GLM(+M)s, explaining population size (LS1), population stability (LS2) at the landscape scale, and the presence (MS1) and abundance (MS2) of larvae at the microhabitat scale. (1) Random effects, with developmental stage (larva/imago) in LS1<sup>+</sup> and LS2<sup>+</sup>, and patch in MS1<sup>+</sup> and MS2<sup>+</sup>, and fixed intercepts. (2) Result of the second best (AIC  $\Delta \leq 2$ ) GLM(+M), explaining the presence (MS1) of larvae at the microhabitat scale. For the best model, see Table 3. The patch was included as random factor. Asterisks indicate significance levels with \*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ , n.s. = non-significant.