Supplementary Material

Milkweed and Floral Resource Availability for Monarch Butterflies (Danaus plexippus) in the United States

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# Supplementary Tables

Table SM1. Plants per hectare for milkweed species observed on random and non-random Integrated Monarch Monitoring Program (IMMP) sites by region (North, South, West Monarch Butterfly Conservation Units) during 2016-2022. When a plot was surveyed multiple times within a year, we used the maximum milkweed density, and when plots were surveyed across multiple years, we averaged the yearly maximum values. Milkweed was present at 706 sites in total. For 63 of the 706, we were unable to compute a milkweed density value because plants were not present within subplots (but the species identity was documented between subplots or transects, ‘Total Sites’). Thus, only 644 of 706 sites have a milkweed density value (‘Sites with Density Values’').

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Region** | **Species** | **Total Sites** | **NON-RANDOM** | | | **RANDOM** | | |
| **Sites with Density Values** | **Mean Plants/ha** | **Max Plants/ha** | **Sites with Density Values** | **Mean Plants/ha** | **Max Plants/ha** |
| **North** | *Asclepias amplexicaulis* | 1 | 1 | 100 | 100 | 0 | 0 | 0 |
| *Asclepias hirtella* | 4 | 3 | 100 | 100 | 0 | 0 | 0 |
| *Asclepias incarnata* | 140 | 73 | 351 | 8,800 | 22 | 1,383 | 14,700 |
| *Asclepias ovalifolia* | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Asclepias purpurascens* | 3 | 2 | 150 | 200 | 0 | 0 | 0 |
| *Asclepias speciosa* | 8 | 6 | 1,817 | 8,500 | 1 | 67 | 67 |
| *Asclepias sullivantii* | 14 | 7 | 3,229 | 21,500 | 4 | 650 | 2,200 |
| *Asclepias syriaca* | 505 | 338 | 3,013 | 48,000 | 134 | 2,339 | 17,991 |
| *Asclepias tuberosa* | 123 | 85 | 458 | 9,649 | 7 | 424 | 2,000 |
| *Asclepias verticillata* | 159 | 104 | 11,309 | 143,683 | 43 | 1,943 | 8,100 |
| *Asclepias viridiflora* | 13 | 8 | 475 | 2300 | 1 | 600 | 600 |
| *Asclepias viridis* | 2 | 2 | 117 | 133 | 1 | 656 | 656 |
| *Cynanchum laeve* | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| **South** | *Asclepias amplexicaulis* | 1 | 1 | 350 | 350 | 0 | 0 | 0 |
| *Asclepias asperula* | 13 | 10 | 435 | 1,000 | 2 | 650 | 1,200 |
| *Asclepias curassavica* | 1 | 1 | 613 | 613 | 0 | 0 | 0 |
| *Asclepias incarnata* | 3 | 3 | 921 | 2,530 | 0 | 0 | 0 |
| *Asclepias linearis* | 3 | 3 | 4,733 | 10,900 | 0 | 0 | 0 |
| *Asclepias oenotheroides* | 8 | 5 | 266 | 500 | 1 | 100 | 100 |
| *Asclepias perennis* | 1 | 1 | 89 | 89 | 0 | 0 | 0 |
| *Asclepias syriaca* | 21 | 13 | 404 | 2,300 | 1 | 1,300 | 1,300 |
| *Asclepias tuberosa* | 12 | 7 | 1,532 | 7,600 | 0 | 0 | 0 |
| *Asclepias verticillata* | 7 | 5 | 1,040 | 1,850 | 0 | 0 | 0 |
| *Asclepias viridiflora* | 2 | 2 | 100 | 100 | 0 | 0 | 0 |
| *Asclepias viridis* | 16 | 11 | 1,054 | 5,000 | 1 | 800 | 800 |
| *Matelea biflora* | 4 | 2 | 400 | 600 | 0 | 0 | 0 |
| **West** | *Asclepias albicans* | 5 | 1 | 119 | 119 | 4 | 36 | 100 |
| *Asclepias angustifolia* | 2 | 2 | 46 | 50 | 0 | 0 | 0 |
| *Asclepias asperula* | 1 | 1 | 750 | 750 | 0 | 0 | 0 |
| *Asclepias californica* | 3 | 2 | 56 | 100 | 0 | 0 | 0 |
| *Asclepias cordifolia* | 10 | 8 | 61 | 300 | 1 | 100 | 100 |
| *Asclepias eriocarpa* | 26 | 25 | 585 | 3,300 | 0 | 0 | 0 |
| *Asclepias erosa* | 1 | 1 | 500 | 500 | 0 | 0 | 0 |
| *Asclepias fascicularis* | 64 | 48 | 10,218 | 440,000 | 7 | 486 | 800 |
| *Asclepias glaucescens* | 1 | 1 | 3 | 3 | 0 | 0 | 0 |
| *Asclepias latifolia* | 1 | 1 | 50 | 50 | 0 | 0 | 0 |
| *Asclepias lemmonii* | 1 | 1 | 2 | 2 | 0 | 0 | 0 |
| *Asclepias linaria* | 2 | 2 | 7 | 10 | 0 | 0 | 0 |
| *Asclepias nyctaginifolia* | 2 | 2 | 8 | 13 | 0 | 0 | 0 |
| *Asclepias speciosa* | 19 | 15 | 386 | 2,720 | 1 | 2,450 | 2,450 |
| *Asclepias subulata* | 13 | 5 | 221 | 824 | 5 | 51 | 200 |
| *Asclepias subverticillata* | 8 | 7 | 11,763 | 44,600 | 0 | 0 | 0 |
| *Asclepias tuberosa* | 4 | 4 | 90 | 244 | 0 | 0 | 0 |

Table SM2. Best-performing models ranked by the second-order (sample-size corrected) Akaike’s Information Criterion (AICc). df is the model degrees of freedom. ΔAICc is the difference in AICc between the competing model and the best model. Weight is the relative likelihood.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Fixed Effects Covariates | Random Effects | df | log-likelihood | AICc | ΔAICc | weight |
| **Milkweed** | | |  |  |  |  |  |  |
|  | 1 | Survey Type + Region + Site Type + Site Selection Type + Day of Year + z(Survey Type + Region + Site Selection Type) | Site + Month:Year + z(Site + Month:Year) | 27 | -12024.00 | 24102.0 | 0.00 | 0.601 |
|  | 2 | Survey Type + Region + Site Type + Site Selection Type + Day of Year + First Year Effect + z(Survey Type + Region + Site Type + Site Selection Type) | Site + Month:Year + z(Site + Month:Year) | 29 | -12022.41 | 24102.8 | 0.82 | 0.399 |
|  | Null | Intercept only + z(Intercept only) | Site + Month:Year + z(Site + Month:Year) | 3 | -13499.85 | 27005.7 | 2903.70 | 0 |
| **Floral Frequency** | | |  |  |  |  |  |  |
|  | Posthoc | Survey Type + Region + Survey Duration | Site + Month:Year | 6 | -1275.0 | 2578.1 |  |  |
|  | 1 | Survey Type + Region + Survey Duration | Month:Year | 6 | -1297.34 | 2606.7 | 0.00 | 0.167 |
|  | 2 | Survey Type + Region + Site Type + Survey Duration | Month:Year | 10 | -1293.37 | 2606.8 | 0.12 | 0.157 |
|  | 3 | Survey Type + Region + Site Type + First Year Effect + Survey Duration | Month:Year | 11 | -1292.48 | 2607.1 | 0.37 | 0.139 |
|  | 4 | Survey Type + Region + Site Type + Area Sampled + Survey Duration | Month:Year | 11 | -1292.60 | 2607.3 | 0.59 | 0.124 |
|  | 5 | Survey Type + Region + Area Sampled + Survey Duration | Month:Year | 7 | -1297.05 | 2608.2 | 1.44 | 0.081 |
|  | 6 | Survey Type + Region + First Year Effect + Area Sampled + Survey Duration | Month:Year | 7 | -1297.14 | 2608.3 | 1.62 | 0.074 |
|  | 7 | Survey Type + Region + Site Type + First Year Effect + Area Sampled + Survey Duration | Month:Year | 12 | -1292.19 | 2608.5 | 1.81 | 0.068 |
|  | Null | Intercept only |  | 1 | -1544.71 | 3091.0 | 484.3 | 0 |
| **Richness** | | |  |  |  |  |  |  |
|  | 1 | Region + Site Type + Day of Year + Area Sampled + z(Region + Survey Type) | Month:Year | 16 | -6529.80 | 13105.6 | 0 | 0.718 |
|  | 2 | Region + Site Type + Day of Year + z(Region + SurveyType) | Month:Year | 14 | -6537.60 | 13107.4 | 1.87 | 0.282 |
|  | Null | Intercept only |  | 2 | -6850.35 | 13704.7 | 613.03 | 0 |

Table SM3. Model-based marginal mean estimates with standard errors (SE) and 95% confidence intervals (CI) of milkweed plants per acre (excluding *Asclepias verticillata* and *A. subverticillata*) from a zero-inflated negative binomial regression of sampled Integrated Monarch Monitoring Program surveys collected 2016–2022. Note that these are model-based values, not summaries of the data, and therefore contain predicted values where no samples were collected. Estimates are for standard surveys.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Random | | | | Non-random | | | |
| Region | Site Type1 | Mean Density | SE | 95% CI | n | Mean Density | SE | 95% CI | n |
| North | ACL | 233.05 | 52.95 | [149.30, 363.79] | 2 | 353.95 | 57.8 | [257.01, 487.45] | 243 |
| South | ACL | 190.19 | 61.73 | [100.67, 359.30] | 0 | 288.85 | 78.28 | [169.83, 491.29] | 64 |
| West | ACL | 167.03 | 52.56 | [ 90.14, 309.51] | 0 | 253.68 | 67.36 | [150.75, 426.87] | 0 |
| North | DEV | 314.58 | 82.93 | [187.65, 527.36] | 21 | 477.76 | 118.58 | [293.73, 777.10] | 29 |
| South | DEV | 256.72 | 87.12 | [132.00, 499.27] | 0 | 389.9 | 123.5 | [209.57, 725.39] | 29 |
| West | DEV | 225.46 | 80.59 | [111.90, 454.29] | 0 | 342.42 | 116.78 | [175.50, 668.12] | 0 |
| North | PGS | 340.36 | 53.41 | [250.25, 462.93] | 189 | 516.92 | 49.25 | [428.87, 623.04] | 597 |
| South | PGS | 277.76 | 78.51 | [159.62, 483.36] | 8 | 421.85 | 101.06 | [263.78, 674.66] | 67 |
| West | PGS | 243.94 | 60.46 | [150.08, 396.50] | 333 | 370.49 | 76.20 | [247.57, 554.43] | 144 |
| North | ROW | 576.84 | 91.54 | [422.65, 787.28] | 287 | 876.07 | 184.30 | [580.06, 1323.15] | 22 |
| South | ROW | 470.75 | 135.16 | [268.16, 826.40] | 13 | 714.95 | 219.86 | [391.31, 1306.27] | 2 |
| West | ROW | 413.43 | 108.39 | [247.31, 691.14] | 0 | 627.90 | 182.24 | [355.50, 1109.01] | 11 |
| North | UGS | 519.94 | 103.45 | [352.04, 767.93] | 76 | 789.66 | 122.48 | [582.66, 1070.19] | 134 |
| South | UGS | 424.32 | 132.07 | [230.54, 780.97] | 6 | 644.43 | 175.77 | [377.58, 1099.89] | 36 |
| West | UGS | 372.65 | 105.47 | [213.99, 648.95] | 1 | 565.96 | 139.78 | [348.79, 918.36] | 19 |

1ACL = Agricultural Conservation Land; DEV = Developed; PGS = Protected Grassland, ROW = Rights-of-Way; UGS = Unclassified Grassland