Supplemental Handout Information for Instructors

This handout includes regression summaries produced by the authors of the activity that may serve as a guide to instructors. Table 1 provides the complete set of experiment results. The *Population* columns contain the population at the time the experiment ended, which is either the death of all bees or the maximum tick threshold, whichever came first. Each cell in the *population* columns is the result of a single simulation run with all parameters except max ticks and the corresponding parameter in the leftmost column at their default values.

Table 1: Every result of the $population$ with different parameter combinations. These results were used in the regression in table 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **ParameterValue** | **Population at 8,000 Ticks** | **Population at 10,000 Ticks** | **Population at 12,000 Ticks** |
| *Initial Bee Cohort Count* | 2 | 54 | 65 | 66 |
| 4 | 59 | 55 | 81 |
| 6 | 75 | 65 | 64 |
| 8 | 54 | 76 | 87 |
| 10 | 58 | 81 | 67 |
| 12 | 56 | 59 | 62 |
| 14 | 51 | 72 | 58 |
| 16 | 59 | 85 | 88 |
| 18 | 68 | 70 | 86 |
| 20 | 50 | 69 | 77 |
| *Initial Flower Density* | 0.05 | 49 | 75 | 73 |
| 0.10 | 69 | 81 | 77 |
| 0.15 | 72 | 75 | 61 |
| 0.20 | 53 | 65 | 72 |
| 0.25 | 71 | 69 | 78 |
| 0.30 | 58 | 53 | 87 |
| 0.35 | 56 | 64 | 82 |
| 0.40 | 48 | 59 | 68 |
| 0.45 | 59 | 70 | 71 |
| 0.50 | 58 | 73 | 79 |
| *Food Per Flower Patch* | 1 | 61 | 54 | 69 |
| 2 | 62 | 86 | 84 |
| 3 | 62 | 57 | 60 |
| 4 | 54 | 72 | 79 |
| 5 | 70 | 75 | 80 |
| 6 | 63 | 54 | 86 |
| 7 | 41 | 44 | 75 |
| 8 | 62 | 71 | 63 |
| 9 | 52 | 66 | 67 |
| 10 | 65 | 59 | 65 |
| *Bee Sight Radius* | 1 | 50 | 75 | 74 |
| 2 | 64 | 75 | 85 |
| 3 | 62 | 68 | 64 |
| 4 | 59 | 56 | 82 |
| 5 | 62 | 52 | 77 |
| 6 | 57 | 79 | 66 |
| 7 | 60 | 67 | 71 |
| 8 | 64 | 68 | 67 |
| 9 | 48 | 73 | 62 |
| 10 | 62 | 79 | 68 |
| *Bee Regeneration Rate* | 0.002 | 72 | 81 | 70 |
| 0.004 | 57 | 81 | 80 |
| 0.006 | 62 | 66 | 82 |
| 0.008 | 62 | 62 | 71 |
| 0.01 | 60 | 70 | 85 |
| 0.012 | 61 | 73 | 77 |
| 0.014 | 50 | 78 | 66 |
| 0.016 | 64 | 70 | 78 |
| 0.018 | 50 | 59 | 69 |
| 0.02 | 61 | 68 | 72 |
| *Cost of New Bee Cohort* | 0 | 57 | 61 | 63 |
| 1 | 52 | 67 | 77 |
| 2 | 57 | 54 | 76 |
| 3 | 57 | 84 | 66 |
| 4 | 55 | 61 | 63 |
| 5 | 57 | 68 | 63 |
| 6 | 59 | 63 | 58 |
| 7 | 52 | 73 | 63 |
| 8 | 69 | 61 | 88 |
| 9 | 61 | 58 | 73 |
| *Bee Cohort Death Probability* | 0.00002 | 85 | 105 | 113 |
| 0.00004 | 61 | 87 | 103 |
| 0.00006 | 69 | 72 | 73 |
| 0.00008 | 70 | 71 | 70 |
| 0.00010 | 50 | 62 | 63 |
| 0.00012 | 57 | 62 | 56 |
| 0.00014 | 50 | 54 | 62 |
| 0.00016 | 55 | 55 | 62 |
| 0.00018 | 42 | 40 | 50 |
| 0.00020 | 36 | 38 | 48 |
| *Flower Patch Regeneration Rate* | 0.002 | 55 | 85 | 66 |
| 0.004 | 70 | 72 | 45 |
| 0.006 | 80 | 55 | 65 |
| 0.008 | 50 | 65 | 77 |
| 0.010 | 73 | 75 | 51 |
| 0.012 | 68 | 55 | 76 |
| 0.014 | 50 | 70 | 65 |
| 0.016 | 68 | 68 | 60 |
| 0.018 | 64 | 60 | 69 |
| 0.020 | 55 | 54 | 76 |
| *Herbicide Drift Probability* | 0.0001 | 78 | 70 | 68 |
| 0.0002 | 49 | 67 | 67 |
| 0.0003 | 68 | 63 | 62 |
| 0.0004 | 64 | 72 | 77 |
| 0.0005 | 55 | 71 | 67 |
| 0.0006 | 61 | 65 | 75 |
| 0.0007 | 64 | 71 | 72 |
| 0.0008 | 69 | 77 | 76 |
| 0.0009 | 57 | 63 | 76 |
| 0.0010 | 64 | 62 | 69 |
| *Honey Harvest Probability* | 0.0 | 67 | 60 | 66 |
| 0.1 | 71 | 68 | 71 |
| 0.2 | 57 | 57 | 73 |
| 0.3 | 58 | 62 | 72 |
| 0.4 | 64 | 63 | 64 |
| 0.5 | 54 | 60 | 62 |
| 0.6 | 63 | 77 | 70 |
| 0.7 | 60 | 73 | 67 |
| 0.8 | 50 | 84 | 75 |
| 0.9 | 52 | 61 | 72 |
| *Grid Height* | 10 | 58 | 70 | 66 |
| 20 | 64 | 66 | 61 |
| 30 | 76 | 55 | 76 |
| 40 | 54 | 48 | 66 |
| 50 | 83 | 60 | 61 |
| 60 | 69 | 60 | 54 |
| 70 | 51 | 68 | 81 |
| 80 | 73 | 73 | 52 |
| 90 | 81 | 62 | 72 |
| 100 | 61 | 54 | 62 |
| *Grid Width* | 10 | 58 | 61 | 66 |
| 20 | 61 | 59 | 84 |
| 30 | 69 | 60 | 87 |
| 40 | 52 | 78 | 72 |
| 50 | 63 | 73 | 74 |
| 60 | 51 | 67 | 90 |
| 70 | 59 | 66 | 56 |
| 80 | 55 | 70 | 60 |
| 90 | 46 | 63 | 65 |
| 100 | 38 | 76 | 81 |
| *Initial Density of Full Nectaries* | 0.1 | 52 | 68 | 71 |
| 0.2 | 58 | 59 | 72 |
| 0.3 | 51 | 66 | 67 |
| 0.4 | 60 | 54 | 78 |
| 0.5 | 47 | 73 | 68 |
| 0.6 | 65 | 59 | 71 |
| 0.7 | 68 | 70 | 52 |
| 0.8 | 55 | 53 | 64 |
| 0.9 | 64 | 72 | 76 |
| 1.0 | 53 | 68 | 75 |
| *Percentage of Honey Harvested* | 0 | 50 | 91 | 57 |
| 0.1 | 61 | 67 | 77 |
| 0.2 | 67 | 57 | 81 |
| 0.3 | 68 | 73 | 69 |
| 0.4 | 57 | 72 | 76 |
| 0.5 | 65 | 78 | 87 |
| 0.6 | 59 | 65 | 77 |
| 0.7 | 53 | 61 | 85 |
| 0.8 | 59 | 64 | 86 |
| 0.9 | 48 | 68 | 74 |

Table 2 describes the regression results of varying parameters on the bee population. Every hyperparameter except the random seed was varied while other parameters remained at default values, and statistically significant regressors are bolded. The *f*-test *p*-value column describes the significance at which the entire equation fits the parameter, and the $β\_{0}$, $β\_{1}$, and $β\_{2}$ columns the significance of the estimated coefficients of the intercept, parameter, and tick, respectively. The most important column for us is$β\_{1}$ because it lists the impacts of changing each variable on the $population$. The impacts of each parameter were estimated using a generalized linear regression model. Linear regression reveals a trend in data by drawing a best-fit line through the data points.

Table 2: This table details the summary of the regression of parameter changes on the population. Statistically significant values are denoted with bolded values.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **F-test p-value** | $$β\_{0}$$ | $$β\_{1}$$ | $$β\_{2}$$ |
| *Initial Bee Population* | 0.3779 | **25.844444** | 0.308081 | **0.003800** |
| *Initial Flower Density* | 9.566 | 3.121e+01 | -8.929e+01 | 3.875e-03 |
| *Food Per Flower* | 2.028 | **39.661111** | 0.246465 | 0.002425 |
| *Bee Sight Radius* | 0.6807 | **71.105556** | -0.694949 | -0.000075 |
| *Bee Regeneration Rate* | 2.47 | **5.819e+01** | -4.434e+02 | 1.525e-03 |
| *Cost of New Bee* | 1.733 | **45.189394** | 0.206061 | 0.001775 |
| *Bee Death Probability* | 6.365 | **6.041e+01** | **-1.738e+05** | 2.275e-03 |
| *Flower Regeneration Rate* | 1.594 | **4.559e+01** | 3.535e+02 | 1.525e-03 |
| *Herbicide Drift Probability* | 2.713 | **5.512e+01** | -4.667e+03 | 1.475e-03 |
| *Honey Harvest Probability* | 0.3064 | **70.5636364** | -3.2525253 | -0.000400 |
| *Grid Height* | 0.8131 | **56.744444** | -0.048687 | 0.001050 |
| *Grid Width* | 0.3041 | **57.322222** | -0.027071 | 0.000950 |
| *Initial Density of Full* *Nectaries* | 0.3282 | **58.116667** | -0.363636 | 0.000875 |
| *Percentage of Honey* *Harvested* | 4.924 | **40.011111** | -7.474747 | 0.003250 |

The maximum number of ticks per simulation was chosen for the convenience of running the simulation. A computer with a 2.6 GHz Quad-Core Intel Core i7 CPU and 16 GB of memory would take approximately two minutes to generate each parameter row below.

It is clear that linear regression did not reveal substantial statistical significance in individual parameter changes. In the use of this handout, it should be posed to students why regression testing does not fully capture the interactions of multi agent systems/ complex adaptive systems, and what other types of testing could lead to more descriptive results.