Homework for Lecture 23 of Dr. Z.'s Dynamical Models in Biology class

Email the answers (either as .pdf file and/or .txt file) to

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by 8:00pm Monday, Dec. 8, 2025.

Subject: hw21

with an attachment hw23FirstLast.pdf and/or hw23FirstLast.txt

1. In the Maple package DMB.txt run

```
ExpGenLotka(2,50);
```

ten times.

In how many cases did all the sepecies survive? In how many cases was there agreement with the positive stable equilibrium points, and between the three initial conditions?

2. In the Maple package DMB.txt run

```
ExpGenLotka(3,50);
```

ten times.

In how many cases did all the sepecies survive? In how many cases was there agreement with the positive stable equilibrium points, and between the three initial conditions?

3. In the Maple package DMB.txt run

```
ExpGenLotka(4,50);
```

ten times.

In how many cases did all the sepecies survive? In how many cases was there agreement with the positive stable equilibrium points, and between the three initial conditions?

4. In the Maple package DMB.txt run

```
ExpGenLotka(5,50);
```

ten times.

In how many cases did all the sepecies survive? In how many cases was there agreement with the positive stable equilibrium points, and between the three initial conditions?

1.)

$\{[0., 0.], [0., 0.8474576271], [0.5208333333, 0.], [0.5220646178, -0.01970055162]\}$

The stable Equilibrium points are
$\{[0.5208333333, 0.]\}$
at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is
$[0.5189098018, 0.02997972993]$

and with initial conditions, $[0.1, 0.1]$

$[0.5190809992, 0.02735103168]$

and with initial conditions, $\left[\frac{1}{2}, 1\right]$

$[0.5188099176, 0.03150983934]$

all survived

agreement between I.C.
↳ *similar values*

> *ExpGenLotka*(2, 50);

The Equilibrium points are

$\{[0., 0.], [0., 1.162790698], [0.2104770814, 0.8886810103], [2.777777778, 0.]\}$

The stable Equilibrium points are
$\{[0., 1.162790698], [2.777777778, 0.]\}$
at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is
$[2.777777723, 7.455287790 \times 10^{-15}]$

and with initial conditions, $[0.1, 0.1]$

$[2.777777723, 2.596930501 \times 10^{-15}]$

and with initial conditions, $\left[\frac{1}{2}, 1\right]$

$[2.777777723, 2.263413087 \times 10^{-12}]$

> *ExpGenLotka*(2, 50);

The Equilibrium points are

$\{[0., 0.], [0., 0.6493506494], [0.5244755245, 0.5880483153], [1.086956522, 0.]\}$

The stable Equilibrium points are
$\{[0.5244755245, 0.5880483153]\}$
at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is
$[0.5301601430, 0.5836721247]$

and with initial conditions, $[0.1, 0.1]$

$[0.6311761384, 0.4963779390]$

and with initial conditions, $\left[\frac{1}{2}, 1\right]$

$[0.5092912292, 0.5992974787]$

All survive

$\{[0., 0.], [0., 4.166666667], [0.6410256410, 0.], [1.103565365, -0.7074136955]\}$

The stable Equilibrium points are
$\{[0., 4.166666667], [1.103565365, -0.7074136955]\}$
at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is
$[3.521629977 \times 10^{-46}, 4.166666592]$

and with initial conditions, $[0.1, 0.1]$

$[1.294779416 \times 10^{-43}, 4.166666592]$

and with initial conditions, $\left[\frac{1}{2}, 1\right]$

$[3.825889182 \times 10^{-48}, 4.166666592]$

> *ExpGenLotka*(2, 50);

The Equilibrium points are

$\{[0., 0.], [0., 0.6944444444], [0.6756756757, 0.], [0.8389261745, -0.4474272931]\}$

The stable Equilibrium points are
$\{[0.6756756757, 0.]\}$
at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is
$[0.6756755828, 1.531484977 \times 10^{-7}]$

and with initial conditions, $[0.1, 0.1]$

$[0.6756754648, 3.492703019 \times 10^{-7}]$

and with initial conditions, $\left[\frac{1}{2}, 1\right]$

$[0.6756755522, 2.046475062 \times 10^{-7}]$

match

> *ExpGenLotka*(2, 50);

The Equilibrium points are

$\{[0., 0.], [0., 0.7812500000], [2.532833021, 0.1876172608], [2.631578947, 0.]\}$

The stable Equilibrium points are
$\{[2.532833021, 0.1876172608]\}$
at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is
$[2.505751554, 0.2348318993]$

and with initial conditions, $[0.1, 0.1]$

$[2.526871595, 0.1981735395]$

and with initial conditions, $\left[\frac{1}{2}, 1\right]$

$[2.499420252, 0.2455921211]$

$\{[0., 0.], [0., 0.9615384615], [1.250000000, 0.], [1.966292135, -1.685393258]\}$

The stable Equilibrium points are
$\{[1.250000000, 0.]\}$
at time t=, 50, with initial conditions, [0.5, 0.5], the ultimate behavior is
$\left[1.249999883, 2.412660284 \times 10^{-9}\right]$

and with initial conditions, [0.1, 0.1]

$\left[1.249999878, 1.553914733 \times 10^{-8}\right]$
and with initial conditions, $\left[\dfrac{1}{2}, 1\right]$

$\left[1.249999883, 3.636927514 \times 10^{-9}\right]$

The Equilibrium points are

$ExpGenLotka(2, 50);$

$\{[-1.574074074, 2.962962963], [0., 0.], [0., 1.388888889], [0.5000000000, 0.]\}$

The stable Equilibrium points are
$\{[0., 1.388888889]\}$
at time t=, 50, with initial conditions, [0.5, 0.5], the ultimate behavior is
$\left[3.300988967 \times 10^{-17}, 1.388888810\right]$

and with initial conditions, [0.1, 0.1]

$\left[3.632411978 \times 10^{-16}, 1.388888810\right]$
and with initial conditions, $\left[\dfrac{1}{2}, 1\right]$

$\left[6.915095200 \times 10^{-18}, 1.388888810\right]$

$ExpGenLotka(2, 50);$

The Equilibrium points are

$\{[0., 0.], [0., 10.], [1.785714286, 0.], [41.17647059, -14.70588235]\}$

The stable Equilibrium points are
$\{[0., 10.], [41.17647059, -14.70588235]\}$
at time t=, 50, with initial conditions, [0.5, 0.5], the ultimate behavior is
$\left[6.440307627 \times 10^{-168}, 9.999999894\right]$

and with initial conditions, [0.1, 0.1]

$\left[2.352550413 \times 10^{-154}, 9.999999894\right]$
and with initial conditions, $\left[\dfrac{1}{2}, 1\right]$

$\left[4.074199769 \times 10^{-174}, 9.999999894\right]$

> $ExpGenLotka(2, 50);$

The Equilibrium points are

$\{[-1.356852103, 1.797829037], [0., 0.], [0., 0.5102040816], [1.250000000, 0.]\}$

The stable Equilibrium points are
$\{[1.250000000, 0.]\}$
at time t=, 50, with initial conditions, [0.5, 0.5], the ultimate behavior is
$\left[1.249998775, 5.741105880 \times 10^{-7}\right]$

and with initial conditions, [0.1, 0.1]

$\left[1.249999517, 2.204198505 \times 10^{-7}\right]$
and with initial conditions, $\left[\dfrac{1}{2}, 1\right]$

$\left[1.249996443, 1.667139436 \times 10^{-6}\right]$

>

- # cases where all species survived = 3
- # times there was agreement w/ positive stable equ pts = 4
- # times there was agreement between 3 initial conditions = 4

2.)

> *ExpGenLotka*(3, 50);

The Equilibrium points are

$\{[-1.569373440, 2.205445250, -0.08322434907], [-1.553166069, 2.090800478, 0.], [0., 0., 0.], [0., 0., 25.], [0, 0.7241063245, 0.01833180568], [0., 0.7462686567, 0.], [0.7498500300, 0., 0.6298740252], [2.173913043, 0., 0.]\}$

The stable Equilibrium points are
$\{[-1.569373440, 2.205445250, -0.08322434907], [0., 0., 25.], [2.173913043, 0., 0.]\}$
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5], the ultimate behavior is

$[2.170935716, 1.339759022 \times 10^{-26}, 0.0009866029924]$

and with initial conditions, [0.1, 0.1, 0.1]

$[2.173837281, 1.202560617 \times 10^{-28}, 0.00002509691146]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$[2.487416341 \times 10^{-173}, 2.526112754 \times 10^{-358}, 22.23601387]$

> *ExpGenLotka*(3, 50);

The Equilibrium points are

$\{[-0.6818181818, 4.924242424, 0.], [0., -10.41666667, 37.50000000], [0., 0., 0.], [0., 0., 2.173913043], [0., 2.083333333, 0.], [0.1800720288, 0., 1.680672269], [0.4129734085, -0.1152744203, 1.433655654], [1.428571429, 0., 0.]\}$

The stable Equilibrium points are
$\{[-0.6818181818, 4.924242424, 0.], [0., -10.41666667, 37.50000000], [1.428571429, 0., 0.]\}$
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5], the ultimate behavior is
$[1.419157437, 7.185853403 \times 10^{-15}, 2.676216565 \times 10^{-11}]$

and with initial conditions, [0.1, 0.1, 0.1]

$[1.297471798, 3.887689892 \times 10^{-6}, 2.412369628 \times 10^{-9}]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$[1.409030965, 2.475792473 \times 10^{-12}, 3.053392176 \times 10^{-10}]$

> *ExpGenLotka*(3, 50);

The Equilibrium points are

$\{[-0.01521606817, 0.9890444309, 0.], [0., 0., 0.], [0., 0., 1.250000000], [0., 0.9803921569, 0.], [0., 1.005981512, -0.4350190321], [0.07504344621, 0.9641546860, -0.4493829761], [0.3947368421, 0., 0.8059210526], [0.5319148936, 0., 0.]$

The stable Equilibrium points are
$\{[0., 0.9803921569, 0.]\}$
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5], the ultimate behavior is
$[0.01263777132, 0.9725043212, 0.00004051307062]$

and with initial conditions, [0.1, 0.1, 0.1]

$[0.01615395280, 0.9701603897, 0.0001396370501]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$[0.01107189505, 0.9735219694, 0.00003587365085]$

> *ExpGenLotka*(3, 50);

The Equilibrium points are

$\{[0., 0., 0.], [0., 0., 1.], [0., 0.03559563360, 0.9373516849], [0., 5.555555556, 0.], [0.2227171492, 0., 0.8351893096], [0.4826538612, 0.2462269698, 0.2094766758], [0.6244109331, 0.2827521206, 0.], [0.9615384615, 0., 0.]\}$

The stable Equilibrium points are
$\{[0., 5.555555556, 0.], [0.2227171492, 0., 0.8351893096]\}$
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5], the ultimate behavior is
$[5.570115013 \times 10^{-64}, 5.555555208, 8.028999371 \times 10^{-86}]$

and with initial conditions, [0.1, 0.1, 0.1]

$[1.668081084 \times 10^{-44}, 5.555501899, 4.886069652 \times 10^{-60}]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$[1.303277672 \times 10^{-68}, 5.555555440, 1.998589910 \times 10^{-91}]$

> *ExpGenLotka*(3, 50);

ExpGenLotka(3, 50);

The Equilibrium points are

$\{[-1.504424779, 0., 1.799410029], [-1.361111111, -2.313492063, 2.898148148], [0., -1.495016611, 1.937984496], [0., 0., 0.], [0., 0., 1.190476190], [0., 0.8928571429, 0.], [0.09633911368, 0.8670520231, 0.], [0.6410256410, 0., 0.]\}$

The stable Equilibrium points are
$\{[0., 0., 1.190476190]\}$
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5], the ultimate behavior is
$[4.490317784 \times 10^{-19}, 2.270247180 \times 10^{-9}, 1.190379535]$

and with initial conditions, [0.1, 0.1, 0.1]

$[2.686779155 \times 10^{-14}, 1.048175637 \times 10^{-6}, 1.188986057]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$[1.336042711 \times 10^{-21}, 7.887464056 \times 10^{-11}, 1.190460799]$

ExpGenLotka(3, 50);

The Equilibrium points are

$\{[-10.07604563, 3.041825095, 0.], [-1.360544218, 0., 1.870748299], [-0.2173646828, 0.3926340926, 0.4951934852], [0., -0.8522727273, 1.014610390], [0., 0., 0.], [0., 0., 0.5102040816], [0., 1.515151515, 0.], [2.380952381, 0., 0.]\}$

The stable Equilibrium points are
$\{[-1.360544218, 0., 1.870748299], [0., 1.515151515, 0.]\}$
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5], the ultimate behavior is
$[3.213217917 \times 10^{-22}, 1.515151413, 1.326396896 \times 10^{-10}]$

and with initial conditions, [0.1, 0.1, 0.1]

$[1.745127132 \times 10^{-20}, 1.515151413, 3.808195337 \times 10^{-10}]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$[6.499788911 \times 10^{-22}, 1.515151413, 4.597429474 \times 10^{-10}]$

ExpGenLotka(3, 50);

The Equilibrium points are

$\{[-0.1667284179, 0., 1.130048166], [0., -0.9391771020, 1.319320215], [0., 0., 0.], [0., 0., 1.], [0., 0.6578947368, 0.], [0.08196721311, 0.6147540984, 0.], [0.4092405552, -0.6485357774, 0.9012945313], [0.5000000000, 0., 0.]\}$

The stable Equilibrium points are
$\{[0., 0., 1.]\}$
at time t=, 50, *with initial conditions,* [0.5, 0.5, 0.5], *the ultimate behavior is*

$\left[0.00004608033477, 8.328159460 \times 10^{-7}, 0.9999559754\right]$

and with initial conditions, [0.1, 0.1, 0.1]

$\left[0.00009453898335, 7.186145671 \times 10^{-7}, 0.9999101640\right]$

and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$\left[0.00002507449630, 6.352220998 \times 10^{-5}, 0.9999759542\right]$

ExpGenLotka(3, 50);

The Equilibrium points are

$\{[-0.5943536404, 1.560178306, 0.], [-0.1869060594, 0.7442780933, 0.2705596665], [0., 0., 0.], [0., 0., 1.086956522], [0., 0.7246376812, 0.], [0., 1.465201465, -0.8241758242], [0.7936507936, 0., 0.4313319531], [3.846153846, 0., 0.]\}$

The stable Equilibrium points are
$\{[-0.5943536404, 1.560178306, 0.], [0., 0., 1.086956522], [3.846153846, 0., 0.]\}$
at time t=, 50, *with initial conditions,* [0.5, 0.5, 0.5], *the ultimate behavior is*

$\left[1.567945019 \times 10^{-13}, 0.03416802557, 1.039914366\right]$

and with initial conditions, [0.1, 0.1, 0.1]

$\left[7.917811303 \times 10^{-18}, 0.01251869442, 1.069728425\right]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$\left[8.906618458 \times 10^{-13}, 0.09594490233, 0.9546785552\right]$

> *ExpGenLotka*(3, 50);

The Equilibrium points are

$\{[0., 0., 0.], [0., 0., 0.9090909091], [0., 0.1611374408, 0.6161137441], [0., 1.428571429, 0.], [0.2152176564, 0.005487135715, 0.5273747104], [0.2187500000, 0., 0.5312500000], [0.6336939722, 0.4327666151, 0.], [1.851851852, 0., 0.]\}$

The stable Equilibrium points are
$\{[0., 0., 0.9090909091], [0., 1.428571429, 0.], [1.851851852, 0., 0.]\}$
at time t=, 50, *with initial conditions,* [0.5, 0.5, 0.5], *the ultimate behavior is*

$\left[8.762401328 \times 10^{-20}, 1.428571365, 5.362429701 \times 10^{-10}\right]$

and with initial conditions, [0.1, 0.1, 0.1]

$\left[4.847190098 \times 10^{-19}, 1.428571365, 1.772378037 \times 10^{-10}\right]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$\left[7.311639811 \times 10^{-18}, 1.428571151, 5.068568484 \times 10^{-8}\right]$

> *ExpGenLotka*(3, 50);

The Equilibrium points are

$\{[-0.3253796095, 0., 2.422270427], [0., 0., 0.], [0., 0., 2.083333333], [0., 0.3972602740, 0.5273972603], [0., 2.941176471, 0.], [0.05065130858, 0.3921951431, 0.4944739097], [0.5434782609, 0., 0.], [1.137270551, -0.7382282522, 0.]\}$

The stable Equilibrium points are
$\{[0., 0., 2.083333333], [0., 2.941176471, 0.]\}$
at time t=, 50, *with initial conditions,* [0.5, 0.5, 0.5], *the ultimate behavior is*

$\left[4.504041613 \times 10^{-6}, 1.149774671 \times 10^{-44}, 2.083326705\right]$

and with initial conditions, [0.1, 0.1, 0.1]

$\left[1.762291592 \times 10^{-42}, 2.941176420, 6.988269436 \times 10^{-73}\right]$
and with initial conditions, $\left[\frac{1}{3}, \frac{2}{3}, 1\right]$

$\left[1.559787299 \times 10^{-6}, 7.299556138 \times 10^{-49}, 2.083331033\right]$

> |

- # cases where all species survived - 0
- # times there was agreement w/ positive stable equ pts = 0
- # times there was agreement between 3 initial conditions = 2

> *ExpGenLotka*(4, 50);

The Equilibrium points are

{[−0.5044625534, 0., 0., 1.416375631], [−0.4756292265, 0.02507711212, 0., 1.353746103], [0., −0.3833865815, 0., 1.118210863], [0., 0., 0., 0.], [0., 0., 0., 0.7462686567], [0., 0., 1.315789474, 0.], [0., 0., 2.035830619, −0.6514657980], [0., 0.2071325648, 2.210914986, −0.9726224784], [0., 0.9615384615, 0.4807692308, 0.], [0., 1.666666667, 0., 0.], [0.2127802165, −0.2155726078, 1.027041517, 0.], [0.2139343239, −0.2653956437, 1.129625715, −0.05600329675], [0.263324048, 0., 0.7267748051, 0.], [0.3446998987, 0., 0.9371698668, −0.3550463412], [0.6797583082, 0.4657603223, 0., 0.], [3.125000000, 0., 0., 0.]}

The stable Equilibrium points are
{[0., 0., 1.315789474, 0.], [0., 0., 1.666666667, 0.], [3.125000000, 0., 0., 0.]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], the ultimate behavior is

$\left[1.414585828 \times 10^{-20}, 0.9052415732, 0.5194185449, 4.678202092 \times 10^{-7} \right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[3.679242274 \times 10^{-28}, 1.524089485, 0.09690621852, 5.991695141 \times 10^{-11} \right]$
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1 \right]$

$\left[1.876725201 \times 10^{-13}, 0.4099195696, 0.8617989046, 0.001053561473 \right]$ (2)

> *ExpGenLotka*(4, 50);
The Equilibrium points are

{[−2.858844550, 1.893488187, 0., 2.109390510], [−2.221866688, 1.484410935, 1.020938744, 0.], [−1.578450716, 0.9708043808, −1.791484373, 4.896914586], [−0.7931034483, 0., −7.241379310, 14.65517241], [0., −4.166666667, 0., 8.333333333], [0., −3.826530612, 4.336734694, 0.], [0., −2.083333333, −2.083333333, 8.333333333], [0., 0., −22.22222222, 38.88888889], [0., 0., 0., 0.], [0., 0., 1.282051282], [0., 0., 1.315789474, 0.], [0., 0.5102040816, 0., 0.], [0.3481012658, 0., 0.7911392405], [1.666666667, 0., 0., 0.], [2.676240209, −1.892950392, 0., 0.], [11.77777778, 0., −3.333333333, 0.]}

The stable Equilibrium points are
{[0., 0., 1.315789474, 0.], [11.77777778, 0., −3.333333333, 0.]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], the ultimate behavior is
$\left[2.307322184 \times 10^{-16}, 4.858824557 \times 10^{-15}, 1.312710791, 0.003523227801 \right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[1.959150851 \times 10^{-14}, 8.072782350 \times 10^{-14}, 1.314034799, 0.002007756769 \right]$
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1 \right]$

$\left[2.595810943 \times 10^{-17}, 2.398215401 \times 10^{-15}, 1.310729073, 0.005789572201 \right]$ (3)

> *ExpGenLotka*(4, 50);

The Equilibrium points are

[−3.045011873, 1.464209635, 2.479451190, −0.3126608685], [−2.077027651, 1.135343457, 1.721451290, 0.], [0., −23.64864865, 21.62162162, 0.], [0., −0.5829557766, 1.000320102, 0.6414360288], [0., 0., 0., 0.], [0., 0., 0., 3.571428571], [0., 0., 0.8942457232, 0.5054432348], [0., 0., 2.272727273, 0.], [0., 0.2403846154, 0., 3.365384615], [0., 0.6097560976, 0., 0.], [0.09861932939, 0.4930966469, 0., 0.], [0.1998957066, 0.02607335303, 0., 3.163566835], [0.5154639175, 0., 0., 2.577319588], [1.242690058, 0., 2.046783626, 0.], [1.257056831, 0., 0.1298456906, 0.7019194580], [1.562500000, 0., 0., 0.]}

The stable Equilibrium points are
{[0., 0.2403846154, 0., 3.365384615], [0.5154639175, 0., 0., 2.577319588], [1.242690058, 0., 2.046783626, 0.]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], the ultimate behavior is
[1.265165565, 0.00001022126680, 1.963570147, 0.006738877078]

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[1.242691056, 5.533931855 \times 10^{-10}, 2.046782480, 2.617927092 \times 10^{-8} \right]$
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1 \right]$

$\left[0.0001181265093, 0.2552530434, 4.647815736 \times 10^{-28}, 3.349250636 \right]$ (4)

> *ExpGenLotka*(4, 50);
The Equilibrium points are

[−6.707317073, 0., 4.268292683, 0.], [−2.836833181, 0., 1.878179210, 0.5347593583], [−1.011286046, 0.5865928342, 1.136816913, 0.], [−0.5078775043, 3.911737373, 3.013766722, −4.391519526], [−0.2123896874, −0.9362484179, 0., 1.558680236], [0., −0.4359197908, 0., 1.002615519], [0., 0., 0., 0.], [0., 0., 0., 0.5617977528], [0., 0., 1.724137931, 0.], [0., 0., 2.094522019, −0.2148227712], [0., 0.7462686567, 0., 0.], [0., 1.996672213, −1.580698835, 0.], [0., 6.218716821, 3.617473078, −7.068102533], [0.8833922261, 0., 0., 0.3533568905], [1.282051282, 0., 0., 0.], [1.350048216, −0.2410800386, 0., 0.]}

The stable Equilibrium points are
{[0., 0., 1.724137931, 0.]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], the ultimate behavior is
$\left[3.923202202 \times 10^{-13}, 2.365266167 \times 10^{-10}, 1.583092687, 0.03916867663 \right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[0.0001093168990, 1.592039810 \times 10^{-6}, 1.126505859, 0.1842244700 \right]$
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1 \right]$

$\left[4.691065079 \times 10^{-16}, 6.418315809 \times 10^{-12}, 1.635957352, 0.02363032341 \right]$ (5)

> *ExpGenLotka*(4, 50);
The Equilibrium points are

{[−50., 0., 50., 0.], [0., −0.6503744580, 0., 0.9262908948], [0., −0.6176890391, −0.3412465342, 1.127918232], [0., 0., −0.1925254813, 0.6568516421], [0., 0., 0., 0.], [0., 0., 0., 0.5319148936], [0., 0., 16.66666667, 0.], [0., 0.8034026465, 1.134215501, 0.], [0., 5., 0., 0.], [0.07096551460, 0., −0.2167325175, 0.6559515133], [0.2643948296, 0., 0., 0.4700352526], [0.3760373444, 0.8169087137, 0.6224066390, 0.], [0.6214745670, 0.1722158439, 0., 0.2820346428], [0.6250000000, 1.875000000, 0., 0.], [0.7638715681, 0.3949831171, −0.3579894741, 0.3459377207], [1.315789474, 0., 0., 0.]}

The stable Equilibrium points are
{[0., −0.6176890391, −0.3412465342, 1.127918232], [0., 0., 16.66666667, 0.], [0., 5., 0., 0.]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], the ultimate behavior is
$\left[1.111804961 \times 10^{-165}, 2.540015156 \times 10^{-86}, 16.66666607, 7.505675392 \times 10^{-120} \right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[2.819128146 \times 10^{-180}, 2.618587036 \times 10^{-94}, 16.66666607, 4.368871484 \times 10^{-130} \right]$
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1 \right]$

$\left[0.07977229223, 4.301122253, 1.242937167 \times 10^{-29}, 7.051478025 \times 10^{-15} \right]$ (6)

> *ExpGenLotka*(4, 50);
The Equilibrium points are

{[−0.4629629630, 4.282407407, 0., 0.], [0., −138.4615385, 119.2307692, 0.], [0., −2.083333333, 0., 2.083333333], [0., −0.9193716984, 0.1196130291, 1.560932491], [0., 0., 0., 0.], [0., 0., 1.724137931], [0., 0., 0.5494505494, 0.], [0., 0.7243877199, −0.2242152466], [0., 3.125000000, 0., 0.], [0.1084982867, 0., 0.5017629509, 0.], [0.2674954930, 0., 0.3400763269, 0.1176511906], [0.3967917162, 0.6821846885, 0., 0.5803344084], [0.6405933918, 0., 0.06743088334], [0.6493506494, 0., 0., 0.], [1.016344882, 0.3998738055, −0.4727551183, 0.2982642766], [1.258222897, 0.9108439667, −0.7843378602, 0.]}

The stable Equilibrium points are
{[0., −138.4615385, 119.2307692, 0.], [0.3967917162, 0.6821846885, 0., 0.5803344084]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], the ultimate behavior is
$\left[0.4057094375, 0.6569651593, 9.108602624 \times 10^{-14}, 0.5696397557 \right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[0.4412275469, 0.5113572135, 4.099044568 \times 10^{-15}, 0.5754393742 \right]$
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1 \right]$

$\left[0.3696917323, 0.7805416054, 8.073775744 \times 10^{-12}, 0.5878062120 \right]$ (7)

> *ExpGenLotka*(4, 50);

The Equilibrium points are

{[−1.256281407, 0., 0., 1.356783920], [−0.8191049388, 0., 1.260842278, 0.4811638049], [0., −0.6723716381, 0., 1.079869601], [0., −0.5081292361, −0.2939831178, 1.181338101], [0., 0., −0.08375209380, 0.8793969849], [0., 0., 0., 0.], [0., 0., 0.8333333333], [0., 0., 0.6666666667, 0.], [0., 0.009790483650, 0.6657528882, 0.], [0., 0.6666666667, 0., 0.], [0.1352296263, −0.4322366762, −0.4845686647, 1.201987203], [0.3863119348, 0.2524551961, 0.1692282084, 0.], [0.9615384615, 0., 0., 0.], [1.709401709, −0.4273504274, 0., 0.], [6.356837607, −2.110042735, 0., −1.041666667], [13.28125000, 0., −15.62500000, 0.]}

The stable Equilibrium points are
{[0., 0., 0., 0.8333333333], [6.356837607, −2.110042735, 0., −1.041666667]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

$\left[8.231414142 \times 10^{-8}, 3.584472476 \times 10^{-13}, 0.003505034505, 0.8312495747\right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[1.322833831 \times 10^{-7}, 1.257653608 \times 10^{-12}, 0.004463497440, 0.8306771989\right]$

and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1\right]$

$\left[2.531265944 \times 10^{-8}, 1.089477809 \times 10^{-13}, 0.004023095570, 0.8309403926\right]$

> *ExpGenLotka*(4, 50);

The Equilibrium points are

{[−6.396148556, 9.697386520, 0., −7.565337001], [−1.087278950, 1.707929264, 0.2304620650, −0.8077581289], [−0.5694423902, 0.7617216388, 0.3697677858, 0.], [−0.1831501832, 0.7326007326, 0., 0.], [−0.1300390117, 0., 0.4765547311, 0.6463703817], [0., −0.2255690270, 0.5157946933, 0.8113679011], [0., 0., 0., 0.], [0., 0., 0., 1.470588235], [0., 0., 0.6250000000, 0.], [0., 0., 0.7189542484, −0.3267973856], [0., 0.3359592215, 0.4402224282, 0.], [0., 0.4182156134, 0., 0.3020446097], [0., 0.6097560976, 0., 0.], [0.3000923361, 0., 0., 0.6232686981], [3.333333333, 0., 0., 0.], [3.608247423, 0., −0.4123711340, 0.]}

The stable Equilibrium points are
{[−1.087278950, 1.707929264, 0.2304620650, −0.8077581289], [−0.1300390117, 0., 0.4765547311, 0.6463703817], [3.333333333, 0., 0., 0.]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

$\left[3.333333006, 1.543919566 \times 10^{-32}, 4.206374054 \times 10^{-8}, 2.715970445 \times 10^{-35}\right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

$\left[3.333331359, 4.787076447 \times 10^{-29}, 2.692139426 \times 10^{-7}, 9.132737852 \times 10^{-50}\right]$

and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1\right]$

$\left[3.333331373, 3.739572829 \times 10^{-29}, 2.678013089 \times 10^{-7}, 1.391725983 \times 10^{-49}\right]$

> *ExpGenLotka*(4, 50);

The Equilibrium points are

{[−5.178571429, 0., 0., 7.500000000], [−0.2311991463, −0.8587969120, 1.043112095, 0.7111588959], [0., −0.3274670139, 0.6204638159, 0.4663053678], [0., 0., 0., 0.], [0., 0., 0.9090909091], [0., 0., 0.6097560976, 0.], [0., 1.063829787, 0., 0.], [0., 1.192052980, 0., −0.06622516556], [0., 2.625437573, −1.983663944, 0.], [0.6785214536, −0.3657573532, 0.7890106541, 0.], [0.9314985123, 0., 2.353259400, −2.972004328], [1.444444444, 0., 0.2222222222, 0.], [1.770428016, −2.665369650, 0., 0.8365758755], [1.785714286, 0., 0., 0.], [2.246543779, −1.612903226, 0., 0.]}

The stable Equilibrium points are
{[−5.178571429, 0., 0., 7.500000000], [1.444444444, 0., 0.2222222222, 0.]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

$\left[1.368022132, 6.523209556 \times 10^{-7}, 0.2466909006, 0.00004974868319\right]$

and with initial conditions, [0.1, 0.1, 0.1, 0.1]

[1.272724838, 0.0006333214482, 0.2726459119, 0.001050995617]
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1\right]$

$\left[1.260625586, 3.489063843 \times 10^{-6}, 0.2777152700, 0.001211678801\right]$

(10)

> *ExpGenLotka*(4, 50);

The Equilibrium points are

{[−0.3360961235, 0., 0.4244713988, 0.4856889070], [−0.06429096253, 0., 0., 0.6612784717], [−0.01793721973, 0., 0.6188340807, 0.], [0., −2.500000000, 0., 3.750000000], [0., −2.238781844, 1.795874822, 2.623496702], [0., 0., 0., 0.], [0., 0., 0.6578947368], [0., 0., 0.3981216823, 0.4797876684], [0., 0., 0.6172839506, 0.], [0., 0.8196721311, 0., 0.], [0., 1.003224651, −0.4478681476, 0.], [0.2437592832, 0.2433999329, 0., 0.3440180154], [0.2496157168, 0.3340386273, 0.1699994779, 0.1555516306], [0.3506319568, 0.3332424845, 0.2331694153, 0.], [0.6413612565, 0.1047120419, 0., 0.], [0.6578947368, 0., 0., 0.]}

The stable Equilibrium points are
{[0., −2.238781844, 1.795874822, 2.623496702], [0.2496157168, 0.3340386273, 0.1699994779, 0.1555516306]}
at time t=, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*
[0.2562740946, 0.4338734324, 0.1032287819, 0.08692505903]

and with initial conditions, [0.1, 0.1, 0.1, 0.1]
[0.3279452003, 0.2912329466, 0.1654058591, 0.1338659866]
and with initial conditions, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1\right]$

[0.3509488616, 0.3719697803, 0.09260953566, 0.06862130035]

} survived

(11)

>

- # cases where all species survived - 1
- # times there was agreement w/ positive stable equ pts = 0
- # times there was agreement between 3 initial conditions = 1

4.

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−30.43478261, 0., 0., 23.55072464, 0.], [−6.578390805, −1.378390805, 2.221379310, 5.539310345, 0.], [−4.528366193, −1.095700443, 2.096079322, 3.990244461, −0.4990053142], [−1.960751734, 0., 0.5019816335, 1.831767613, 0.2324498406], [−1.491748765, 0., 0.5986418871, 1.496410480, 0.], [−1.232169954, 0., 0., 1.145675266, 1.614567527], [−1.176803236, 0.2389121742, 0., 1.150098222, 0.8170431605], [−1.527016246, 0., 0.6484102262, 0., 0.04065267876], [−1.242750621, 0., 0.6628003314, 0., 0.], [−0.09287925697, 0., 0., 1.733746130], [−0.06727719283, 0.2141448963, 0.3031356007, 0., 0.2277798581], [−0.002102448091, 0.3628825404, 0., 0., 0.5230890849], [0., −13.91982183, 3.034521158, 6.726057906, 0.], [0., −1.486822580, 1.911067302, 1.033452099, −1.480354458], [0., 0., 0., 0., 1.562500000], [0., 0., 0., 0.3819036428, 0.8225616921], [0., 0., 0., 0.5555555556, 0.], [0., 0., 0.2049180328, 0.4918032787, 0.], [0., 0., 0.2304451568, 0.4895440069, −0.02691710573], [0., 0., 0.5574406205, 0., 0.01211827436], [0., 0., 0.9741269694, 0., 0.3977002963, 0.5118941722], [0., 0.1392165937, 0.3660599807, 0., 0.1441479717], [0., 0.1872659176, 0.4681647940, 0., 0.], [0., 0.3617363344, 0., 0., 0.5225080386], [0., 1.851851852, 0., 0., 0.], [0., 2.317880795, 0., −0.6291390728, 0.], [0.02549959066, 0.1483002510, 0.4695615412, 0., 0.], [1.022222222, 0.4888888889, 0., 0., 0.], [1.439304073, 0.5258995650, 0., −0.8007117438, 0.], [16.66666667, 0., 0., 0.]}

The stable Equilibrium points are
{[−1.232169954, 0., 0., 1.145675266, 1.614567527], [0., 1.851851852, 0., 0., 0.], [16.66666667, 0., 0., 0., 0.]}
at time t=, 50, *with initial conditions*, [0.5, 0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

[16.66666598, 4.257236015 × 10⁻¹²³, 1.133632193 × 10⁻⁴⁹, 7.282079148 × 10⁻¹⁵³, 9.905505656 × 10⁻⁵⁶]

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

[4.776934081 × 10⁻²⁶, 1.841715511, 0.002408007943, 7.670225693 × 10⁻⁶, 3.837254274 × 10⁻⁸]
and with initial conditions, [$\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{4}{5}$, 1]

[16.66666598, 1.420538390 × 10⁻¹¹⁴, 4.690985485 × 10⁻⁴⁶, 8.675375780 × 10⁻¹⁴¹, 3.585536792 × 10⁻⁵¹]   (2)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[0., 0., −0.9459459459, 0., 1.621621622], [0., 0., 0., −26.66666667, 14.44444444], [0., 0., 0., 0., 0.], [0., 0., 0., 0.6172839506], [0., 0., 0., 3.125000000, 0.], [0., 0., 0.3476033663, 1.408708379, 0.], [0., 0., 0.7483525075, 2.943147548, −1.703339663], [0., 0., 25., 0., 0.], [0., 0.4193244136, 0.2967780314, 0.1295972216, 0.1573350591], [0., 0.4641665644, 0.3323179690, 0.1497011556, 0.], [0., 0.5150554675, 0.5348652932, 0., 0.], [0., 0.5443338075, 0.5704125178, 0., −0.08914177335], [0., 0.7439031419, 0.03945612807, 0.4590653775], [0., 0.8226037196, 0., 0.4649499285], [0., 1.060968320, 0., 0.07471607890, 0.], [0., 1.219512195, 0., 0., 0.], [0.1448376828, 0.5091895515, 0.4817936949, 0., −0.006425652594], [0.1458112407, 0.5070254507, 0.4788573701, 0., 0.], [0.1958224543, 1.109660574, 0., 0., 0.], [0.2434902174, 0.6908438130, 0., 0.4592893905], [0.3759398496, 0., 0., 0.3759398496, 0.3759398496], [0.4451256516, 0.3670363656, −0.1276877519, 0.3633190532, 0.], [0.4551413843, 0.1169512231, 0., 0.3992729656, 0.], [0.4947195092, −0.2374077793, 0., 0.3972174168, 0.3942072851], [0.5030893471, 0.1383839277, −0.3587846946, 0.2942956212, 0.7578816699], [0.5170316302, 0., 0., 0.4105839416, 0.], [0.6311682350, 0., 0., 0.5393619463], [0.7938345092, 0., −0.7634683348, 0.2285985811, 1.211343102], [0.8771929825, 0., 0., 0.9983640253, 0., −0.8819581358, 0., 1.430429129], [12.90322581, 0., −13.70967742, 0., 0.], [60.12216405, 0., −62.21640489, −5.322862129, 0.]}

The stable Equilibrium points are
{[0., 0., 0., 3.125000000, 0.], [0., 0., 25., 0., 0.], [0.2434902174, 0.6908438130, 0., 0., 0.4592893905]}
at time t=, 50, *with initial conditions*, [0.5, 0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

[1.869743777 × 10⁻³⁴⁵, 7.739103963 × 10⁻¹³², 24.99999922, 2.051901662 × 10⁻³⁸⁰, 1.546738906 × 10⁻⁵²²]

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

[1.089560128 × 10⁻³⁶², 1.051970879 × 10⁻¹³⁸, 24.99999922, 1.445108214 × 10⁻⁴⁰⁵, 1.195020186 × 10⁻⁵⁴⁸]
and with initial conditions, [$\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{4}{5}$, 1]

[1.479480643 × 10⁻³⁷⁵, 1.417477576 × 10⁻¹⁴², 24.99999922, 1.584067203 × 10⁻⁴¹⁶, 1.967788778 × 10⁻⁵⁶⁴]   (3)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−3.474903475, 0., 3.523166023, 0., 0.], [−1.530612245, 0., 0., 0., 8.928571429], [−0.3949855553, 1.014010145, 0.7438781367, −0.5488725351, 0.4247001406], [−0.2812751138, 0., 2.782614519, 0., −2.996919368], [−0.2656339002, 1.611502156, 0., −0.8746389047, 0.5256352226], [−0.1670592058, 0.2217202208, 1.621018541, 0., −1.486988628], [0., 0., −0.7017767422, 1.119566009, 0.7136095536], [0., 0., 0., 0., 0.], [0., 0., 0., 2.500000000], [0., 0., 0.6439894320, 0.5036372609], [0., 0., 0., 50., 0.], [0., 0., 0.5000000000, 0., 0.], [0., 0., 1.730769231, −1.923076923, 0.], [0., 0., 1.898734177, 0., −2.056962025], [0., 0.09359400098, 1.559900166, 0., −1.580698835], [0., 0.6048387097, 0.4032258065, 0., 0.], [0., 0.7343499197, 1.504815409, −1.753611557, 0.], [0., 0.7366754334, 0.5595512855, −0.5716279319, 0.2770919435], [0., 0.9259259259, 0., 0., 0.], [0., 1.300156915, 0., −0.8322125084, 0.3992938803], [0., 4.166666667, 0., 0., −12.50000000], [0., 6.666666667, 0., −10., 0.], [0.1711614439, 0., 0., 0.4435473976, 0.4061250031], [0.2208723443, 0.4755121397, 0.2317591181, 0., 0.], [0.3250157266, 0.5347032921, 0., 0., 0.], [0.3462460605, 0., −0.4471032217, 0.5415017438, 0.4401588720], [0.8705592684, 0., 0., 0.3781217024, 0.], [1.008999814, 0., −0.9658563741, 0., 1.179717944, 0.], [1.502734568, 0., −1.209471317, 0.6282691292, 0.], [1.754176611, 1.145584726, 0., 0., −8.991646778], [2.031327566, −0.6855531725, −2.032773454, 1.367510904, 0.], [3.571428571, 0., 0., 0.]}

The stable Equilibrium points are
{[0., 0., 0., 50., 0.], [3.571428571, 0., 0., 0., 0.]}
at time t=, 50, *with initial conditions*, [0.5, 0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

[3.32426145 × 10⁻³⁹⁸⁰, 0.00002478786387, 1.374991439 × 10⁻⁶⁵, 49.99895894, 4.096865645 × 10⁻¹¹⁸⁰]

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

[3.391112284, 0.02859025538, 2.622055672 × 10⁻⁷, 5.335547191 × 10⁻¹⁹, 1.546047463 × 10⁻⁷⁵]
and with initial conditions, [$\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{4}{5}$, 1]

[5.3955145 × 10⁻⁴¹³⁹, 0.00001466570880, 1.372037458 × 10⁻⁶⁷, 49.99937240, 1.774709446 × 10⁻¹²¹⁸]   (4)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−0.9064688916, 1.524515863, 1.297898640, 0., 0.], [−0.02146576326, 0.3720529944, −1.431071120, 0.6803411426, 1.921138292], [0., 0., −5.113636364, 7.765151515, 0.], [0., 0., −3.181060680, 0.7548279580, 5.001960592], [0., 0., 0., 0., 0.], [0., 0., 0., 0., 3.125000000], [0., 0., 0., 0.5140186916, 0.7476635514], [0., 0., 0., 1.190476190, 0.], [0., 0., 3.846153846, 0., 0.], [0., 0.3833313299, −1.159975272, 0.6390882760, 1.559975272], [0., 0.4094631483, 0., 0.5080376099, 0.], [0., 0.4302944459, 0., 0.5558417032, −0.09120954588], [0., 0.5253940455, 0.6129597198, 0., 0.], [0., 0.5340857036, −0.4403864573, 0.8665445106, 0.], [0., 1.074938575, 4.299754300, 0., −5.743243243], [0., 1.488095238, 0., 0.8928571429], [0., 16.66666667, 0., 0., 0.], [0.1376581262, 0., 0.3740448212, 0.8444101971], [0.1805712089, 0.3270074564, 0.3987925373, 0.06394164898, 0.], [0.2322202661, 0.4335687337, 0., 0.3200331764, 0.06561239405], [0.250000728, 0.4515469909, 0., 0.3426594827, 0.], [0.3718020804, 0., 0.3450941805, 0.6051447849, 0.], [0.4889006342, 0., 1.004228330, 0.], [0.4938271605, 0., 0.1234567901, 0., 0.], [0.5133701907, 0., 1.246756177, 0., −1.032381812], [0.5434782609, 0., 0., 0., 0.], [0.6049708211, 0., 2.783266868, −0.3118326819, −2.549588720], [0.8148831488, −0.4458794588, 0., 0., 0.], [1.069078947, 0., 0., −1.151315789], [1.132039574, −0.6835725158, 0., 0., −0.3777995216], [1.137710588, −0.6934246796, −0.01068728990, 0., −0.3676705317]}

The stable Equilibrium points are
{[0., 0., 3.846153846, 0., 0.], [0., 16.66666667, 0., 0., 0.], [0.4889006342, 0., 0., 1.004228330, 0.]}
at time t=, 50, *with initial conditions*, [0.5, 0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

[0.0008688864704, 4.244066250 × 10⁻²⁹, 3.818424622, 1.453698356 × 10⁻¹⁵, 0.007563235670]

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

[3.120938678 × 10⁻⁶, 2.029128674 × 10⁻⁴⁵, 3.845769491, 2.830824185 × 10⁻²⁹, 0.0001793847265]
and with initial conditions, [$\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{4}{5}$, 1]

[7.095359351 × 10⁻⁷, 1.317073093 × 10⁻⁴⁹, 3.844828964, 4.505901542 × 10⁻³², 0.0007034398503]   (5)

> ExpGenLotka(5, 50);

The Equilibrium points are

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−1.808375635, 1.572697607, 0., 0., 2.234408992], [0., −0.1718213058, 0., 0.6248047485, 0.], [0., 0., −1.909722222, 0., 5.034722222], [0., 0., −0.9879587523, 0.4723627746, 2.991097163], [0., 0., 0., 0., 0.], [0., 0., 0., 0., 3.125000000], [0., 0., 0., 0.2491694352, 2.533222591], [0., 0., 0., 0.5050505050, 0.], [0., 0., 0.9531590414, 0.2450980392, 0.], [0., 0., 1.111111111, 0., 0.], [0., 0.3936585293, 0., 0.1922747167, 0.3800517792], [0., 0.4238164151, 0., 0.6615670870], [0., 0.4868614112, 1.361377884, 0., −1.066259837], [0., 0.4965422913, 1.230261962, −0.100529393, −0.7526720624], [0., 0.7497827659, 0.6340113118, −0.1904375380, 0.], [0., 1.039168665, 0.2797761791, 0., 0.], [0., 1.724137931, 0., 0., 0.], [0., 1.957696897, 0., −0.5117755959, 0.4756793110, 1.613838023], [0.2270876096, 0.2870361320, 0., 0.2981135764, 0.], [0.2376103191, 0., 0.4978501924, 0.], [0.2608474576, 0.2004347826, 0., 0.3679587325, −0.1040456890], [0.2687140115, 0., 0.6333973129, 0., 0.], [0.3201024328, 0., 0., 1.664532650], [0.3236449332, 0.3613511390, 0.2466614297, 0., 0.], [0.3462189505, 0.2233988112, 0.4219235917, 0., −0.1750531433], [0.5521472393, 0.4294478528, 0., 0., 0.], [0.5545884079, 0.3797079981, −0.3914963508, 0.3303715593, 0.], [0.6883225138, 0., 0., 0.6390664073, −1.533254187], [0.7073769308, 0., −0.5557961600, 0.6351956114, 0.], [1.063829787, 0., 0., 0., 1.344262295, 0., 1.315573770, 0., −4.323770492], [1.570361371, −0.8507160423, −0.9687016769, 1.480479985, −1.642425046]}

The stable Equilibrium points are
{[0., 0., 0., 0.2491694352, 2.533222591], [0., 1.724137931, 0., 0., 0.], [0.7073769308, 0., −0.5557961600, 0.6351956114, 0.]}
at time t=, 50, *with initial conditions*, [0.5, 0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

[2.752663073 × 10⁻⁶, 2.731491985 × 10⁻¹⁹, 0.3562274546, 0.3082231456, 0.9737629331]

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

[7.930247786 × 10⁻⁸, 4.767223375 × 10⁻¹⁵, 0.8003860009, 0.2614313127, 0.2447297751]
and with initial conditions, [$\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{4}{5}$, 1]

[8.313105571 × 10⁻⁶, 3.918623749 × 10⁻²³, 0.03375344708, 0.3291229950, 1.656874864]   (6)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−2.287142280, −0.8131269903, 0.6502889405, 0., 2.200207601], [−1.883947833, −1.029613650, 0., 0., 2.494361640], [−0.02618478260, 0.2018821317, 0.3919887378, 0.2946626973, 0.], [0., −73.75000000, 0., 0., 30.], [0., −0.7773648833, 0., 0.3975627083, 0.6598721242], [0., −0.3665689150, 0.7697947214, 0., 0.], [0., 0., 0., 0., 0.], [0., 0., 1.219512195], [0., 0., 0.5376344086, 0.], [0., 0., 0.5889281508, −0.05889281508], [0., 0., 0.1623903865, 0., 1.120493667], [0., 0., 0.5166008823, 0.3598792663, 0.], [0., 0., 0.5319148936, 0., 0.], [0., 0., 0.5597033572, 0.4714168158, −0.1450897691], [0., 0.006366509523, 0.5573031819, 0.4734879957, −0.1506067150], [0., 0.2693879718, 0.3456924465, 0.2680609374, 0.], [0., 1.250000000, 0., 0., 5.399675626, −3.353799815, 0., 1.157321594], [0.1567027256, 0.4151065579, 0.2408655802, 0.], [0.2074361870, 0.2335204159, 0.4380419361, 0.5030146931, −0.3267553731], [0.3038117944, 0., 0.4763583402, 0.3181906732, 0.], [0.3672716381, 0.06773591842, 0., 0.4326248860, 0.], [0.3960128842, 0., 0.4955120091, 0.3867070345, −0.1055846608], [0.4060734463, 0.3972457627, 0., 0., 0.], [0.4463106474, 0.07222044578, 0., 0.4960490953, −0.09228777835], [0.4889975550, 0., 0.4482477588, 0.], [0.5086724483, 0., 0., 0.4628085390, −0.02084723149], [0.9305210918, 0., 0.4032258065, 0., 0.], [1.282051282, 0., 0., 0., 0.], [71.04545455, 0., 1.454545455, 0., −32.59090909], [137.5000000, 0., 0., 0., −62.50000000]}

The stable Equilibrium points are
{[0., 0., 0.1623903865, 0., 1.120493667], [0., 5.399675626, −3.353799815, 0., 1.157321594], [0.3960128842, 0., 0.4955120091, 0.3867070345, −0.1055846608]}
at time t=, 50, *with initial conditions*, [0.5, 0.5, 0.5, 0.5, 0.5], *the ultimate behavior is*

[2.085861368 × 10⁻¹⁴, 2.943654585 × 10⁻²⁹, 0.1819688398, 6.461313310 × 10⁻¹², 1.102635747]

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

[7.168986534 × 10⁻⁷, 2.688136522 × 10⁻¹⁷, 0.2390669729, 0.00001209577350, 1.023001230]
and with initial conditions, [$\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{4}{5}$, 1]

[1.139816992 × 10⁻¹⁷, 4.635952408 × 10⁻³³, 0.1743327269, 3.040866411 × 10⁻¹⁴, 1.109987381]   (7)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−6.800911601, 1.493568371, 0., 8.029706995, 2.479025849], [−1.281853692, −0.1193875901, 1.893633719, 1.825731254, −1.163000345], [−0.8234387477, 0., 1.401136236, 1.361388704, −0.8982870673], [−0.4329133576, 0., 0.7225174658, 0.9285245119, 0.], [−0.2479994709, 0.9579865277, 0., 0., 0.3608982777], [−0.1086999848, 0.1127393313, 0.4462891622, 0.6104955223, 0.], [−0.04612564060, 0.4272263842, 0.8338147728, 0., −0.5267637754], [0., −1.737451737, 0., 0., 1.544401544], [0., 0., −8.463949843, 0., 10.18808777], [0., 0., −0.9731982531, 0.9233190716, 1.137245339], [0., 0., 0., 0., 0.], [0., 0., 0., 0.6024096386], [0., 0., 0., 0.7137842265, 0.1638193307], [0., 0., 0., 0.7692307692, 0.], [0., 0., 1.724137931, 0., 0.], [0., 0., 6.611570248, −2.892561983, 0.], [0., 0.1494676546, 0.3981627882, 0.4797247690, 0.], [0., 0.3847609436, 0.3973760565, 0., 0.], [0., 0.4062057465, 1.848467925, 0.1732040461, −1.817694577], [0., 0.4359331805, 1.095149210, 0., −0.8742291425], [0., 1.260053619, 0., 0.1876675603, 0.], [0., 1.351351351, 0., 0., 0.], [0., 3.837321948, 0., −0.6332747300, −1.088945499], [0.2036353133, 0.3334089831, 0.3076193031, 0., 0.], [0.7246376812, 0., 0., 0.], [0.9269356598, 0., 0., −0.4362050164], [1.330798479, 0., 0., −0.9505703422, 0.], [1.446030529, −0.03710942332, 0., −1.082358180, 0.], [2.624074330, 0., 0., −2.311301228, −0.9176210846], [3.090052972, 0., −4.037134143, 0., 1.712237145], [3.633217993, −3.460207612, 0., 0., 0.], [24.50980392, 0., 0., −30.39215686, 0., 0.]}

The stable Equilibrium points are
{[0., 0., 1.724137931, 0., 0.], [0., 0., 1.260053619, 0., 0.1876675603, 0.]}
at time $t=$, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5, 0.5], the ultimate behavior is

$$[2.425513157 \times 10^{-8}, 1.258619657, 9.687552883 \times 10^{-22}, 0.1901260110, 3.961122935 \times 10^{-7}]$$

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

$$[9.953174417 \times 10^{-6}, 1.252366141, 1.347480296 \times 10^{-13}, 0.2006023533, 7.684066546 \times 10^{-7}]$$

and with initial conditions, $\left[\frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}, 1\right]$

$$[4.975752202 \times 10^{-8}, 1.257162849, 1.004778997 \times 10^{-19}, 0.1926086478, 6.075860655 \times 10^{-7}]$$

(8)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−4.074274383, −0.01352082207, 0., 2.505859023, 0.], [−3.985507246, 0., 0., 2.463768116, 0.], [−2.792703513, 2.612213062, −2.404215714, 0., 2.100509443], [−1.167547068, 2.975755113, −2.033048896, 0., 0.], [−0.9932299016, 1.200986158, −0.8856179514, 0.6523964598, 0.7261195043], [−0.5620155039, 0., 1.046511628, 0., 0.], [−0.3732694981, 0., 0.8434666823, 0.3074272063, 0.], [−0.2006226672, 0.8095770269, −0.3572973172, 0.8569579909, 0.], [−0.05261943822, 0.4957359397, 0., 1.128221587, −0.4478552925], [0., −0.2458709712, −11.62809343, 0., 13.03383398], [0., 0., −7.894736842, 0., 8.851674641], [0., 0., 0., 0., 0.], [0., 0., 0., 4.545454545], [0., 0., 0., 0.5882352941, 0.], [0., 0., 0., 68.46153846, −57.69230769], [0., 0., 0.5689313984, 0.2803430079, 0.], [0., 0., 0.6250000000, 0., 0.], [0., 0., 29.26053538, 26.14630268, −35.18420355], [0., 0.2072968491, 0., 0., 2.736318408], [0., 0.4526746668, 0.4835401027, 1.058911873, −0.6315570329], [0., 0.4566948838, 0., 1.165790813, −0.5000560891], [0., 0.8163359891, −0.5138176716, 0.8470934225, 0.], [0., 0.9498787389, 0., 0.5658852061, 0.], [0., 1.666666667, 0., 0., 0.], [0., 2.875536481, −2.789699571, 0., 0.], [0.3616636528, 0., 0., 2.079566004], [0.5947151450, 0., 0., 3.866324255, −3.024261675], [0.6121630549, 0., 0.7847316827, 0.8363700631, −0.8167563497], [0.7788826289, 0., 1.636326906, 0., −1.657650782], [1.234725051, −0.8974032587, 0., 3.958757637], [2.898550725, 0.6038647343, 0., 0., 0.], [8.333333333, 0., 0., 0.]}

The stable Equilibrium points are
{[0., 0., 0., 4.545454545], [0., 0., 29.26053538, 26.14630268, −35.18420355], [0., 0.9498787389, 0., 0.5658852061, 0.], [8.333333333, 0., 0., 0., 0.]}
at time $t=$, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5, 0.5], the ultimate behavior is

$$[0.0004460774143, 0.9628053222, 3.187412202 \times 10^{-19}, 0.5651784626, 0.00005637439567]$$

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

$$[8.183690977, 0.01334524793, 4.800455113 \times 10^{-93}, 1.254910225 \times 10^{-62}, 1.062510807 \times 10^{-27}]$$

and with initial conditions, $\left[\frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}, 1\right]$

$$[0.00006737444388, 1.010921031, 2.069424826 \times 10^{-21}, 0.5639022519, 0.0002230892811]$$

(9)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[0., 0., −0.2577718079, 0.4505570963, 0.3990993690], [0., 0., −0.1272074229, 0.6510026938, 0.], [0., 0., 0., 0., 0.], [0., 0., 0., 0., 0.6250000000], [0., 0., 0., 0.5779531999, 0.1409641951], [0., 0., 0., 0.6493506494, 0.], [0., 0., 0.05767012687, 0., 0.5911188005], [0., 0., 0.5681818182, 0., 0.], [0., 0.3102625298, 0.3460620525, 0., 0.], [0., 0.3181818182, 0., 0., 0.5454545455], [0., 0.3372869467, 0., 0.05875761799, 0.4914687583], [0., 0.3884337601, −0.2396738269, −0.1384258666, 0.7846315965], [0., 0.4969634925, 0.05731314350, 0.1451887590, 0.], [0., 0.5377950403, 0., 0.104571257 8, 0.], [0., 0.5674136589, −0.5182514646, 0., 0.7876193207], [0.2068014706, 0., 0.5284926471, 0.], [0.2094344837, 0., 0.3806672678, 0.1394218404, 0.1346827442, 0.], [0.2177324436, 0.3806672678, 0.1394218404, 0.1346827442, 0.], [0.2513285980, 0., 0.4168251390, 0.1690942919], [0.2760715947, 0., −0.03654610943, 0.3829004409, 0.2084612923], [0.2865836400, 0.4617180866, 0., 0.01415227852, 0.], [0.2969457014, 0.4595588235, 0., 0., 0.], [0.3230174886, 0.3009563221, −0.04437602619, 0., 0.4385494022], [0.3275360098, 0.2790760037, 0., 0., 0.4160281949], [0.3468118328, 0.2546811338, 0.03200663797, −0.02060937745, 0.4123911414], [0.3591461917, 0.1407180985, 0.4470344186, 0., 0.], [0.3693574002, 0.2565853847, 0., −0.05381306133, 0.4489451976], [0.4117572533, 0., 0.5447865197, 0., 0.], [0.4254696192, 0., 0.3256129321, 0., 0.2528778142], [0.4800590842, 0., 0., 0.4209748892], [0.5494505494, 0., 0., 0., 0.]}

The stable Equilibrium points are
{[0.3275360098, 0.2790760037, 0., 0., 0.4160281949]}

at time $t=$, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5, 0.5], the ultimate behavior is
[0.2154799200, 0.3389904462, 0.2244238491, 0.04907594846, 0.2700241110]

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

[0.2439807495, 0.1443315741, 0.07885314336, 0.2567546569, 0.2183838065]

and with initial conditions, $\left[\frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}, 1\right]$

[0.1754460548, 0.3086078622, 0.2321204835, 0.1401223215, 0.2064564254]

(handwritten annotations: "no agreement"; "all survived = agreement between I.C.")

(10)

> ExpGenLotka(5, 50);

The Equilibrium points are

{[−0.3597769383, 0., 0., −0.7910095741, 1.184265755], [−0.2177639337, 0.3575408934, 0., −0.04972913223, 0.7168062818], [−0.1897559586, 0.3799673201, 0.08256515040, −0.06926151321, 0.6452546513], [−0.1425201494, 0.3366424219, 0., 0., 0.6290544525], [−0.1032958850, 0., 1.108692205, −1.677646448, 0.6171886727], [−0.06563900260, 0.3556323794, 0.1102761578, 0., 0.4874535359], [0., 0., 0., 0.5376344086], [0., 0., 8.333333333, 0.], [0., 0., 0.4381161008, 0., 0.2738225630], [0., 0., 0.5208333333, 0., 0.], [0., 0., 1.248112286, −1.941014480, 0.5374433686], [0., 0., 3.104575163, −5.637254902, 0.], [0., 0.3462441315, 0., 0.4929577465], [0., 0.3617387179, 0.1237243454, 0., 0.4164577639], [0., 0.4595830045, 0., −0.2170481452, 0.5623520126], [0., 0.4727271463, 0.1166662963, −0.2142396827, 0.4893181745], [0., 0.5077030812, 0.1400560224, 0., 0.], [0., 0.5208333333, 0., 0., 0.], [0., 1.086418675, 0.122249388 8, −0.9081383165, 0.], [0., 1.169217687, 0., −1.020408163, 0.], [0.009406452827, 1.081322144, 0.1238516289, −0.9043632503, 0.], [0.2143501805, 0., 2.822277377, −5.045690433, 0.], [0.2587694077, 0.4336783592, 0.1820969906, 0., 0.], [0.2941176471, 0.4411764706, 0., 0., 0.], [0.3503709810, 0., 0., 0.2061005771], [0.4030957756, 0., 0.4998387617, 0., 0.], [0.5102040816, 0., 0., 0.], [1.051486846, 0., 0.7385614796, 0., −0.9020460782]}

The stable Equilibrium points are
{[0., 0., 0., 8.333333333, 0.], [0., 0.4727271463, 0.1166662963, −0.2142396827, 0.4893181745]}
at time $t=$, 50, with initial conditions, [0.5, 0.5, 0.5, 0.5, 0.5], the ultimate behavior is

$$[0.01824017979, 1.581970019 \times 10^{-30}, 3.337602564 \times 10^{-74}, 8.272871183, 7.203933757 \times 10^{-47}]$$

and with initial conditions, [0.1, 0.1, 0.1, 0.1, 0.1]

$$[0.01866365908, 3.067639236 \times 10^{-30}, 2.279682203 \times 10^{-72}, 8.271396782, 2.339506966 \times 10^{-46}]$$

and with initial conditions, $\left[\frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}, 1\right]$

$$[0.01741695508, 1.009910124 \times 10^{-31}, 4.807978031 \times 10^{-77}, 8.275727287, 2.630927754 \times 10^{-48}]$$

(handwritten annotation: "0 survive")

(11)

>

(handwritten notes at bottom:)

- # cases where all species survived = 1
- # times there was agreement w/ positive stable equ pts = 0
- # times there was agreement between 3 initial conditions = 0