

> read `DMB.txt`

For a list of the Main procedures type: *Help()*; for help with a specific procedure type: *Help(ProcedureName)*; for example *Help(Feig)*;

For a list of the Continuous Dynamical Models procedures type: *HelpC()*; for help with a specific procedure type: *Help(ProcedureName)*; for example *Help(Feig)*; (1)

> ExpGenLotka(2, 50);

The Equilibrium points are

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

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, $\left[\frac{1}{2}, 1\right]$

$[0.5188099176, 0.03150983934]$

(2)

> 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, $\left[\frac{1}{2}, 1\right]$

(3)

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

(3)

> 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, $\left[\frac{1}{2}, 1\right]$

$$[0.5092912292, 0.5992974787]$$

(4)

> ExpGenLotka(2, 50);

The Equilibrium points are

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

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, $\left[\frac{1}{2}, 1\right]$

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

(5)

> 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, $\left[\frac{1}{2}, 1\right]$

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

(6)

> *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, $\left[\frac{1}{2}, 1\right]$

$[2.499420252, 0.2455921211]$

(7)

> *ExpGenLotka*(2, 50);

The Equilibrium points are

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

The stable Equilibrium points are

$\{[1.250000000, 0.]\}$

at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is

$$[1.249999883, 2.412660284 \times 10^{-9}]$$

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

$$[1.249999878, 1.553914733 \times 10^{-8}]$$

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

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

(8)

> ExpGenLotka(2, 50);

The Equilibrium points are

$$\{[-1.574074074, 2.962962963], [0., 0.], [0., 1.388888889], [0.500000000, 0.]\}$$

The stable Equilibrium points are

$$\{[0., 1.388888889]\}$$

at time $t=$, 50, with initial conditions, $[0.5, 0.5]$, the ultimate behavior is

$$[3.300988967 \times 10^{-17}, 1.388888810]$$

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

$$[3.632411978 \times 10^{-16}, 1.388888810]$$

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

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

(9)

> 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

$$[6.440307627 \times 10^{-168}, 9.999999894]$$

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

$$[2.352550413 \times 10^{-154}, 9.999999894]$$

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

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

(10)

> 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

$$[1.249998775, 5.741105880 \times 10^{-7}]$$

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

$$[1.249999517, 2.204198505 \times 10^{-7}]$$

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

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

(11)

- 1) there were 3 cases where both species survived
 8 cases where the ultimate behavior matched a stable eq. point
 7 cases where all 3 initial conditions agree

```
> #prob 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, $[0.1, 0.1, 0.1]$

$$[2.173837281, 1.202560617 \times 10^{-28}, 0.00002509691146]$$

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

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

(12)

> *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]

$$[1.297471798, 3.887689892 \times 10^{-6}, 2.412369628 \times 10^{-9}]$$

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

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

(13)

> *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]

$$[0.01615395280, 0.9701603897, 0.0001396370501]$$

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

$$[0.01107189505, 0.9735219694, 0.00003587365085]$$

(14)

> 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

$$[5.570115013 \times 10^{-64}, 5.555555208, 8.028999371 \times 10^{-86}]$$

$$\text{and with initial conditions, } [0.1, 0.1, 0.1]$$

$$[1.668081084 \times 10^{-44}, 5.555501899, 4.886069652 \times 10^{-60}]$$

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

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

(15)

> 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

$$[4.490317784 \times 10^{-19}, 2.270247180 \times 10^{-9}, 1.190379535]$$

$$\text{and with initial conditions, } [0.1, 0.1, 0.1]$$

$$[2.686779155 \times 10^{-14}, 1.048175637 \times 10^{-6}, 1.188986057]$$

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

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

(16)

> *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

$$[3.213217917 \times 10^{-22}, 1.515151413, 1.326396896 \times 10^{-10}]$$

$$\text{and with initial conditions, } [0.1, 0.1, 0.1]$$

$$[1.745127132 \times 10^{-20}, 1.515151413, 3.808195337 \times 10^{-10}]$$

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

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

(17)

> *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

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

$$\text{and with initial conditions, } [0.1, 0.1, 0.1]$$

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

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

$$[0.00002507449630, 6.352220998 \times 10^{-7}, 0.9999759542]$$

(18)

> 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

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

$$\text{and with initial conditions, } [0.1, 0.1, 0.1]$$

$$[7.917811303 \times 10^{-18}, 0.01251869442, 1.069728425]$$

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

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

(19)

> 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

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

$$\text{and with initial conditions, } [0.1, 0.1, 0.1]$$

$$[4.847190098 \times 10^{-19}, 1.428571365, 1.772378037 \times 10^{-10}]$$

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

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

(20)

> 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

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

$$\text{and with initial conditions, } [0.1, 0.1, 0.1]$$

$$[1.762291592 \times 10^{-42}, 2.941176420, 6.988269436 \times 10^{-73}]$$

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

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

(21)

- 2) there were 0 cases where all species survived
 11 cases where the ultimate behavior matched a stable eq. point
 6 cases where all 3 initial conditions agree

➤ *proof*
➤ *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], [0.2633242048, 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

$\{[0., 0., 1.315789474, 0.], [0., 1.666666667, 0., 0.], [3.125000000, 0., 0., 0.]\}$
 at time $t=, 50$, with initial conditions, $[0.5, 0.5, 0.5, 0.5]$, the ultimate behavior is
 $[1.414585828 \times 10^{-20}, 0.9052415732, 0.5194185449, 4.678202092 \times 10^{-7}]$

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

$[3.679242274 \times 10^{-28}, 1.524089485, 0.09690621852, 5.991695141 \times 10^{-11}]$

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

$[1.876725201 \times 10^{-13}, 0.4099195696, 0.8617989046, 0.001053561473]$ (22)

> *ExpGenLotka*(4, 50);

The Equilibrium points are

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

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
 $[2.307322184 \times 10^{-16}, 4.858824557 \times 10^{-15}, 1.312710791, 0.003523227801]$

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

$[1.959150851 \times 10^{-14}, 8.072782350 \times 10^{-14}, 1.314034799, 0.002007756769]$

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

$[2.595810943 \times 10^{-17}, 2.398215401 \times 10^{-15}, 1.310729073, 0.005789572201]$ (23)

> *ExpGenLotka*(4, 50);

The Equilibrium points are

$\{[-3.045011873, 1.464209635, 2.479451190, -0.3120608685], [-2.077027651, 1.135343457,$

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]

[1.242691056, $5.533931855 \times 10^{-10}$, 2.046782480, $2.617927092 \times 10^{-8}$]

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

[0.0001181265093, 0.2552530434, $4.647815736 \times 10^{-28}$, 3.349250636]

(24)

> 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

[$3.923202202 \times 10^{-13}$, $2.365266167 \times 10^{-10}$, 1.583092687, 0.03916867663]

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

$$[0.0001093168990, 1.592039810 \times 10^{-6}, 1.126505859, 0.1842244700]$$

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

$$[4.691065079 \times 10^{-16}, 6.418315809 \times 10^{-12}, 1.635957352, 0.02363032341]$$

(25)

> ExpGenLotka(4, 50);

The Equilibrium points are

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

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

$$[1.111804961 \times 10^{-165}, 2.540015156 \times 10^{-86}, 16.66666607, 7.505675392 \times 10^{-120}]$$

$$\text{and with initial conditions, } [0.1, 0.1, 0.1, 0.1]$$

$$[2.819128146 \times 10^{-180}, 2.618587036 \times 10^{-94}, 16.66666607, 4.368871484 \times 10^{-130}]$$

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

$$[0.07977229223, 4.301122253, 1.242937167 \times 10^{-29}, 7.051478025 \times 10^{-15}]$$

(26)

> ExpGenLotka(4, 50);

The Equilibrium points are

$$\{ [-0.4629629630, 4.282407407, 0., 0.], [0., -138.4615385, 119.2307692, 0.], [0., -2.083333333, 0., 2.083333333], [0., -0.9193716984, 0.1196130291, 1.560932491], [0., 0., 0., 0.], [0., 0., 0., 1.724137931], [0., 0., 0.5494505494, 0.], [0., 0., 0.7243877199, -0.2242152466], [0., 3.125000000, 0., 0.], [0.1084892867, 0., 0.5017629509, 0.], [0.2674954930, 0., 0.3400763269, 0.1176511906], [0.3967917162, 0.6821846885, 0., 0.5803344084], [0.6405933918, 0., 0., 0.06743088334], [0.6493506494, 0., 0., 0.] \}$$

$[1.016344882, 0.3998738055, -0.4727551183, 0.2982642766], [1.258222897, 0.9108439667, -0.7843378602, 0.]]\}$

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

$[0.4057094375, 0.6569651593, 9.108602624 \times 10^{-14}, 0.5696397557]$

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

$[0.4412275469, 0.5113572135, 4.099044568 \times 10^{-15}, 0.5754393742]$

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

$[0.3696917323, 0.7805416054, 8.073775744 \times 10^{-12}, 0.5878062120]$

(27)

> *ExpGenLotka*(4, 50);

The Equilibrium points are

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

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

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

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

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

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

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

(28)

> 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

$$[3.333333006, 1.543919566 \times 10^{-32}, 4.206374054 \times 10^{-8}, 2.715970445 \times 10^{-55}]$$

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

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

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

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

(29)

> ExpGenLotka(4, 50);

The Equilibrium points are

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

The stable Equilibrium points are

$\{ [-5.178571429, 0., 0., 7.500000000], [1.444444444, 0., 0.222222222, 0.] \}$
at time $t=, 50$, with initial conditions, $[0.5, 0.5, 0.5, 0.5]$, the ultimate behavior is
 $[1.368022132, 6.523209556 \times 10^{-7}, 0.2466909006, 0.00004974868319]$

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

$[1.272724838, 0.0006333214482, 0.2726459119, 0.001050995617]$

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

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

(30)

> ExpGenLotka(4, 50);

The Equilibrium points are

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

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, $\left[\frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1 \right]$

$[0.3509488616, 0.3719697803, 0.09260953566, 0.06862130035]$

(31)

there were 1 cases where all species survived

9 cases where the ultimate behavior matched a stable eq. point

3 cases where all 3 initial conditions agree

> #prob 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], [-0.1527016246, 0., 0.6484102262, 0., 0.04065267876], [-0.1242750621, 0., 0.6628003314, 0., 0.], [-0.09287925697, 0., 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., 0.], [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., 0.5681818182, 0., 0.], [0., 0.09741269694, 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., 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, $4.257236015 \times 10^{-123}$, $1.133632193 \times 10^{-49}$, $7.282079148 \times 10^{-153}$, $9.905505656 \times 10^{-56}$]

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

[$4.776934081 \times 10^{-26}$, 1.841715511, 0.002408007943, $7.670225693 \times 10^{-6}$, $3.837254274 \times 10^{-8}$]

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

[16.66666598, $1.420538390 \times 10^{-114}$, $4.690985485 \times 10^{-46}$, $8.675375780 \times 10^{-141}$, $3.585536792 \times 10^{-51}$] (32)

> 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., 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., 0.03945612612, 0.4590653775], [0., 0.8226037196, 0., 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., 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., 0.5393619463], [0.7938345092, 0., -0.7634683348, 0.2285985811, 1.211343102], [0.8771929825, 0., 0., 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

[$1.869743777 \times 10^{-345}$, $7.739103963 \times 10^{-132}$, 24.99999922, $2.051901662 \times 10^{-386}$, $1.546738906 \times 10^{-522}$]

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

[$1.089560128 \times 10^{-362}$, $1.051970879 \times 10^{-138}$, 24.99999922, $1.445108214 \times 10^{-405}$, $1.195020186 \times 10^{-548}$]

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

[$1.479480643 \times 10^{-373}$, $1.417477576 \times 10^{-142}$, 24.99999922, $1.584067203 \times 10^{-416}$, $1.967788778 \times 10^{-564}$]

(33)

> 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., 0., 2.500000000], [0., 0., 0., 0.6439894320, 0.5036327609], [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., 0.09359400998, 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, -0.9658563741,
 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., 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

[$3.32426145 \times 10^{-3980}$, 0.00002478786387, $1.374991439 \times 10^{-65}$, 49.99895894, 4.096865645
 $\times 10^{-1180}$]

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

[3.391112284, 0.02859025538, $2.622055672 \times 10^{-7}$, $5.335547191 \times 10^{-19}$, 1.546047463
 $\times 10^{-75}$]

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

[$5.3955145 \times 10^{-4139}$, 0.00001466570880, $1.372037458 \times 10^{-67}$, 49.99937240, 1.774709446
 $\times 10^{-1218}$]

(34)

> 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, 1.551678000], [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., 0.8928571429], [0., 16.66666667, 0., 0., 0.], [0.1376581262, 0., 0., 0.3740448212, 0.8444101971], [0.1805712089, 0.3270074564, 0.3987925373, 0.06394146898, 0.], [0.2322202661, 0.4335687337, 0., 0.3200331764, 0.06561239405], [0.2500007728, 0.4515469909, 0., 0.3426594827, 0.], [0.3718020804, 0., 0.3450941805, 0.6051447849, 0.], [0.4889006342, 0., 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., 2.783366868, -0.3118326819, -2.549588720], [0.8148831488, -0.4458794588, 0., 0., 0.], [1.069078947, 0., 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, $4.244066250 \times 10^{-29}$, 3.818424622, $1.453698356 \times 10^{-15}$, 0.007563235670]

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

[$3.120938678 \times 10^{-6}$, $2.029128674 \times 10^{-45}$, 3.845769491, $2.830824185 \times 10^{-29}$, 0.0001793847265]

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

[$7.095359351 \times 10^{-7}$, $1.317073093 \times 10^{-49}$, 3.844828964, $4.505901542 \times 10^{-32}$, 0.0007034398503]

(35)

> 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., 0.3936852935, 0., 0.1922747167, 0.3800517792], [0., 0.4238164151, 0., 0., 0.6615670870], [0., 0.4868614112, 1.361377884, 0., -1.066259837], [0., 0.4965422913, 1.230261962, -0.1005229338, -0.7526720624], [0., 0.7497827659, 0.6340113118, -0.1904375380, 0.], [0., 1.039168665, 0.2797761791, 0., 0.], [0., 1.724137931, 0., 0., 0.], [0.1957696897, 0., -0.5117755959, 0.4756793110, 1.613838023], [0.2270876096, 0.2870361320, 0., 0.2981135764, 0.], [0.2376103191, 0., 0., 0.4978501924, 0.], [0.2608474576, 0.2004347826, 0., 0.3679587325, -0.1040456890], [0.2687140115, 0., 0.6333973129, 0., 0.], [0.3201024328, 0., 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., 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

[$2.752663073 \times 10^{-6}$, $2.731491985 \times 10^{-19}$, 0.3562274546, 0.3082231456, 0.9737629331]

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

[$7.930247786 \times 10^{-8}$, $4.767223375 \times 10^{-15}$, 0.8003860009, 0.2614313127, 0.2447297751]

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

[$8.313105571 \times 10^{-6}$, $3.918623749 \times 10^{-25}$, 0.03375344708, 0.3291229950, 1.656874864] (36)

> 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.] }

0.6598721242], [0., -0.3665689150, 0.7697947214, 0., 0.], [0., 0., 0., 0., 0.], [0., 0., 0., 0., 1.219512195], [0., 0., 0., 0.5376344086, 0.], [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., 0.], [0., 1.576834862, 0., -0.3440366972, 0.], [0., 5.399675626, -3.353799815, 0., 1.157321594], [0.1567027256, 0.4151065579, 0.2408655802, 0., 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., 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

[$2.085861368 \times 10^{-14}$, $2.943654585 \times 10^{-29}$, 0.1819688398, $6.461313310 \times 10^{-12}$, 1.102635747]

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

[$7.168986534 \times 10^{-7}$, $2.688136522 \times 10^{-17}$, 0.2390669729, 0.00001209577350, 1.023001230]

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

[$1.139816992 \times 10^{-17}$, $4.635952408 \times 10^{-33}$, 0.1743327269, $3.040866411 \times 10^{-14}$, 1.109987381]

(37)

> 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, 0.8381477728, 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., 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.], [0.9269356598, 0., 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., −30.39215686, 0., 0.]]

The stable Equilibrium points are

{[0., 0., 1.724137931, 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, $6.075860655 \times 10^{-7}$] (38)

> 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., 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., 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., 0., 3.958757637], [2.898550725,
 0.6038647343, 0., 0., 0.], [8.333333333, 0., 0., 0., 0.]}

The stable Equilibrium points are

{[0., 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, $2.069247826 \times 10^{-21}$, 0.5639022519, 0.0002230892811] (39)

> 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., 0.1045712578, 0.], [0., 0.5434782609, 0., 0., 0.],
 [0., 0.5674136589, -0.5182514646, 0., 0.7876193207], [0.2068014706, 0., 0.,
 0.5284926471, 0.], [0.2094344837, 0., -0.006693267005, 0.5270407987, 0.]}

[0.2177324436, 0.3806672678, 0.1394218404, 0.1346827442, 0.], [0.2513285980, 0., 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., 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]

(40)

> 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., -1.560121766, 1.141552511], [0., 0., 0., 0., 0.5376344086], [0., 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., 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, 0.1222493888, -0.9081383165, 0.], [0., 1.169217687, 0., -1.020408163, 0.], [0.009406452827, 1.081322144, 0.1238516289, 0., 0.] }

$-0.9043632503, 0.]$, $[0.2143501805, 0., 2.822277377, -5.045690433, 0.]$, $[0.2587694077, 0.4336783592, 0.1820969906, 0., 0.]$, $[0.2941176471, 0.4411764706, 0., 0., 0.]$,
 $[0.3503709810, 0., 0., 0., 0.2061005771]$, $[0.4030957756, 0., 0.4998387617, 0., 0.]$,
 $[0.5102040816, 0., 0., 0., 0.]$, $[1.051486846, 0., 0.7385614796, 0., -0.9020460782]]$

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, $\left[\frac{1}{5}, \frac{2}{5}, \frac{3}{5}, \frac{4}{5}, 1\right]$

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

(41)

there were 1 cases where all species survived
 9 cases where the ultimate behavior matched a stable eq. point
 4 cases where all 3 initial conditions agree