**Title:** Flight capacity increases then declines from the core to the margins of an invasive species’ range.

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**Supplementary Tables:**

**Table S1.** Kudzu bug sample sizes from each site and description of nymphal densities of the colonies from which they were reared. Number of rearing enclosures is less than total number of egg masses, because one to two egg masses were placed in each enclosure. Both transects began at a core site in DeKalb Co., GA: a county where kudzu bugs were initially detected in 2009 [1]. Sites were a minimum of 80 km apart from one another, and the area within sites that was searched ranged from approximately 10 to 20 m2. Two years prior to this study, in June of 2014, kudzu bugs were not observed at range margin sites (Polk Co. and Harrison Co.), suggesting that these sites had kudzu bugs at subdetectable abundances or had been colonized between the prior survey and this study. The sex ratio of adults collected by hand at frontline sites did not significantly differ from a 1:1 female to male ratio (22:15 and 15:14, at southern and western frontlines respectively).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **site** | **transect** | **distance from origin (km)** | **total number of reared egg masses** | **number of rearing enclosures** | **mean number of nymphs reared per enclosure** | **range of nymphs per enclosure** | **total individuals flown per site** |  |
| 1 | Origin | 0 | 14 | 10 | 12.2 | 5 – 23 | 19 |  |
| 2 | North-South | 116 | 18 | 10 | 13.5 | 4 – 34 | 19 |  |
| 3 | North-South | 361 | 15 | 10 | 10.6 | 2 – 22 | 19 |  |
| 4 | North-South | 469 | 15 | 10 | 11.4 | 2 – 24 | 19 |  |
| 5 | North-South | 696 | 4 | 4 | 8 | 3 – 13 | 9 |  |
| 6 | East-West | 251 | 19 | 13 | 12.5 | 4 – 31 | 20 |  |
| 7 | East-West | 430 | 22 | 13 | 10.2 | 2 – 24 | 24 |  |
| 8 | East-West | 560 | 18 | 13 | 13.5 | 4 – 24 | 22 |  |
| 9 | East-West | 697 | 13 | 8 | 9.8 | 3 – 15 | 15 |  |
| 10 | East-West | 882 | 13 | 9 | 11.6 | 3 – 23 | 17 |  |
| 11 | East-West | 964 | 5 | 4 | 8.8 | 6 – 12 | 13 |  |

**Table S2:** GLMM estimates of factors influencing kudzu bug duration of flight and distance flown including insects that did not fly. For distance flown, results are shown with and without the addition of a zero-inflated term for the intercept. This latter model was a far superior fit than the model without zero inflation (F-test: ΔAIC = 2616.1, p< 0.001) suggesting that non-flight is better explained by a separate process than the process that explains flight distance once an insect is in flight. Condition and size of individuals were not recorded for individuals that did not fly and are, therefore, not included in the models. Models were built with glmmTMB() in R v. 3.5.1. Bold values are considered significant.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | β | SE | χ2 | P |
| **proportion of hr in flight (m s-1)** | |  |  |  |  |
| nymphal density | -0.07093 | 0.07006 | 1.025 | 0.3113 |
| distance from core | -0.02397 | 0.07928 | 0.0914 | 0.7624 |
| distance from core 2 | -0.06416 | 0.07384 | 0.755 | 0.3849 |
| **distance flown (m)** |  |  |  |  |
| nymphal density | -111.55 | 40.39 | 7.6255 | **0.005755** |
| distance from core | -24.48 | 45.16 | 0.2938 | 0.587827 |
| distance from core 2 | -46.38 | 40.72 | 1.2972 | 0.254725 |
| **distance flown (m) w/ zero inflated intercept** | | | |  |
| nymphal density | -98.19 | 54.79 | 3.2109 | 0.07315 |
| distance from core | 24.49 | 63.49 | 0.1488 | 0.69971 |
| distance from core 2 | -142.75 | 57.12 | 6.2455 | **0.01245** |
| zero-inflation intercept\* | -0.10774 | 0.09893 | NA | NA |
|  |  |  |  |  |

\* Significance for the zero-inflation model intercept was determine by Wald test. Z =-1.089, P = 0.276

**Table S3:** GLMM estimates of factors influencing kudzu bug dispersal-related traits, including mean temperature and cumulative precipitation from sites between June 1st – July 21st—conditions likely to have been experienced by the maternal generation. Bold values are considered significant. Climatic variables were accessed through PRISM (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, accessed July 2019).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | β | SE | χ2 | P |
| **size (pronotum mm)** | |  |  |  |
| sex | -0.306 | 0.026 | 139.914 | **<0.001** |
| Julian day | 0.002 | 0.014 | 0.012 | 0.915 |
| nymphal density | -0.041 | 0.014 | 8.444 | **0.004** |
| distance from core | -0.028 | 0.020 | 2.013 | 0.157 |
| distance from core 2 | -0.002 | 0.021 | 0.007 | 0.923 |
| mean temp Jun - July | -0.011 | 0.021 | 0.296 | 0.596 |
| mean Precip Jun - July | -0.006 | 0.024 | 0.069 | 0.781 |
| **speed (m s-1)** |  |  |  |  |
| size (pronotum mm) | 0.069 | 0.008 | 76.539 | **<0.001** |
| condition (scaled mass index) | 0.045 | 0.008 | 32.278 | **<0.001** |
| nymphal density | -0.022 | 0.007 | 9.804 | **0.002** |
| distance from core | 0.006 | 0.008 | 0.553 | 0.464 |
| distance from core 2 | -0.004 | 0.008 | 0.247 | 0.605 |
| mean temp Jun - July | -0.014 | 0.008 | 2.802 | 0.125 |
| mean Precip Jun - July | 0.007 | 0.009 | 0.622 | 0.472 |
| **proportion of hr in flight** | |  |  |  |
| size (pronotum mm) | 0.299 | 0.100 | 9.051 | **0.003** |
| condition (scaled mass index) | 0.262 | 0.098 | 7.132 | **0.007** |
| nymphal density | -0.049 | 0.083 | 0.341 | 0.626 |
| rdistance from core | 0.093 | 0.097 | 0.930 | 0.330 |
| distance from core 2 | -0.176 | 0.102 | 2.943 | 0.086 |
| mean temp Jun - July | -0.044 | 0.105 | 0.176 | 0.687 |
| mean Precip Jun - July | 0.054 | 0.118 | 0.207 | 0.656 |
| **distance flown (m)** | |  |  |  |
| size (pronotum mm) | 329.130 | 52.300 | 39.608 | **<0.001** |
| condition (scaled mass index) | 248.610 | 52.170 | 22.713 | **<0.001** |
| nymphal density | -59.560 | 45.050 | 1.748 | 0.213 |
| relative distance from core | 54.240 | 48.940 | 1.228 | 0.281 |
| relative distance from core 2 | -101.680 | 51.490 | 3.899 | 0.052 |
| mean temp Jun - July | -38.770 | 51.130 | 0.575 | 0.500 |
| mean Precip Jun - July | 45.060 | 58.640 | 0.591 | 0.471 |

**Table S4:** GLMM estimates of factors influencing kudzu bug duration of flight and distance flown including log distance to the nearest soybean field. Models were built with glmmTMB() in R v. 3.5.1. Soybean field locations were provided by CropScape [1], accessed July 2019. Bold values are considered significant.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | β | SE | χ2 | P |
| **size (pronotum mm)** | |  |  |  |
| sex | -0.309060 | 0.026015 | 141.1377 | **<0.001** |
| Julian day | -0.003202 | 0.013910 | 0.0530 | 0.817934 |
| nymphal density | -0.041395 | 0.014077 | 8.6475 | **0.003275** |
| log distance to soybean field | -0.031170 | 0.019229 | 2.6275 | 0.105028 |
| distance from core | -0.027306 | 0.018844 | 2.0998 | 0.147316 |
| distance from core 2 | 0.007427 | 0.018340 | 0.1640 | 0.685512 |
| **speed (m s-1)** |  |  |  |  |
| size (pronotum mm) | 0.068865 | 0.007900 | 75.9792 | **<0.001** |
| condition (scaled mass index) | 0.043562 | 0.007859 | 30.7267 | **<0.001** |
| nymphal density | -0.019298 | 0.006965 | 7.6758 | **0.005596** |
| log distance (m) to soybean field | -0.001311 | 0.008288 | 0.0250 | 0.874315 |
| distance from core | 0.001282 | 0.008027 | 0.0255 | 0.873103 |
| distance from core 2 | -0.007041 | 0.007827 | 0.8094 | 0.368299 |
| **proportion of hr in flight** | |  |  |  |
| size (pronotum mm) | 0.285427 | 0.099820 | 8.1762 | **0.004244** |
| condition (scaled mass index) | 0.239561 | 0.096712 | 6.1357 | **0.013248** |
| nymphal density | -0.049459 | 0.082553 | 0.3589 | 0.549093 |
| log distance (m) to soybean field | 0.007334 | 0.099574 | 0.0054 | 0.941287 |
| distance from core | 0.075618 | 0.095861 | 0.6223 | 0.430212 |
| distance from core 2 | -0.223239 | 0.091726 | 5.9232 | **0.014943** |
| **distance flown (m)** | |  |  |  |
| size (pronotum mm) | 327.462 | 52.054 | 39.5742 | **<0.001** |
| condition (scaled mass index) | 242.475 | 50.262 | 23.4650 | **<0.001** |
| nymphal density | -54.573 | 44.387 | 1.5116 | 0.218897 |
| log distance (m) to soybean field | 1.598 | 48.829 | 0.0011 | 0.973896 |
| distance from core | 38.411 | 46.293 | 0.6885 | 0.406681 |
| distance from core 2 | -131.534 | 44.861 | 8.5968 | **0.003367** |

1. Han W, Yang Z, Di L, Mueller R. 2012 CropScape: a web service based application for exploring and disseminating US conterminous geospatial cropland data products for decision support. *Comput. Electron. Agric.* , 111–123.