Bryce Graves

Professor Mike Bailey

CS 475

2020 5 4 (ISO 8601)

# Project: 3

Bryce Graves
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**Hardware**: still on mine on my desktop. Find out next week if I ever manage to get my laptop development environment set up.

- **OS:** Linux Mint 19.3 Cinnamon
- **Kernel:** 5.3
- **CPU:** Intel© Core™ i7-6700K CPU
    - **Cores:** 4
    - **Threads:** 8
    - **Core Clock:** 4 GHz
    - **Boost Clock**: 4.2 GHz
    - **L1 Cache**:
        - 4 x 32 kB Instruction
        - 4 x 32 kB Data
    - **L2 Cache**: 4 x 256 kB
    - **L3 Cache**: 1 x 8 MB
    - **Simultaneous Multithreading:** yes - Hyper-Threading
- **Memory:** 32 GB DDR4 overclocked to 3200 MHz from base 2133 MHz

**Early thoughts:** As soon as I read the topic of this project my mind immediately jumped to the study of how releasing wolves into Yellowstone strengthened the ecosystem. By controlling the Elk population throughout Yellowstone it brought stability to the system as a whole allowing plants to grow back in areas that they were being grazed out of. I was curious to see if adding

wolves to the simulation would have similar results to adding predation to simulations during my previous Biology course.

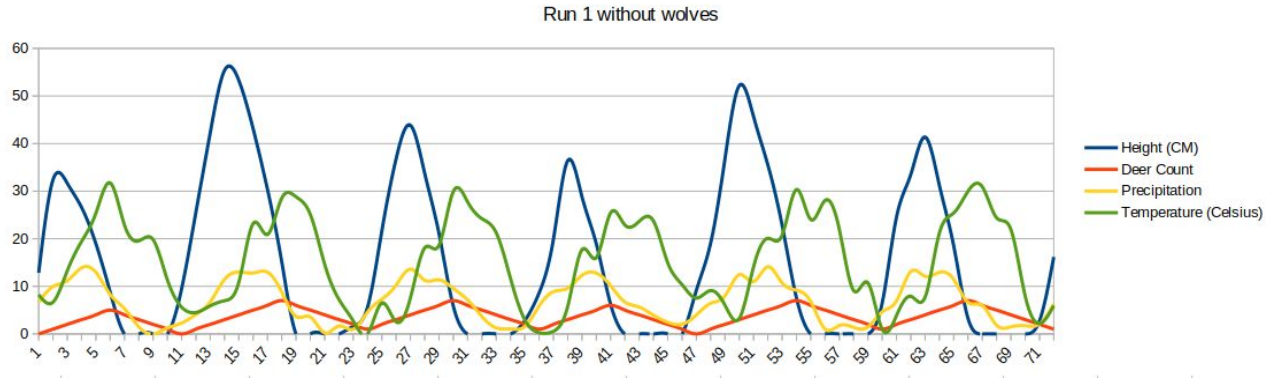
**Data & Graphs:** sorry this is a lot of data and runs

Run 1:

| Month | Height (CM) | Deer Count | Precipitation | Temperature (Celsius) |
|---|---|---|---|---|
| 1 | 12.83882 | 0 | 6.730515 | 8.253223 |
| 2 | 32.380955 | 1 | 9.956156 | 6.644308 |
| 3 | 31.657719 | 2 | 11.171998 | 13.261159 |
| 4 | 26.591444 | 3 | 13.900003 | 19.419513 |
| 5 | 18.971458 | 4 | 12.952075 | 25.35322 |
| 6 | 8.811458 | 5 | 8.293401 | 31.74124 |
| 7 | 0 | 4 | 5.32262 | 22.881919 |
| 8 | 0 | 3 | 1.467883 | 19.538506 |
| 9 | 0 | 2 | 0 | 19.828101 |
| 10 | 0 | 1 | 1.233066 | 11.39189 |
| 11 | 9.508873 | 0 | 2.278368 | 5.612189 |
| 12 | 25.616125 | 1 | 4.083503 | 4.49084 |
| 13 | 42.273263 | 2 | 6.728976 | 5.889227 |
| 14 | 55.385394 | 3 | 11.47175 | 6.970476 |
| 15 | 53.275101 | 4 | 13.014397 | 10.856266 |
| 16 | 43.115338 | 5 | 12.798284 | 23.20354 |
| 17 | 30.418652 | 6 | 12.988258 | 20.877961 |
| 18 | 15.178652 | 7 | 8.79353 | 28.516613 |
| 19 | 0 | 6 | 3.63674 | 28.820869 |
| 20 | 0 | 5 | 3.55707 | 25.115929 |

| | | | | |
|---|---|---|---|---|
| 21 | 0 | 4 | 0.215509 | 14.66532 |
| 22 | 0 | 3 | 1.660036 | 7.260217 |
| 23 | 1.565996 | 2 | 0.960726 | 2.735502 |
| 24 | 5.574807 | 1 | 4.578739 | 0.040309 |
| 25 | 21.591747 | 2 | 7.292857 | 6.487641 |
| 26 | 36.794169 | 3 | 10.245357 | 2.527722 |
| 27 | 43.858108 | 4 | 13.628863 | 7.542373 |
| 28 | 33.752087 | 5 | 11.26463 | 18.089625 |
| 29 | 21.085111 | 6 | 11.37099 | 18.631422 |
| 30 | 5.845111 | 7 | 9.561783 | 29.916628 |
| 31 | 0 | 6 | 7.159439 | 27.757098 |
| 32 | 0 | 5 | 3.660249 | 24.215681 |
| 33 | 0 | 4 | 1.255611 | 21.274473 |
| 34 | 0 | 3 | 1.044045 | 11.668646 |
| 35 | 2.771392 | 2 | 1.530739 | 2.962797 |
| 36 | 8.587282 | 1 | 5.833894 | 0.259527 |
| 37 | 19.844608 | 2 | 8.873041 | 0.546782 |
| 38 | 36.391684 | 3 | 9.595907 | 5.733164 |
| 39 | 28.845223 | 4 | 12.298985 | 17.692409 |
| 40 | 18.96329 | 5 | 12.792938 | 16.00651 |
| 41 | 6.263305 | 6 | 10.155231 | 25.429209 |
| 42 | 0 | 5 | 6.702262 | 22.879359 |
| 43 | 0 | 4 | 5.648849 | 23.65259 |
| 44 | 0 | 3 | 3.929876 | 23.735288 |
| 45 | 0 | 2 | 2.455488 | 14.930878 |
| 46 | 0 | 1 | 2.027035 | 10.354008 |
| 47 | 9.159145 | 0 | 3.973798 | 7.521248 |

| | | | | |
|---|---|---|---|---|
| 48 | 19.080767 | 1 | 6.418547 | 9.11377 |
| 49 | 36.745364 | 2 | 7.978967 | 6.04144 |
| 50 | 52.18164 | 3 | 12.451968 | 3.226666 |
| 51 | 45.685685 | 4 | 10.992031 | 14.071138 |
| 52 | 35.532647 | 5 | 14.114788 | 20.086123 |
| 53 | 22.836826 | 6 | 10.708632 | 20.738326 |
| 54 | 7.596826 | 7 | 9.186756 | 30.33123 |
| 55 | 0 | 6 | 6.800962 | 24.041371 |
| 56 | 0 | 5 | 1.016132 | 28.045112 |
| 57 | 0 | 4 | 1.776136 | 21.971707 |
| 58 | 0 | 3 | 1.372809 | 9.088851 |
| 59 | 0 | 2 | 1.459445 | 10.742611 |
| 60 | 6.49942 | 1 | 4.642444 | 0.961128 |
| 61 | 24.540619 | 2 | 6.931309 | 3.865973 |
| 62 | 33.500373 | 3 | 13.116172 | 7.915624 |
| 63 | 41.373405 | 4 | 12.103811 | 7.706356 |
| 64 | 31.215764 | 5 | 12.958014 | 21.195984 |
| 65 | 18.515779 | 6 | 11.440806 | 25.404663 |
| 66 | 3.275779 | 7 | 6.607455 | 29.968859 |
| 67 | 0 | 6 | 5.988577 | 30.925123 |
| 68 | 0 | 5 | 1.807863 | 24.387987 |
| 69 | 0 | 4 | 1.482453 | 21.94909 |
| 70 | 0 | 3 | 1.709921 | 7.981046 |
| 71 | 2.728712 | 2 | 2.092151 | 2.172869 |
| 72 | 16.170345 | 1 | 6.315938 | 5.963116 |




Run 2: contains early false wolf output

| Month | Height (CM) | Deer Count | Wolf Count | Precipitation | Temperature (Celsius) |
|---|---|---|---|---|---|
| 1 | 21.215108 | 0 | 1 | 10.052896 | 2.926576 |
| 2 | 30.311255 | 1 | 1 | 10.00599 | 9.777597 |
| 3 | 30.769314 | 2 | 1 | 11.233725 | 12.332948 |
| 4 | 25.888027 | 3 | 1 | 14.071921 | 16.333167 |
| 5 | 18.32714 | 4 | 1 | 11.008376 | 17.993075 |
| 6 | 8.16731 | 5 | 1 | 6.625544 | 23.442531 |
| 7 | 0 | 4 | 1 | 7.403463 | 25.859773 |
| 8 | 0 | 3 | 1 | 1.568459 | 22.190526 |
| 9 | 0 | 2 | 1 | 0.073183 | 18.706411 |
| 10 | 0 | 1 | 1 | 1.591115 | 12.319934 |
| 11 | 5.67253 | 0 | 1 | 1.431174 | 7.433518 |
| 12 | 25.108589 | 1 | 1 | 5.977421 | 4.561927 |
| 13 | 34.699263 | 2 | 1 | 9.194962 | 8.844117 |
| 14 | 36.091116 | 3 | 1 | 11.551768 | 10.625475 |
| 15 | 41.654265 | 4 | 1 | 14.597466 | 7.679488 |
| 16 | 32.049022 | 5 | 1 | 14.243294 | 14.895024 |
| 17 | 19.368905 | 6 | 1 | 10.728214 | 19.187105 |

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|---|---|---|---|---|---|
| 18 | 4.128905 | 7 | 1 | 9.128187 | 30.067469 |
| 19 | 0 | 6 | 1 | 5.18334 | 27.421773 |
| 20 | 0 | 5 | 1 | 1.076428 | 28.426887 |
| 21 | 0 | 4 | 1 | 2.803203 | 19.043838 |
| 22 | 0 | 3 | 1 | 2.487141 | 10.133245 |
| 23 | 1.129014 | 2 | 1 | 2.048586 | 7.627142 |
| 24 | 11.00313 | 1 | 1 | 4.343414 | 6.239779 |
| 25 | 28.134797 | 2 | 1 | 8.789572 | 6.4899 |
| 26 | 42.757923 | 3 | 1 | 12.386168 | 2.762356 |
| 27 | 47.832478 | 4 | 1 | 13.771173 | 8.154615 |
| 28 | 39.726451 | 5 | 1 | 11.96183 | 12.999145 |
| 29 | 27.037524 | 6 | 1 | 10.202848 | 19.792637 |
| 30 | 11.797904 | 7 | 1 | 7.291478 | 22.813827 |
| 31 | 0 | 6 | 1 | 3.662637 | 30.01183 |
| 32 | 0 | 5 | 1 | 3.373669 | 22.570381 |
| 33 | 0 | 4 | 1 | 0.086995 | 15.60191 |
| 34 | 0 | 3 | 1 | 2.973917 | 9.44191 |
| 35 | 6.742189 | 2 | 1 | 3.381598 | 5.353201 |
| 36 | 16.868336 | 3 | 1 | 4.918106 | 2.296861 |
| 37 | 31.607819 | 2 | 2 | 10.476093 | 3.661298 |
| 38 | 32.541025 | 3 | 1 | 11.538011 | 10.807376 |
| 39 | 33.429573 | 2 | 2 | 14.034113 | 9.492291 |
| 40 | 28.361355 | 3 | 1 | 12.745828 | 19.653982 |
| 41 | 20.741387 | 2 | 2 | 9.298892 | 24.839689 |
| 42 | 15.66159 | 3 | 1 | 8.559405 | 23.368407 |
| 43 | 8.04159 | 2 | 2 | 5.23006 | 27.673183 |
| 44 | 2.961596 | 3 | 1 | 2.26899 | 25.605668 |

| | | | | | |
|---|---|---|---|---|---|
| 45 | 0 | 2 | 2 | 1.761333 | 18.297797 |
| 46 | 0 | 1 | 1 | 0.655465 | 8.871746 |
| 47 | 0.618954 | 0 | 0 | 4.661524 | 11.675538 |
| 48 | 15.084467 | 1 | -1 | 3.555476 | 5.587086 |
| 49 | 26.568519 | 0 | 0 | 9.820011 | 0.562344 |
| 50 | 29.522026 | 1 | -1 | 10.533799 | 12.386258 |
| 51 | 28.077751 | 0 | 0 | 11.2285 | 14.103572 |
| 52 | 28.092612 | 1 | -1 | 12.229558 | 19.44313 |
| 53 | 25.554533 | 2 | 0 | 13.05735 | 21.37886 |
| 54 | 20.474654 | 3 | 1 | 8.121943 | 23.783769 |
| 55 | 12.855817 | 2 | 2 | 6.073849 | 21.775131 |
| 56 | 7.807053 | 3 | 1 | 2.935503 | 18.161723 |
| 57 | 0.193175 | 2 | 2 | 2.103264 | 19.761679 |
| 58 | 0 | 3 | 1 | 2.135955 | 17.00097 |
| 59 | 0 | 2 | 2 | 2.183096 | 12.36485 |
| 60 | 10.976302 | 3 | 1 | 4.716252 | 5.956815 |
| 61 | 24.801914 | 2 | 2 | 10.069499 | 3.040962 |
| 62 | 22.315205 | 3 | 1 | 13.140688 | 12.452583 |
| 63 | 19.92998 | 4 | 2 | 13.492654 | 10.904384 |
| 64 | 11.304029 | 5 | 3 | 11.921836 | 13.513016 |
| 65 | 0 | 4 | 4 | 9.45999 | 24.997491 |
| 66 | 0 | 5 | 3 | 8.656038 | 27.48224 |
| 67 | 0 | 4 | 4 | 5.934439 | 23.144514 |
| 68 | 0 | 5 | 3 | 1.67109 | 25.889664 |
| 69 | 0 | 4 | 4 | 1.563245 | 19.619764 |
| 70 | 0 | 5 | 3 | 2.75871 | 15.564927 |
| 71 | 0.839876 | 4 | 4 | 3.037677 | 3.347168 |

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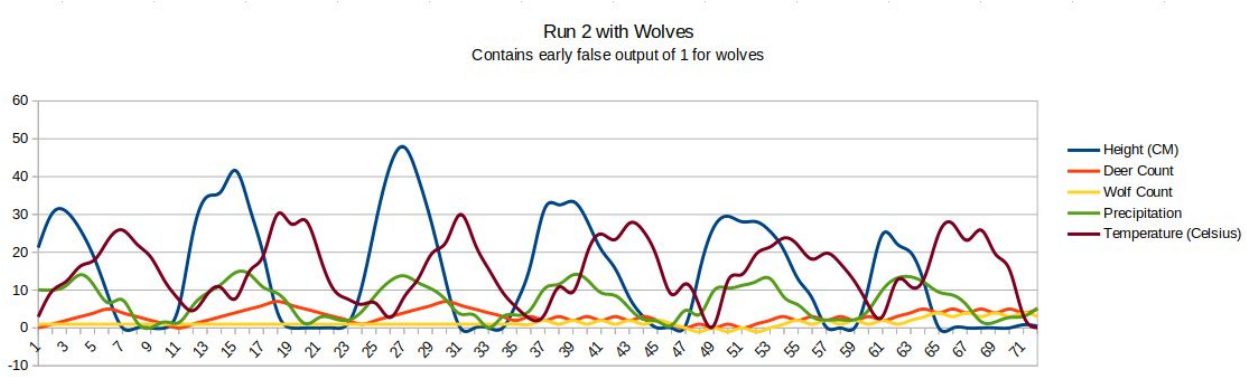
|---|---|---|---|---|---|
| 72 | 0.484414 | 5 | 3 | 5.23225 | 0.072717 |

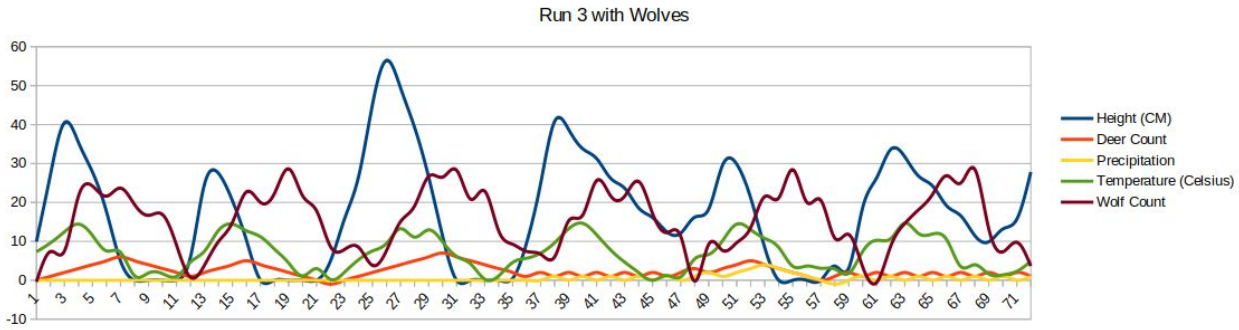



| Month | Height (CM) | Deer Count | Precipitation | Temperature (Celsius) | Wolf Count |
|---|---|---|---|---|---|
| 1 | 9.926396 | 0 | 0 | 7.317607 | -0.405905 |
| 2 | 27.150925 | 1 | 0 | 9.597031 | 7.391667 |
| 3 | 40.508792 | 2 | 0 | 12.456715 | 7.501763 |
| 4 | 35.430151 | 3 | 0 | 14.427994 | 21.598409 |
| 5 | 27.810221 | 4 | 0 | 11.516191 | 24.208247 |
| 6 | 17.651791 | 5 | 0 | 7.544683 | 21.590644 |
| 7 | 4.951919 | 6 | 0 | 7.187295 | 23.700841 |
| 8 | 0 | 5 | 0 | 1.161904 | 19.474636 |
| 9 | 0 | 4 | 0 | 1.878121 | 16.660099 |
| 10 | 0 | 3 | 0 | 1.695832 | 16.894993 |
| 11 | 0 | 2 | 0 | 0.970042 | 9.047546 |
| 12 | 5.983283 | 1 | 0 | 4.676665 | 0.749361 |
| 13 | 24.671377 | 2 | 0 | 7.48097 | 3.872248 |
| 14 | 27.474248 | 3 | 0 | 12.809542 | 9.960306 |
| 15 | 20.392142 | 4 | 0 | 14.407329 | 14.919633 |

| | | | | | |
|---|---|---|---|---|---|
| 16 | 10.232559 | 5 | 0 | 12.697606 | 22.735994 |
| 17 | 0 | 4 | 0 | 11.184057 | 19.982715 |
| 18 | 0 | 3 | 0 | 7.976735 | 22.339295 |
| 19 | 0 | 2 | 0 | 4.467032 | 28.644956 |
| 20 | 0 | 1 | 0 | 1.097636 | 21.746695 |
| 21 | 0 | 0 | 0 | 2.995368 | 17.858281 |
| 22 | 4.989725 | -1 | 0 | 0.204407 | 8.611005 |
| 23 | 15.792916 | 0 | 0 | 2.082426 | 7.916991 |
| 24 | 26.59732 | 1 | 0 | 5.279798 | 8.476077 |
| 25 | 45.276941 | 2 | 0 | 7.539124 | 3.789376 |
| 26 | 56.519564 | 3 | 0 | 9.475945 | 7.655585 |
| 27 | 49.424372 | 4 | 0 | 13.266153 | 15.083637 |
| 28 | 39.286071 | 5 | 0 | 11.070076 | 19.088792 |
| 29 | 26.586073 | 6 | 0 | 12.958342 | 26.687029 |
| 30 | 11.346076 | 7 | 0 | 9.861216 | 26.487444 |
| 31 | 0 | 6 | 0 | 6.147122 | 28.292525 |
| 32 | 0 | 5 | 0 | 4.198631 | 20.8255 |
| 33 | 0 | 4 | 0 | 0.301301 | 22.940331 |
| 34 | 0 | 3 | 0 | 1.094955 | 12.736693 |
| 35 | 0.452714 | 2 | 0 | 4.576199 | 9.245173 |
| 36 | 9.646417 | 1 | 0 | 5.658893 | 7.397355 |
| 37 | 24.821537 | 2 | 0 | 6.983239 | 6.69401 |
| 38 | 40.827208 | 1 | 1 | 9.639 | 6.010793 |
| 39 | 38.747814 | 2 | 0 | 13.23048 | 15.274552 |
| 40 | 33.808886 | 1 | 1 | 14.639465 | 16.707804 |
| 41 | 31.268896 | 2 | 0 | 11.685034 | 25.646968 |
| 42 | 26.190344 | 1 | 1 | 7.782647 | 21.673313 |

| | | | | | |
|---|---|---|---|---|---|
| 43 | 23.651582 | 2 | 0 | 4.654032 | 21.601418 |
| 44 | 18.571589 | 1 | 1 | 1.966288 | 25.401573 |
| 45 | 16.079023 | 2 | 0 | 0 | 17.085982 |
| 46 | 12.479987 | 1 | 1 | 1.242519 | 12.241565 |
| 47 | 12.086082 | 2 | 0 | 0.85778 | 11.316145 |
| 48 | 16.212077 | 3 | 1 | 5.487104 | -0.22312 |
| 49 | 18.278337 | 2 | 2 | 6.613293 | 9.236357 |
| 50 | 29.640817 | 3 | 1 | 10.205248 | 7.63151 |
| 51 | 29.851475 | 4 | 2 | 14.433478 | 9.640552 |
| 52 | 21.13356 | 5 | 3 | 12.991674 | 13.528752 |
| 53 | 8.435352 | 4 | 4 | 10.763281 | 21.521204 |
| 54 | 0 | 3 | 3 | 8.439573 | 21.131888 |
| 55 | 0 | 2 | 2 | 3.592579 | 28.444375 |
| 56 | 0 | 1 | 1 | 3.653887 | 20.05967 |
| 57 | 0 | 0 | 0 | 3.073087 | 20.600565 |
| 58 | 3.653819 | 1 | -1 | 2.884476 | 10.844938 |
| 59 | 3.138389 | 2 | 0 | 1.758213 | 11.782744 |
| 60 | 18.710169 | 1 | 1 | 7.429968 | 3.39716 |
| 61 | 26.371118 | 2 | 0 | 10.280971 | -0.54356 |
| 62 | 33.63535 | 1 | 1 | 10.703581 | 8.787914 |
| 63 | 31.748278 | 2 | 0 | 14.687104 | 14.591493 |
| 64 | 26.717667 | 1 | 1 | 11.955189 | 18.164741 |
| 65 | 24.178512 | 2 | 0 | 11.900069 | 22.16167 |
| 66 | 19.098514 | 1 | 1 | 10.39532 | 26.877831 |
| 67 | 16.558531 | 2 | 0 | 3.502437 | 24.981571 |
| 68 | 11.478531 | 1 | 1 | 4.005564 | 28.54293 |
| 69 | 9.874501 | 2 | 0 | 1.593216 | 13.208887 |

| | | | | | |
|---|---|---|---|---|---|
| 70 | 13.171098 | 1 | 1 | 1.375162 | 7.277607 |
| 71 | 15.674993 | 2 | 0 | 2.293725 | 9.765447 |
| 72 | 27.83849 | 1 | 1 | 4.890185 | 3.642218 |




**Conclusion:** I was quite surprised how well and how quickly the model adopted the same trophic cascades that were seen in Yellowstone when wolves were introduced into the system. With some further tweaking the simulation could take into account the feeding of the deer on the grain and how overfeeding causes really large swings in population that risk wiping out species from the area. While when there is predation there are smaller and more controlled swings which less of a threat of species extinction. Extinction would be a good addition to the system as a whole and would probably provide more interesting and informative outcomes. The current state of the system allows for negative amounts of wolves... even though this is an oversight I am going to say this is a feature and not a bug. A negative number just indicates that wolves from a different migration migrated to the area of the simulation due to the abundance of deer.