**Appendix**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.000 | 0.000 |  |  |
| Residual |  | 0.005 | 0.071 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.133 | 0.011 | 3178 | 11.917 | **<0.001** |
| NestSect | -0.001 | 0.005 | 3178 | -0.193 | 0.847 |
| NestSect2 | 0.000 | 0.001 | 3178 | -0.375 | 0.708 |
| Nest | 0.151 | 0.014 | 3178 | 10.661 | **<0.001** |
| Density | 0.025 | 0.014 | 3178 | 1.767 | 0.077 |
| Day | 0.000 | 0.000 | 3178 | 0.000 | 1.000 |
| Corner | 0.019 | 0.004 | 3178 | 5.541 | **<0.001** |
| NestSect \* Nest | -0.055 | 0.007 | 3178 | -7.462 | **<0.001** |
| NestSect2 \* Nest | 0.003 | 0.001 | 3178 | 4.334 | **<0.001** |
| NestSect \* Density | -0.009 | 0.007 | 3178 | -1.302 | 0.193 |
| NestSect2 \* Density | 0.001 | 0.001 | 3178 | 0.864 | 0.388 |
| Nest \* Density | -0.088 | 0.020 | 3178 | -4.447 | **<0.001** |
| NestSect \* Nest \* Density | 0.030 | 0.010 | 3178 | 2.980 | **0.003** |
| NestSect2 \* Nest \* Density | -0.002 | 0.001 | 3178 | -1.695 | 0.090 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 3192, groups: ColonyID, 20  Marginal *R*2 = 0.246, Conditional *R*2 = 0.246 | | | | | |

Table A1.Proportions of workers in each nest section related to nest shape and physical properties. Here and below: Sections (NestSect) begin at the nest entrance (1) and complete at the back of the nest (8) and is a quadratic term. Density is the amount of area allocated for each worker (high = 0.033 cm2, low = 0.066 cm2 x 2), Day is the observation day along the experimental timeline. Corner is the presence of corners in the nest section. The random effect ColonyID is colony identification. Asterisks denote interactions, and bold *P* values indicate significance. Linear mixed effects model: PropWorker ~ poly(NestSect, degree = 2, raw = TRUE) \* Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.000 | 0.000 |  |  |
| Residual |  | 0.012 | 0.109 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | -0.151 | 0.017 | 3170 | -8.854 | **<0.001** |
| NestSect | 0.091 | 0.008 | 3170 | 11.275 | **<0.001** |
| NestSect2 | -0.005 | 0.001 | 3170 | -6.286 | **<0.001** |
| Nest | 0.105 | 0.022 | 3170 | 4.846 | **<0.001** |
| Density | 0.047 | 0.022 | 3170 | 2.190 | **0.029** |
| Day | 0.000 | 0.001 | 3170 | 0.000 | 1.000 |
| Corner | 0.027 | 0.005 | 3170 | 5.060 | **<0.001** |
| NestSect \* Nest | 0.016 | 0.011 | 3170 | 1.426 | 0.154 |
| NestSect2 \* Nest | -0.008 | 0.001 | 3170 | -6.122 | **<0.001** |
| NestSect \* Density | -0.003 | 0.011 | 3170 | -0.239 | 0.811 |
| NestSect2 \* Density | -0.001 | 0.001 | 3170 | -1.165 | 0.244 |
| Nest \* Density | -0.038 | 0.030 | 3170 | -1.265 | 0.206 |
| NestSect \* Nest \* Density | -0.015 | 0.015 | 3170 | -0.993 | 0.321 |
| NestSect2 \* Nest \* Density | 0.004 | 0.002 | 3170 | 2.513 | **0.012** |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 3184, groups: ColonyID, 20  Marginal *R*2 = 0.297, Conditional *R*2 = 0.297 | | | | | |

Table A2. Proportions of brood in each nest section related to nest shape and physical properties. Linear mixed effects: PropBrood ~ poly(NestSect, degree = 2, raw = TRUE) \* Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.000 | 0.000 |  |  |
| Residual |  | 0.060 | 0.246 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | -0.187 | 0.038 | 3178 | -4.863 | **<0.001** |
| NestSect | 0.122 | 0.018 | 3178 | 6.645 | **<0.001** |
| NestSect2 | -0.009 | 0.002 | 3178 | -4.800 | **<0.001** |
| Nest | 0.096 | 0.049 | 3178 | 1.961 | **0.050** |
| Density | 0.050 | 0.049 | 3178 | 1.041 | 0.298 |
| Day | 0.000 | 0.001 | 3178 | 0.000 | 1.000 |
| Corner | 0.029 | 0.012 | 3178 | 2.412 | **0.016** |
| NestSect \* Nest | -0.003 | 0.026 | 3178 | -0.099 | 0.921 |
| NestSect2 \* Nest | -0.004 | 0.003 | 3178 | -1.403 | 0.161 |
| NestSect \* Density | -0.010 | 0.025 | 3178 | -0.416 | 0.677 |
| NestSect2 \* Density | 0.000 | 0.003 | 3178 | -0.061 | 0.952 |
| Nest \* Density | -0.028 | 0.069 | 3178 | -0.412 | 0.681 |
| NestSect \* Nest \* Density | 0.000 | 0.035 | 3178 | -0.010 | 0.992 |
| NestSect2 \* Nest \* Density | 0.001 | 0.004 | 3178 | 0.308 | 0.759 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 3192, groups: ColonyID, 20  Marginal *R*2 = 0.076, Conditional *R*2 = 0.076 | | | | | |

Table A3. Proportions of queens in each nest section related to nest shape and physical properties. Linear mixed effects: PropQueens ~ poly(NestSect, degree = 2, raw = TRUE) \* Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.000 | 0.000 |  |  |
| Residual |  | 0.033 | 0.181 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.363 | 0.060 | 448 | 6.073 | **<0.001** |
| NestSect | -0.083 | 0.027 | 448 | -3.028 | **0.003** |
| NestSect2 | 0.006 | 0.003 | 448 | 1.924 | 0.055 |
| Nest | -0.192 | 0.069 | 448 | -2.787 | **0.006** |
| Day | 0.000 | 0.003 | 448 | 0.000 | 1.000 |
| Corner | -0.054 | 0.023 | 448 | -2.340 | **0.020** |
| NestSect \* Nest | 0.052 | 0.037 | 448 | 1.414 | 0.158 |
| NestSect2 \* Nest | -0.001 | 0.004 | 448 | -0.150 | 0.881 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 456, groups: ColonyID, 7  Marginal *R*2 = 0.097, Conditional *R*2 = 0.097 | | | | | |

Table A4. Proportions of alates in each nest section related to nest shape and physical properties. Linear mixed effects: PropAlates ~ poly(NestSect, degree = 2, raw = TRUE) \* Nest + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.001 | 0.028 |  |  |
| Residual |  | 0.035 | 0.188 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.161 | 0.010 | 22.140 | 16.656 | **<0.001** |
| Nest | 0.279 | 0.004 | 30150 | 77.655 | **<0.001** |
| Density | -0.021 | 0.013 | 18.980 | -1.569 | 0.133 |
| Day | 0.001 | 0.000 | 30240 | 4.685 | **<0.001** |
| Corner | -0.082 | 0.003 | 30240 | -30.664 | **<0.001** |
| Nest \* Density | 0.053 | 0.004 | 30240 | 12.024 | **<0.001** |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 30247, groups: ColonyID, 20  Marginal *R*2 = 0.337, Conditional *R*2 = 0.352 | | | | | |

Table A5. Relationships between workers scaled distance to the nest entrance and nest shape and physical properties. Distance to the entrance is scaled such that 1 is the back of the tube nest shape. Linear mixed effects: ScaledDist ~ Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.002 | 0.050 |  |  |
| Residual |  | 0.027 | 0.163 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.192 | 0.016 | 18.710 | 11.978 | **<0.001** |
| Nest | 0.225 | 0.002 | 59460 | 90.670 | **<0.001** |
| Density | -0.028 | 0.022 | 18.100 | -1.234 | 0.233 |
| Day | 0.001 | 0.000 | 59450 | 3.256 | **<0.001** |
| Corner | 0.047 | 0.002 | 59460 | 23.962 | **<0.001** |
| Nest \* Density | 0.078 | 0.003 | 59450 | 27.976 | **<0.001** |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 59459, groups: ColonyID, 20  Marginal *R*2 = 0.439, Conditional *R*2 = 0.487 | | | | | |

Table A6. Relationships between brood scaled distance to the nest entrance and nest shape and physical properties. Linear mixed effects: ScaledDist ~ Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.003 | 0.058 |  |  |
| Residual |  | 0.022 | 0.148 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.192 | 0.024 | 32.108 | 8.170 | **<0.001** |
| Nest | 0.262 | 0.016 | 1162.085 | 16.772 | **<0.001** |
| Density | 0.000 | 0.030 | 21.403 | 0.008 | 0.994 |
| Corner | 0.071 | 0.014 | 1165.526 | 5.130 | **<0.001** |
| Day | -0.001 | 0.001 | 1158.258 | -0.760 | 0.448 |
| Nest \* Density | -0.003 | 0.018 | 1157.370 | -0.176 | 0.860 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 1178, groups: ColonyID, 20  Marginal *R*2 = 0.492, Conditional *R*2 = 0.564 | | | | | |

Table A7. Relationships between queens scaled distance to the nest entrance and nest shape and physical properties. Linear mixed effects: ScaledDist ~ Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.025 | 0.158 |  |  |
| Residual |  | 0.054 | 0.233 |  |  |
| Fixed effects: | *β* a | *SE* b | *df* c | *t* d | *P* |
| (Intercept) | 0.298 | 0.089 | 15.800 | 3.348 | **0.004** |
| Nest | 0.566 | 0.044 | 412.300 | 12.814 | **<0.001** |
| Sex | -0.064 | 0.019 | 994.600 | -3.362 | **0.001** |
| Ratio | -0.077 | 0.072 | 948 | -1.073 | 0.283 |
| Day | -0.009 | 0.003 | 1000 | -3.488 | **0.001** |
| Corner | -0.026 | 0.016 | 995.400 | -1.660 | 0.097 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 1006, groups: ColonyID, 7  Marginal *R*2 = 0.451, Conditional *R*2 = 0.623 | | | | | |

Table A8. Relationships between workers scaled distance to the nest entrance and nest shape, nest physical properties, and alate sex. Sex is male or female alates, and ratio is the proportion of male alates over all alate types in the observation. Linear mixed effects: ScaledDist ~ Nest + Sex + Ratio + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.000 | 0.020 |  |  |
| Residual |  | 0.012 | 0.112 |  |  |
| Fixed effects: | *β* a | *SE* b | *df* c | *t* d | *P* |
| (Intercept) | 0.093 | 0.007 | 21.788 | 14.035 | **<0.001** |
| Nest | 0.103 | 0.002 | 26669.530 | 45.580 | **<0.001** |
| Density | -0.009 | 0.009 | 18.902 | -0.994 | 0.333 |
| Day | 0.000 | 0.000 | 26722.370 | 0.802 | 0.423 |
| Corner | 0.036 | 0.002 | 26720.943 | 21.145 | **<0.001** |
| Nest \* Density | 0.034 | 0.003 | 26709.876 | 11.769 | **<0.001** |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 26733, groups: ColonyID, 20  Marginal *R*2 = 0.279, Conditional *R*2 = 0.301 | | | | | |

Table A9. Relationships between workers scaled distance to the brood center and nest shape and physical properties. The brood center is a colony's brood center in each observation. Distance to the brood center is the absolute value of the difference between the scaled distances of the brood center from each worker to the entrance and is scaled such that 1 is the back of the tube nest. Linear mixed effects: ToBrood ~ Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.001 | 0.035 |  |  |
| Residual |  | 0.010 | 0.098 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.057 | 0.015 | 40.029 | 3.803 | **<0.001** |
| Nest | 0.090 | 0.011 | 1067.062 | 8.143 | **<0.001** |
| Density | 0.025 | 0.018 | 23.069 | 1.374 | 0.183 |
| Day | -0.002 | 0.001 | 1061.054 | -1.870 | 0.062 |
| Corner | 0.033 | 0.010 | 1070.522 | 3.300 | **0.001** |
| Nest \* Density | 0.001 | 0.013 | 1060.719 | 0.105 | 0.916 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 1080, groups: ColonyID, 20  Marginal *R*2 = 0.249, Conditional *R*2 = 0.335 | | | | | |

Table A10.Relationships between queen scaled distance to the brood center and nest shape and physical properties. Linear mixed effects: ToBrood ~ Nest \* Density + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.000 | 0.014 |  |  |
| Residual |  | 0.021 | 0.145 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.100 | 0.039 | 16.816 | 2.566 | **0.020** |
| Nest | 0.211 | 0.018 | 2.895 | 11.672 | **0.002** |
| Sex | 0.043 | 0.015 | 669.917 | 2.870 | **0.004** |
| Ratio | -0.004 | 0.002 | 610.635 | -1.961 | 0.050 |
| Day | 0.011 | 0.012 | 667.910 | 0.922 | 0.357 |
| Corner | -0.018 | 0.043 | 18.203 | -0.424 | 0.676 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 676, groups: ColonyID, 7  Marginal *R*2 = 0.340, Conditional *R*2 = 0.346 | | | | | |

Table A11. Relationships between alate scaled distance to the brood center and nest shape and physical properties. Linear mixed effects: ToBrood ~ Nest + Sex + Ratio + Day + Corner + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.035 | 0.187 |  |  |
| Residual |  | 0.705 | 0.839 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 1.679 | 0.122 | 21.889 | 13.728 | **<0.001** |
| Nest | -0.145 | 0.146 | 378.727 | -0.994 | 0.321 |
| Density | -0.320 | 0.159 | 14.107 | -2.010 | 0.064 |
| Nest \* Density | 0.142 | 0.187 | 360.033 | 0.757 | 0.449 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, groups: ColonyID, 19  Marginal *R*2 = 0.022, Conditional *R*2 = 0.068 | | | | | |

Table A12. The relationship between worker spatial fidelity zone size and nest shape. Fidelity zone size is the summation of all zones that a worker was found in (zones must have at least 7 observations and 15% of total observations), with twenty-four total possible zones. Linear mixed effects: SFZ ~ Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.102 | 0.320 |  |  |
| Residual |  | 1.495 | 1.223 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 5.939 | 0.188 | 28.821 | 31.547 | **<0.001** |
| Nest | -0.080 | 0.214 | 378.858 | -0.372 | 0.710 |
| Density | 0.282 | 0.248 | 19.358 | 1.137 | 0.270 |
| Nest \* Density | -0.229 | 0.274 | 371.029 | -0.838 | 0.403 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, groups: ColonyID, 19  Marginal *R*2 = 0.015, Conditional *R*2 = 0.078 | | | | | |

Table A13.The relationship between worker occurrence zone size and nest shape. Occurrence zone size is the ratio between the summation of all zones that a worker was found in (zones must have at least 7 observations), and twenty-four (total possible zones). Linear mixed effects: Occur ~ Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.021 | 0.147 |  |  |
| Residual |  | 0.061 | 0.247 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.222 | 0.059 | 22.808 | 3.786 | **0.001** |
| Nest | -0.022 | 0.044 | 377.968 | -0.494 | 0.622 |
| Density | 0.148 | 0.082 | 19.161 | 1.799 | 0.088 |
| Nest\*Density | 0.039 | 0.057 | 377.999 | 0.693 | 0.489 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, groups: ColonyID, 19  Marginal *R*2 = 0.072, Conditional *R*2 = 0.314 | | | | | |

Table A14. The relationship between true worker spatial fidelity zone size (cm2) and nest shape. Here and below the ratio between the total number of occupied zones with >15% observations (fidelity zone size) and the twenty-four possible zones is multiplied by nest area to produce true fidelity zone size. Linear mixed effects: SFZ\_Area ~ Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.499 | 0.706 |  |  |
| Residual |  | 0.155 | 0.393 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.783 | 0.232 | 16.827 | 3.375 | **0.004** |
| Nest | -0.023 | 0.071 | 366.580 | -0.324 | 0.746 |
| Density | 0.808 | 0.337 | 16.682 | 2.398 | **0.029** |
| Nest\*Density | -0.104 | 0.092 | 366.077 | -1.131 | 0.259 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 1155, groups: ColonyID, 19  Marginal *R*2 = 0.174, Conditional *R*2 = 0.805 | | | | | |

Table A15. The relationship between true worker occurrence zone size (cm2) and nest shape. Here and below the ratio between the total number of occupied zones (occurrence zone size) and the twenty-four possible zones is multiplied by nest area to produce true occurrence zone size. Linear mixed effects: Occur\_Area ~ Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| Colony | (Intercept) | 0.000 | 0.021 |  |  |
| Residual |  | 0.061 | 0.246 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | -0.005 | 0.075 | 62.200 | -0.069 | 0.945 |
| Number.workers | 0.002 | 0.001 | 40.688 | 3.786 | **<0.001** |
| Nest | 0.066 | 0.124 | 321.073 | 0.531 | 0.596 |
| Density | 0.057 | 0.097 | 21.005 | 0.590 | 0.562 |
| Number.workers\*Nest | -0.001 | 0.001 | 341.609 | -0.837 | 0.403 |
| Number.workers\*Density | 0.001 | 0.001 | 17.367 | 1.207 | 0.244 |
| Number.workers\*Density | -0.246 | 0.162 | 199.129 | -1.520 | 0.130 |
| Number.workers\*Nest\*Density | 0.002 | 0.001 | 264.646 | 1.867 | 0.063 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, groups: Colony, 19  Marginal *R*2 = 0.349, Conditional *R*2 = 0.354 | | | | | |

Table A16. The relationship between true worker spatial fidelity zone size (cm2) and colony size (worker.number). Linear mixed effects: SFZ\_Area ~ Number.workers \* Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| Colony | (Intercept) | 0.007 | 0.084 |  |  |
| Residual |  | 0.153 | 0.391 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 0.003 | 0.133 | 50.935 | 0.020 | 0.984 |
| Number.workers | 0.008 | 0.001 | 37.727 | 7.292 | **<0.001** |
| Nest | 0.113 | 0.201 | 339.160 | 0.566 | 0.572 |
| Density | 0.006 | 0.182 | 26.546 | 0.032 | 0.974 |
| Number.workers\*Nest | -0.001 | 0.002 | 356.105 | -0.670 | 0.503 |
| Number.workers\*Density | 0.009 | 0.002 | 21.755 | 5.961 | **<0.001** |
| Number.workers\*Density | 0.072 | 0.266 | 291.213 | 0.271 | 0.786 |
| Number.workers\*Nest\*Density | -0.001 | 0.002 | 332.301 | -0.662 | 0.509 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, groups: ColonyID, 19  Marginal *R*2 = 0.802, Conditional *R*2 = 0.810 | | | | | |

Table A17. The relationship between true worker occurrence zone size (cm2) and colony size (worker.number). Linear mixed effects: Occur\_Area ~ Number.workers \* Nest \* Density + (1 | ColonyID) + (1 | AntID)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Random effects: | Name | | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | | 0.028 | 0.167 |  |  |
| Residual | |  | 0.697 | 0.835 |  |  |
| Fixed effects: | | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | | 1.137 | 0.424 | 310.941 | 2.681 | **0.008** |
| MeanScaledDist | | 3.083 | 2.301 | 364.051 | 1.339 | 0.181 |
| Nest | | 1.189 | 0.569 | 374.918 | 2.091 | **0.037** |
| Density | | 0.392 | 0.554 | 329.099 | 0.707 | 0.480 |
| MeanScaledDist \* Nest | | -4.697 | 2.418 | 367.398 | -1.943 | 0.053 |
| MeanScaledDist \* Density | | -4.165 | 3.210 | 374.966 | -1.297 | 0.195 |
| Nest\*Density | | -1.883 | 0.739 | 372.864 | -2.549 | **0.011** |
| MeanScaledDist \* Nest \* Density | | 6.710 | 3.339 | 375.000 | 2.010 | **0.045** |
| Model Statistics: | |  |  |  |  |  |
| Number of obs: 383, groups: ColonyID, 19  Marginal *R*2 = 0.045, Conditional *R*2 = 0.082 | | | | | | |

Table A18. The relationship between a worker’s spatial fidelity zone size and average scaled distance to the nest entrance across nest shapes. Linear mixed effects: SFZ ~ MeanScaledDist \* Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.102 | 0.319 |  |  |
| Residual |  | 1.469 | 1.212 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 6.669 | 0.625 | 310.554 | 10.670 | **<0.001** |
| MeanScaledDist | -4.136 | 3.370 | 367.486 | -1.227 | 0.220 |
| Nest | -1.195 | 0.829 | 374.919 | -1.441 | 0.150 |
| Density | -1.916 | 0.816 | 321.845 | -2.348 | **0.020** |
| MeanScaledDist \* Nest | 4.927 | 3.538 | 368.797 | 1.392 | 0.165 |
| MeanScaledDist \* Density | 13.697 | 4.683 | 375.000 | 2.925 | **0.004** |
| Nest \* Density | 2.415 | 1.076 | 373.068 | 2.245 | **0.025** |
| MeanScaledDist \* Nest \* Density | -14.610 | 4.870 | 374.994 | -3.000 | **0.003** |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, ColonyID, 19  Marginal *R*2 = 0.041, Conditional *R*2 = 0.103 | | | | | |

Table A19. The relationship between a worker’s occurrence zone size and average scaled distance to the nest entrance across nest shapes. Linear mixed effects: Occur ~ MeanScaledDist \* Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.023 | 0.153 |  |  |
| Residual |  | 0.706 | 0.840 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 2.037 | 0.310 | 245.493 | 6.563 | **<0.001** |
| MeanToBrood | -3.899 | 3.167 | 374.956 | -1.231 | 0.219 |
| Nest | -0.295 | 0.380 | 367.481 | -0.776 | 0.438 |
| Density | -0.377 | 0.434 | 182.735 | -0.869 | 0.386 |
| MeanToBrood \* Nest | 2.860 | 3.319 | 371.276 | 0.861 | 0.390 |
| MeanToBrood \* Density | 0.566 | 4.546 | 355.292 | 0.125 | 0.901 |
| Nest \* Density | -0.308 | 0.534 | 349.052 | -0.576 | 0.565 |
| MeanToBrood \* Nest \* Density | 1.517 | 4.715 | 360.029 | 0.322 | 0.748 |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, groups: ColonyID, 19  Marginal *R*2 = 0.036, Conditional *R*2 = 0.067 | | | | | |

Table A20. The relationship between a worker’s spatial fidelity zone size and average scaled distance to the brood center across nest shapes. Linear mixed effects: SFZ ~ MeanToBrood \* Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Random effects: | Name | Variance | Std. dev |  |  |
| ColonyID | (Intercept) | 0.133 | 0.365 |  |  |
| Residual |  | 1.470 | 1.213 |  |  |
| Fixed effects: | *β* | *SE* | *df* | *t* | *P* |
| (Intercept) | 5.095 | 0.465 | 257.123 | 10.966 | **0.000** |
| MeanToBrood | 9.216 | 4.605 | 374.258 | 2.001 | **0.046** |
| Nest | 0.799 | 0.551 | 369.480 | 1.451 | 0.148 |
| Density | 1.857 | 0.655 | 219.549 | 2.835 | **0.005** |
| MeanToBrood \* Nest | -9.485 | 4.812 | 371.201 | -1.971 | **0.049** |
| MeanToBrood \* Density | -17.359 | 6.649 | 374.472 | -2.611 | **0.009** |
| Nest \* Density | -2.217 | 0.782 | 374.341 | -2.835 | **0.005** |
| MeanToBrood \* Nest \* Density | 18.951 | 6.889 | 374.920 | 2.751 | **0.006** |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 383, groups: ColonyID, 19  Marginal *R*2 = 0.038, Conditional *R*2 = 0.118 | | | | | |

Table A21. The relationship between a worker’s occurrence zone size and average scaled distance to the brood center across nest shapes. Linear mixed effects: Occur ~ MeanToBrood \* Nest \* Density + (1 | ColonyID)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Coefficients: | *df* | *Sum sq* | *Mean sq* | *F* | *P* |
| Nest | 1 | 17.699 | 17.699 | 1542.430 | **<0.001** |
| Density | 1 | 0.939 | 0.939 | 81.820 | **<0.001** |
| AntIDColNest | 380 | 18.227 | 0.048 | 4.180 | **<0.001** |
| Residuals | 2328 | 26.714 | 0.011 |  |  |
| Model Statistics: |  |  |  |  |  |
| Number of obs: 2,711 | | | | | |

Table A22. Individual worker (marked) fidelity in relation to distance from the brood center across all observations. AntIDColNest is each identifiable ant in the study. ANOVA: ToBrood ~ Nest \* Density + AntIDColNest

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Distributions compared: |  |  | *N1* | *N2* | *T* | *P* | *P*.adj |
| Worker v. sim. in high density tube nests | | | 800 | 8000 | 11.530 | **<0.001** | **<0.001** |
| Worker v. sim. in low density tube nests | | | 792 | 8000 | 6.802 | **<0.001** | **<0.001** |
| Worker v. sim in high density circle nests | | | 800 | 8000 | 2.731 | **<0.001** | **<0.001** |
| Worker v. sim in low density circle nests | | | 800 | 8000 | 3.897 | **<0.001** | **<0.001** |
| Worker high density tube v. sim. low density tube | | | 800 | 8000 | 11.668 | **<0.001** | **<0.001** |
| Worker low density tube v. sim. high density tube | | | 792 | 8000 | 6.691 | **<0.001** | **<0.001** |
| Worker high density circle v. sim. low density circle | | | 800 | 8000 | 2.745 | **<0.001** | **<0.001** |
| Worker low density tube v. sim. high density tube | | | 800 | 8000 | 3.881 | **<0.001** | **<0.001** |
| Sim high density tube v. sim low density tube | | | 8000 | 8000 | 0.000 | 0.976 | 1.000 |
| Sim high density circle v. sim low density circle | | | 8000 | 8000 | 0.000 | 1.000 | 1.000 |

Table A23. Distribution comparisons between the worker and Netlogo random walk simulation results. Two-sample Cramér-von Mises's test statistics were calculated through 2000 random resample bootstraps of the worker and simulated distributions, from which the *P* value was derived. False Discovery Rates inherent to multiple comparisons were corrected using the Benjamini-Hochberg method.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Coefficients | *β* | *SE* | *t* | *P* |
| (Intercept) | 0.152 | 0.005 | 28.115 | **<0.001** |
| NestSect | -0.009 | 0.003 | -3.205 | **0.001** |
| NestSect2 | 0.000 | 0.000 | 1.661 | 0.097 |
| Nest | 0.141 | 0.008 | 18.603 | **<0.001** |
| WorkerType | -0.032 | 0.006 | -5.773 | **<0.001** |
| Density | 0.025 | 0.008 | 3.275 | **0.001** |
| Corner | 0.003 | 0.001 | 4.402 | **<0.001** |
| NestSect \* Nest | -0.046 | 0.004 | -11.776 | **<0.001** |
| NestSect2 \* Nest | 0.002 | 0.000 | 5.888 | **<0.001** |
| NestSect \* WorkerType | 0.014 | 0.003 | 4.833 | **<0.001** |
| NestSect2 \* WorkerType | -0.001 | 0.000 | -3.768 | **<0.001** |
| Nest \* WorkerType | -0.147 | 0.008 | -18.495 | **<0.001** |
| NestSect \* Density | -0.009 | 0.004 | -2.412 | **0.016** |
| NestSect2 \* Density | 0.001 | 0.000 | 1.601 | 0.109 |
| Nest \* Density | -0.088 | 0.011 | -8.240 | **<0.001** |
| WorkerType \* Density | -0.001 | 0.008 | -0.120 | 0.904 |
| NestSect \* Nest \* WorkerType | 0.046 | 0.004 | 11.371 | **<0.001** |
| NestSect2 \* Nest \* WorkerType | -0.002 | 0.000 | -5.385 | **<0.001** |
| NestSect \* Nest \* Density | 0.030 | 0.005 | 5.522 | **<0.001** |
| NestSect2 \* Nest \* Density | -0.002 | 0.001 | -3.140 | **0.002** |
| NestSect \* WorkerType \* Density | -0.006 | 0.004 | -1.517 | 0.129 |
| NestSect2 \* WorkerType \* Density | 0.001 | 0.000 | 2.553 | **0.011** |
| Nest \* WorkerType \* Density | 0.079 | 0.011 | 7.004 | **<0.001** |
| NestSect \* Nest \* WorkerType \* Density | -0.022 | 0.006 | -3.752 | **<0.001** |
| NestSect2 \* Nest \* WorkerType \* Density | 0.001 | 0.001 | 1.138 | 0.255 |
| Model Statistics: |  |  |  |  |
| Number of obsv: 35192  Residual standard error = 0.038; Degrees of freedom: 35167  Multiple *R*2 = 0.098; Adjusted *R*2 = 0.097  F(24, 35167) =158.8; *P <* 0.001 | | | | |

Table A24.The relationship between proportions of worker and Netlogo random walk simulated results in each nest section and nest shape and physical properties. WorkerType is whether the observation was a worker or Netlogo random walk simulated result. Linear regression: PropWorker ~ poly(NestSect, degree = 2, raw = TRUE) \* Nest \* WorkerType \* Density + Corner

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Coefficients | *β* | *SE* | *Z* | *P* |
| (Intercept) | 0.116 | 0.326 | 0.357 | 0.721 |
| NestSect | -0.785 | 0.188 | -4.176 | **<0.001** |
| NestSect2 | 0.066 | 0.021 | 3.095 | **0.002** |
| WorkerType | -1.817 | 0.348 | -5.222 | **<0.001** |
| Nest | 2.721 | 0.519 | 5.245 | **<0.001** |
| Density | -0.470 | 0.469 | -1.003 | 0.316 |
| NestSect\*WorkerType | 0.921 | 0.198 | 4.640 | **<0.001** |
| NestSect2\*WorkerType | -0.092 | 0.022 | -4.110 | **<0.001** |
| NestSect\*Nest | -1.550 | 0.335 | -4.621 | **<0.001** |
| NestSect2\*Nest | 0.126 | 0.040 | 3.185 | **0.001** |
| WorkerType\*Nest | -3.294 | 0.549 | -6.004 | **<0.001** |
| NestSect\*Density | 0.373 | 0.272 | 1.374 | 0.169 |
| NestSect2\*Density | -0.051 | 0.031 | -1.638 | 0.101 |
| WorkerType\*Density | 1.704 | 0.497 | 3.431 | **0.001** |
| Nest\*Density | -0.934 | 0.711 | -1.312 | 0.189 |
| NestSect\*WorkerType\*Nest | 1.721 | 0.347 | 4.953 | **<0.001** |
| NestSect2\*WorkerType\*Nest | -0.133 | 0.041 | -3.262 | **0.001** |
| NestSect\*WorkerType\*Density | -1.242 | 0.286 | -4.348 | **<0.001** |
| NestSect2\*WorkerType\*Density | 0.156 | 0.033 | 4.737 | **<0.001** |
| NestSect\*Nest\*Density | 0.535 | 0.450 | 1.189 | 0.234 |
| NestSect2\*Nest\*Density | -0.034 | 0.053 | -0.629 | 0.529 |
| WorkerType\*Nest\*Density | 0.450 | 0.751 | 0.598 | 0.550 |
| NestSect\*WorkerType\*Nest\*Density | -0.018 | 0.467 | -0.038 | 0.969 |
| NestSect2\*WorkerType\*Nest\*Density | -0.037 | 0.055 | -0.677 | 0.498 |
| Number of obs: 35192  Null deviance: 29825 on 35191 degrees of freedom  Residual deviance: 29117 on 35168 degrees of freedom  AIC: 29165  Number of Fisher’s scoring iterations: 6 | | | | |

Table A25. The maximum worker and Netlogo random walk simulated result proportions in each nest section. Nest sections with the max worker or simulated result proportion in each observation were assigned a 1, where the other sections are 0. Logistic regression: MaxNestSect ~ NestSect \* WorkerType \* Nest \* Density, family = Binomial

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Coefficients: | *β* | *SE* | *t* | *P* |
| (Intercept) | 0.168 | 0.001 | 305.396 | **<0.001** |
| Nest | 0.400 | 0.001 | 545.179 | **<0.001** |
| WorkerType | -0.002 | 0.002 | -1.101 | 0.271 |
| Density | -0.002 | 0.001 | -4.040 | **<0.001** |
| Corner | -0.097 | 0.001 | -131.976 | **<0.001** |
| Nest\*WorkerType | -0.083 | 0.002 | -34.303 | **<0.001** |
| Model Statistics: |  |  |  |  |
| Number of obsv: 430426  Residual standard error = 0.201; Degrees of freedom: 430420  Multiple *R*2 = 0.441; Adjusted *R*2 = 0.441  F(5, 430241) = 67910; *P <* 0.001 | | | | |

Table A26. Relationships between worker and Netlogo random walk simulated result scaled distance to the nest entrance and nest shape and physical properties. Linear regression: ScaledDist ~ Nest \* WorkerType + Density + Corner