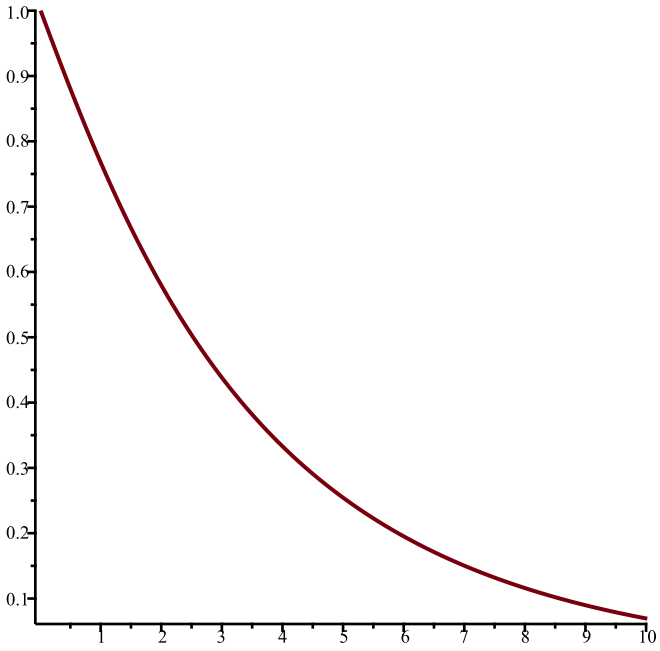
```
> #Hrudai Battini Hw 21
  read "/Users/hb334/Documents/DMB.txt":

> #ChemoStat
  a1:=trunc(evalf(rand()*10^(-11)));
  a2:=trunc(evalf(rand()*10^(-11)));
  F:=ChemoStat(N,C,a1,a2);
  SEquP(F,[N,C]);
  TimeSeries(F,[N,C],[a1,a2],0.01,10,1);
  TimeSeries(F,[N,C],[a1,a2],0.01,10,2);
  PhaseDiag(F,[N,C],[a1,a2],0.01,10);

  a1:=trunc(evalf(rand()*10^(-11)));
  a2:=trunc(evalf(rand()*10^(-11)));
  F:=ChemoStat(N,C,a1,a2);
  SEquP(F,[N,C]);
  TimeSeries(F,[N,C],[a1,a2],0.01,10,1);
  TimeSeries(F,[N,C],[a1,a2],0.01,10,2);
  PhaseDiag(F,[N,C],[a1,a2],0.01,10);

  a1:=trunc(evalf(rand()*10^(-11)));
  a2:=trunc(evalf(rand()*10^(-11)));
  F:=ChemoStat(N,C,a1,a2);
  SEquP(F,[N,C]);
  TimeSeries(F,[N,C],[a1,a2],0.01,10,1);
  TimeSeries(F,[N,C],[a1,a2],0.01,10,2);
  PhaseDiag(F,[N,C],[a1,a2],0.01,10);
```

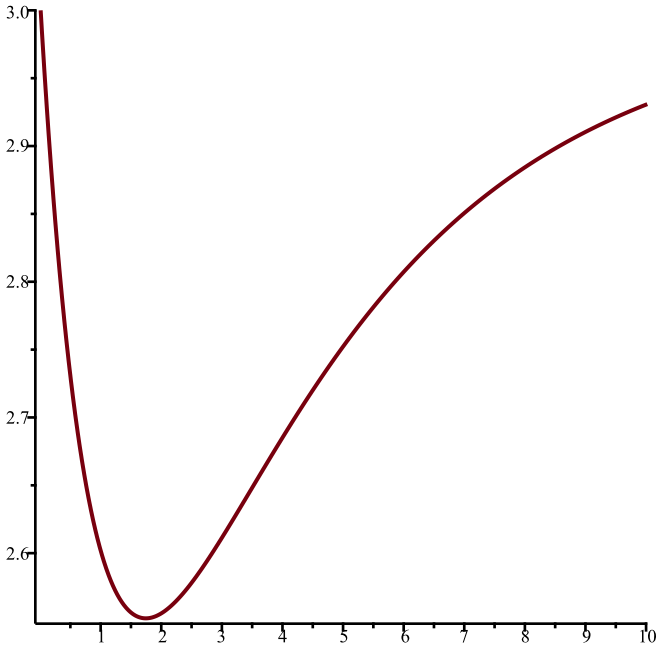
$$a1 := 1$$

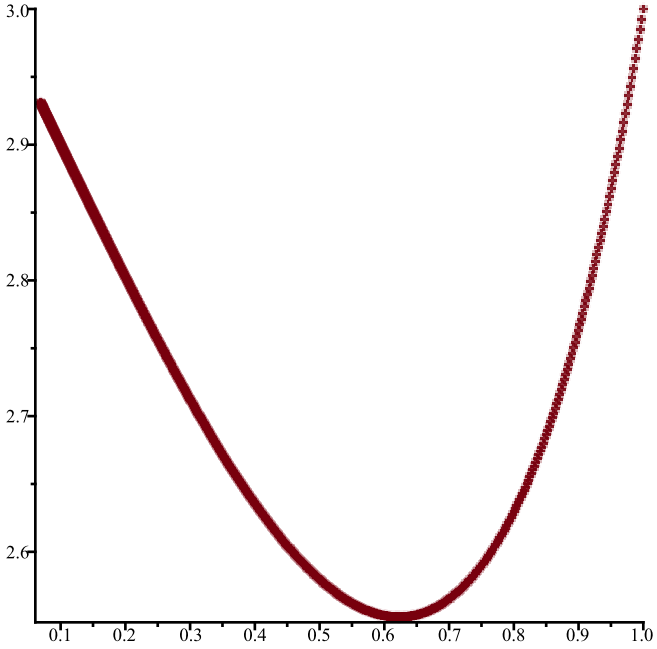
$$a2 := 3$$

$$F := \left[\frac{C\,N}{C+1} - N, -\frac{C\,N}{C+1} - C + 3 \right]$$

$$\{[0., 3.]\}$$





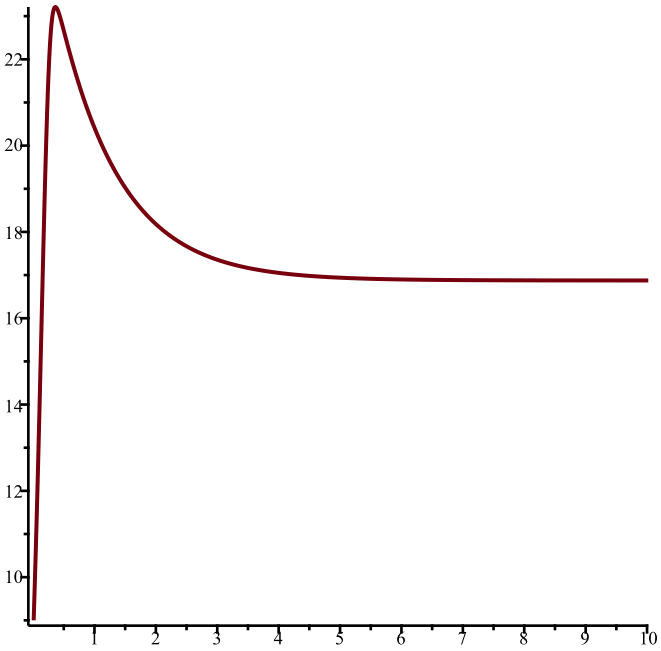


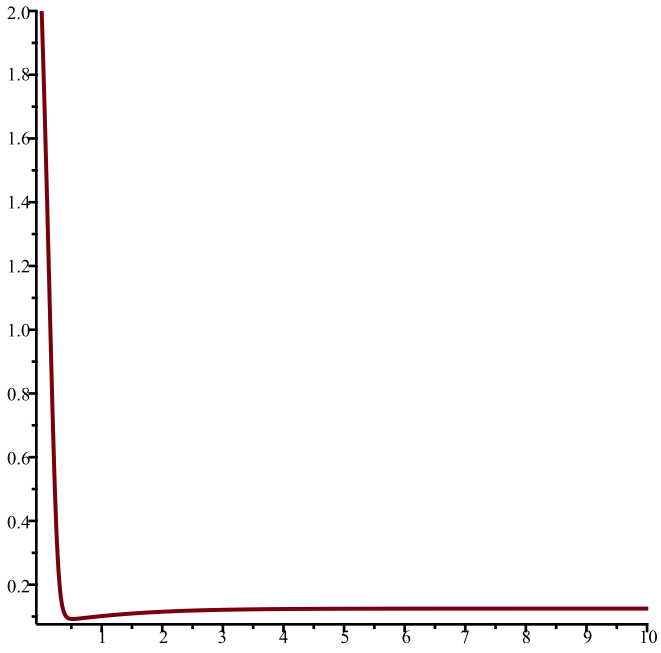
$$a1 := 9$$

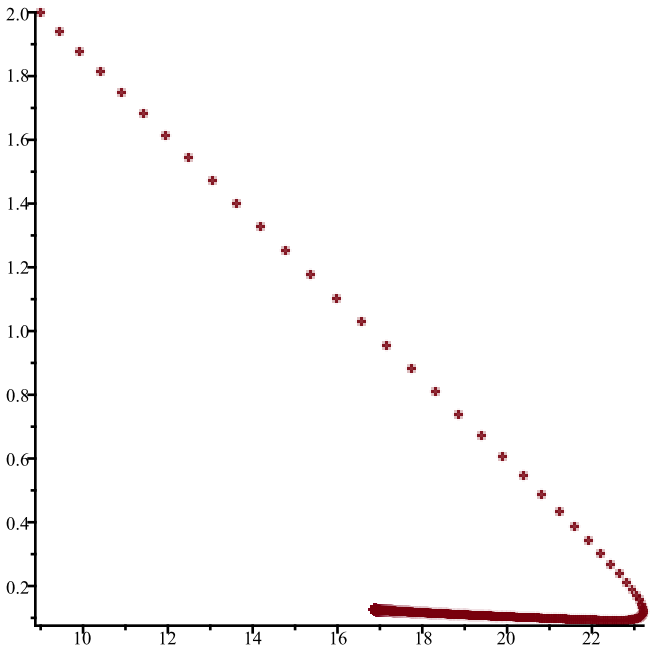
$$a2 := 2$$

$$F := \left[\frac{9\,C\,N}{C+1} - N, -\frac{C\,N}{C+1} - C + 2\right]$$

$$\{[16.87500000, 0.1250000000]\}$$


22
20
18
16
14
12
10
1
2
3
4
5
6
7
8
9
10


2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1
2
3
4
5
6
7
8
9
10

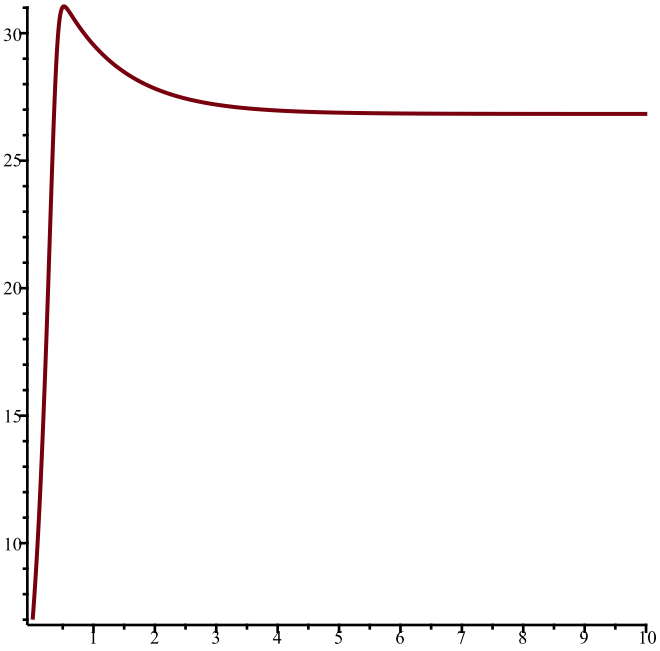


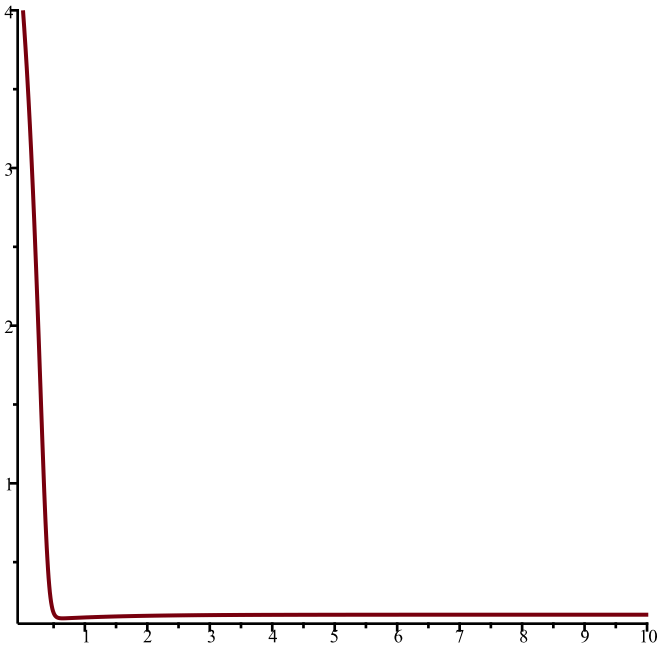
$$a1 := 7$$

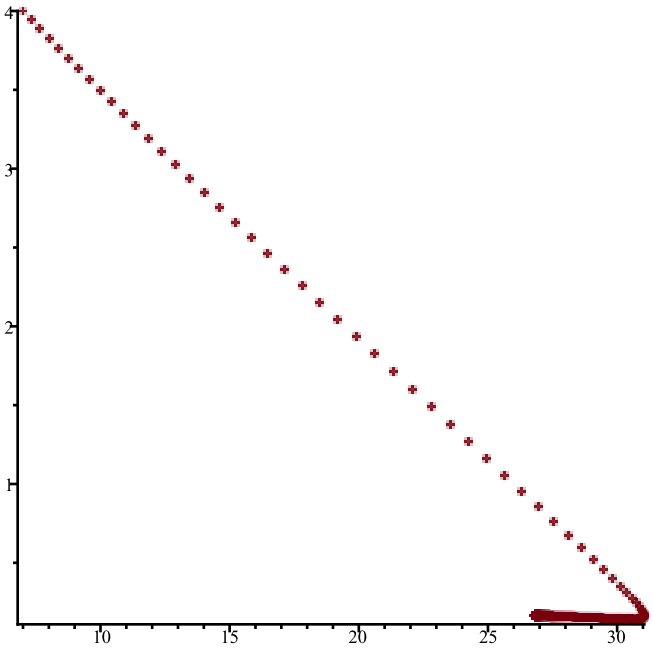
$$a2 := 4$$

$$F := \left[\frac{7\,C\,N}{C+1} - N, -\frac{C\,N}{C+1} - C + 4 \right]$$

$$\{[26.83333333, 0.1666666667]\}$$








```
> #GeneNet
  a0:=trunc(evalf(rand()*10^(-11)));
  a:=trunc(evalf(rand()*10^(-11)));
  b:=trunc(evalf(rand()*10^(-11)));
  n:=trunc(evalf(rand()*10^(-11)));
  G:=GeneNet(a0,a,b,n,m01,m02,m03,p01,p02,p03);
  m1:=trunc(evalf(rand()*10^(-11)));
  m2:=trunc(evalf(rand()*10^(-11)));
  m3:=trunc(evalf(rand()*10^(-11)));
  p1:=trunc(evalf(rand()*10^(-11)));
  p2:=trunc(evalf(rand()*10^(-11)));
  p3:=trunc(evalf(rand()*10^(-11)));
  SEquP(G,[m01,m02,m03,p01,p02,p03]);
  TimeSeries(G,[m01,m02,m03,p01,p02,p03],[m1,m2,m3,p1,p2,p3],0.01,
  10,1);
```

```
a0:=trunc(evalf(rand()*10^(-11)));
a:=trunc(evalf(rand()*10^(-11)));
b:=trunc(evalf(rand()*10^(-11)));
n:=trunc(evalf(rand()*10^(-11)));
G:=GeneNet(a0,a,b,n,m01,m02,m03,p01,p02,p03);
m1:=trunc(evalf(rand()*10^(-11)));
m2:=trunc(evalf(rand()*10^(-11)));
m3:=trunc(evalf(rand()*10^(-11)));
p1:=trunc(evalf(rand()*10^(-11)));
p2:=trunc(evalf(rand()*10^(-11)));
p3:=trunc(evalf(rand()*10^(-11)));
SEquP(G,[m01,m02,m03,p01,p02,p03]);
TimeSeries(G,[m01,m02,m03,p01,p02,p03],[m1,m2,m3,p1,p2,p3],0.01,
10,1);

a0:=trunc(evalf(rand()*10^(-11)));
a:=trunc(evalf(rand()*10^(-11)));
b:=trunc(evalf(rand()*10^(-11)));
n:=trunc(evalf(rand()*10^(-11)));
G:=GeneNet(a0,a,b,n,m01,m02,m03,p01,p02,p03);
m1:=trunc(evalf(rand()*10^(-11)));
m2:=trunc(evalf(rand()*10^(-11)));
m3:=trunc(evalf(rand()*10^(-11)));
p1:=trunc(evalf(rand()*10^(-11)));
p2:=trunc(evalf(rand()*10^(-11)));
p3:=trunc(evalf(rand()*10^(-11)));
SEquP(G,[m01,m02,m03,p01,p02,p03]);
TimeSeries(G,[m01,m02,m03,p01,p02,p03],[m1,m2,m3,p1,p2,p3],0.01,
10,1);
```

$$a0 := 1$$

$$a := 5$$

$$b := 0$$

$$n := 0$$

$$G := \left[-m01 + \frac{7}{2}, -m02 + \frac{7}{2}, -m03 + \frac{7}{2}, 0, 0, 0\right]$$

$$m1 := 2$$

$$m2 := 9$$

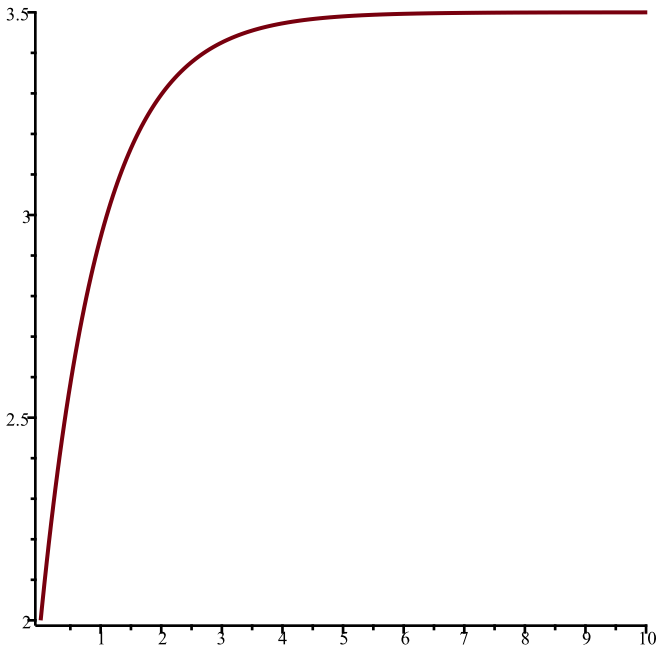
$$m3 := 7$$

$$p1 := 0$$

$$p2 := 6$$

$$p3 := 5$$

$$\varnothing$$



$$a0 := 9$$

$$a := 7$$

$$b := 9$$

$$n := 2$$

$$G := \left[-m01 + \frac{7}{p03^2 + 1} + 9,\ -m02 + \frac{7}{p01^2 + 1} + 9,\ -m03 + \frac{7}{p02^2 + 1} + 9,\ -9\,p01 + 9\,m01,\ -9\,p02 + 9\,m02,\ -9\,p03 + 9\,m03 \right]$$

$$m1 := 1$$

$$m2 := 2$$

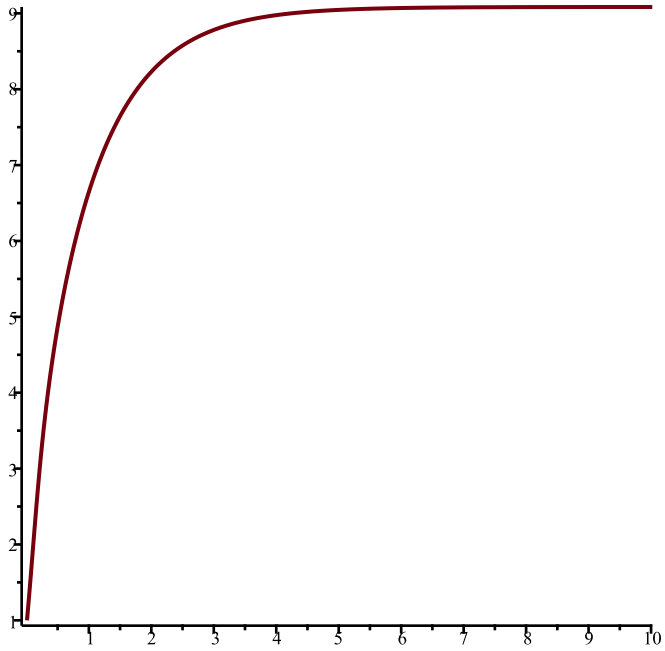
$$m3 := 0$$

$$p1 := 4$$

$$p2 := 6$$

$$p3 := 2$$

$$\{[9.083816553, 9.083816553, 9.083816553, 9.083816553, 9.083816553, 9.083816553]\}$$



$$a0 := 4$$

$$a := 6$$

$$b := 8$$

$$n := 0$$

$$G := [-m01 + 7, -m02 + 7, -m03 + 7, -8\,p01 + 8\,m01, -8\,p02 + 8\,m02, -8\,p03 + 8\,m03]$$

$$m1 := 0$$

$$m2 := 7$$

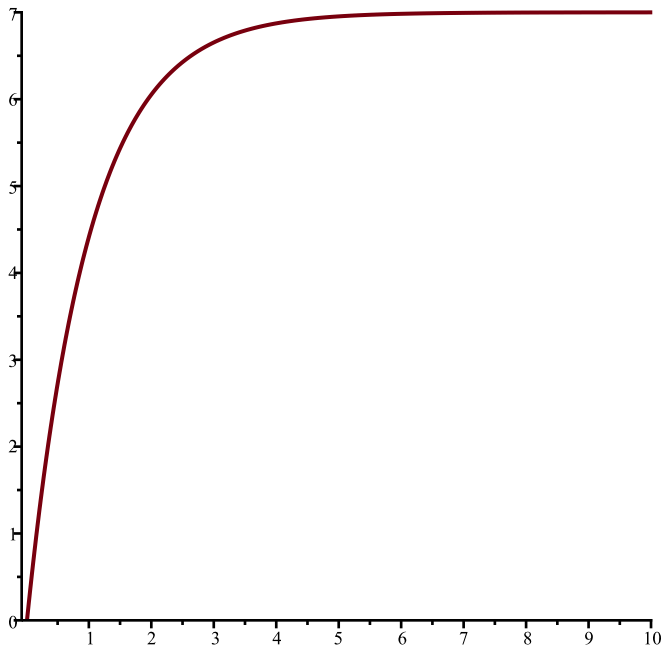
$$m3 := 0$$

$$p1 := 7$$

$$p2 := 9$$

$$p3 := 3$$

$$\{[7., 7., 7., 7., 7., 7.]\}$$




```
> #Lotka
  Help(Lotka);
  r1:=trunc(evalf(rand()*10^(-11)));
  r2:=trunc(evalf(rand()*10^(-11)));
  k1:=trunc(evalf(rand()*10^(-11)));
  k2:=trunc(evalf(rand()*10^(-11)));
  b12:=trunc(evalf(rand()*10^(-11)));
  b21:=trunc(evalf(rand()*10^(-11)));
  L:=Lotka(r1,k1,r2,k2,b12,b21,N1,N2);
  n1:=trunc(evalf(rand()*10^(-11)));
  n2:=trunc(evalf(rand()*10^(-11)));
  SEquP(L,[N1,N2]);
  TimeSeries(L,[N1,N2],[n1,n2],0.01,10,1);
  TimeSeries(L,[N1,N2],[n1,n2],0.01,10,2);
  PhaseDiag(L,[N1,N2],[n1,n2],0.01,10);

  r1:=trunc(evalf(rand()*10^(-11)));
  r2:=trunc(evalf(rand()*10^(-11)));
  k1:=trunc(evalf(rand()*10^(-11)));
  k2:=trunc(evalf(rand()*10^(-11)));
  b12:=trunc(evalf(rand()*10^(-11)));
  b21:=trunc(evalf(rand()*10^(-11)));
  L:=Lotka(r1,k1,r2,k2,b12,b21,N1,N2);
  n1:=trunc(evalf(rand()*10^(-11)));
  n2:=trunc(evalf(rand()*10^(-11)));
  SEquP(L,[N1,N2]);
  TimeSeries(L,[N1,N2],[n1,n2],0.01,10,1);
  TimeSeries(L,[N1,N2],[n1,n2],0.01,10,2);
  PhaseDiag(L,[N1,N2],[n1,n2],0.01,10);

  r1:=trunc(evalf(rand()*10^(-11)));
  r2:=trunc(evalf(rand()*10^(-11)));
  k1:=trunc(evalf(rand()*10^(-11)));
  k2:=trunc(evalf(rand()*10^(-11)));
  b12:=trunc(evalf(rand()*10^(-11)));
  b21:=trunc(evalf(rand()*10^(-11)));
```

```
L:=Lotka(r1,k1,r2,k2,b12,b21,N1,N2);
n1:=trunc(evalf(rand()*10^(-11)));
n2:=trunc(evalf(rand()*10^(-11)));
SEquP(L,[N1,N2]);
TimeSeries(L,[N1,N2],[n1,n2],0.01,10,1);
TimeSeries(L,[N1,N2],[n1,n2],0.01,10,2);
PhaseDiag(L,[N1,N2],[n1,n2],0.01,10);
```

Lotka(r1,k1,r2,k2,b12,b21,N1,N2): The Lotka-Volterra continuous-time dynamical system, Eqs. (9a),(9b) (p. 224, section 6.3) of Edelstein-Keshet

with popoluations N1, N2, and parameters r1,r2,k1,k2, b12, b21 (called there beta_12 and beta_21)

Try:

Lotka(r1,k1,r2,k2,b12,b21,N1,N2);

Lotka(1,2,2,3,1,2,N1,N2);

$$r1 := 6$$

$$r2 := 8$$

$$k1 := 1$$

$$k2 := 6$$

$$b12 := 6$$

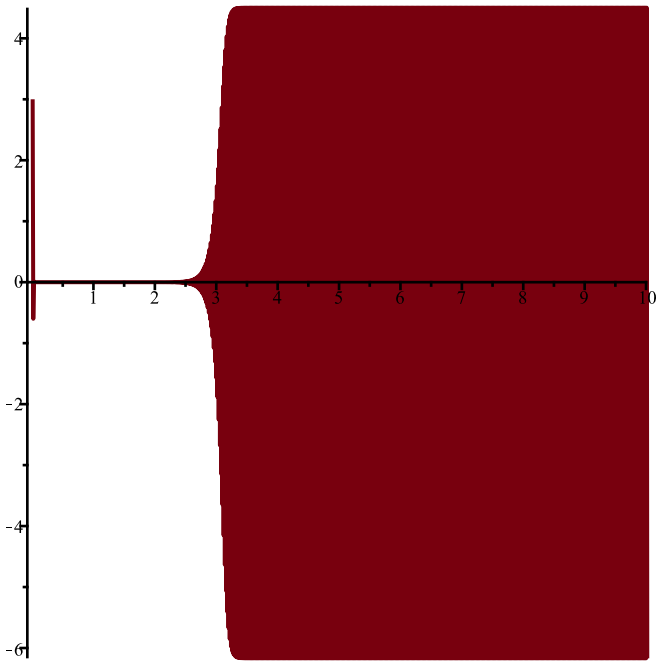
$$b21 := 0$$

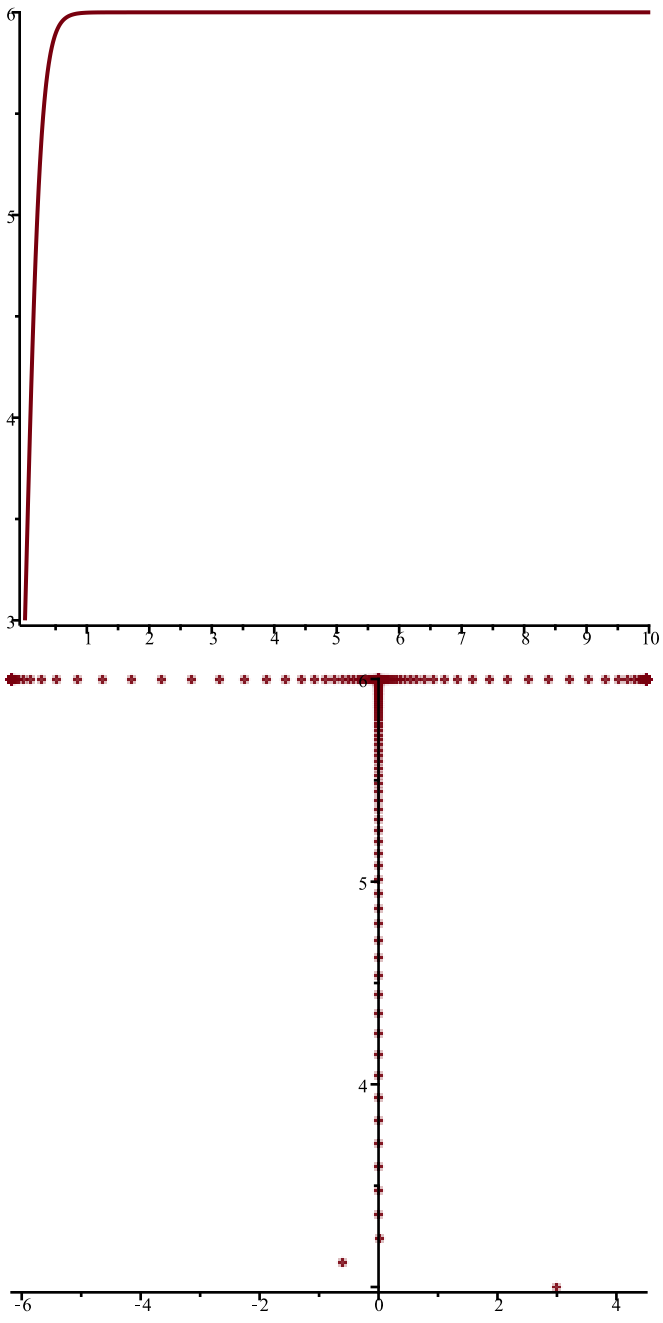
$$L := \left[6\,N1\,(1 - N1 - 6\,N2),\ \frac{4\,N2\,(6 - N2)}{3}\right]$$

$$n1 := 3$$

$$n2 := 3$$

$$\{[0., 6.]\}$$





$$r1 := 7$$

$$r2 := 6$$

$$k1 := 6$$

$$k2 := 4$$

$$b12 := 1$$

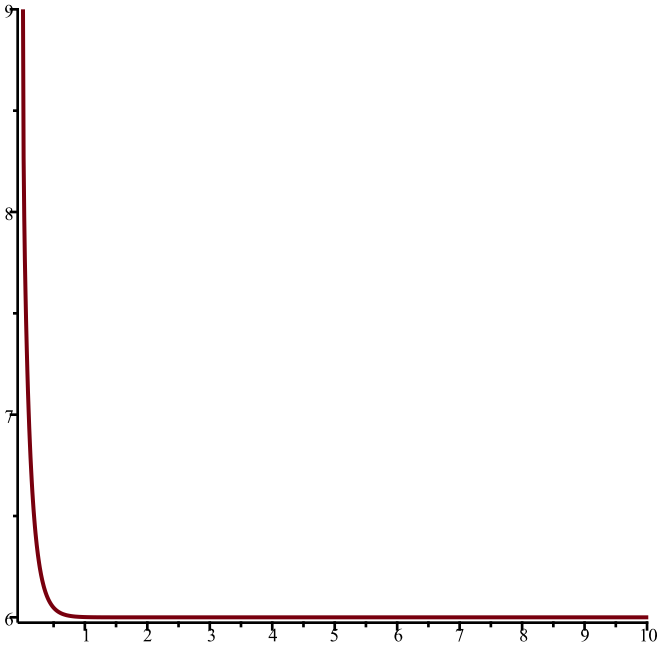
$$b21 := 6$$

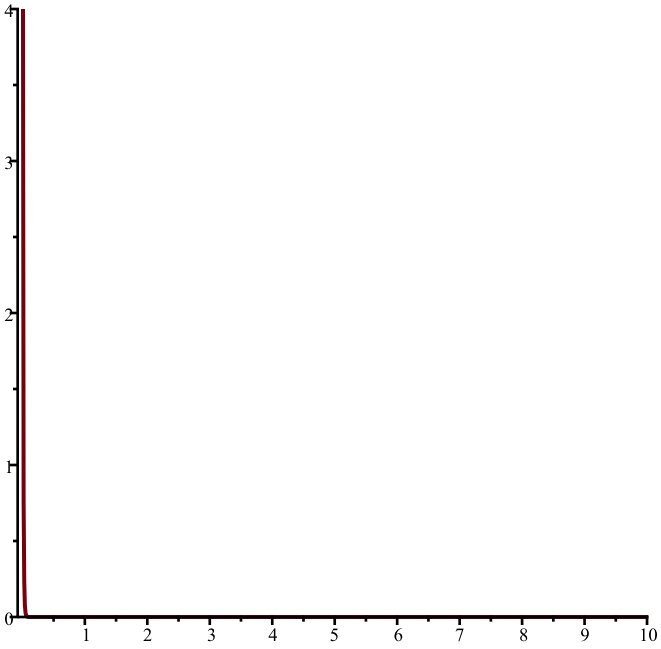
$$L := \left[\frac{7\,N1\,(6 - N1 - N2)}{6}, \frac{3\,N2\,(4 - N2 - 6\,N1)}{2} \right]$$

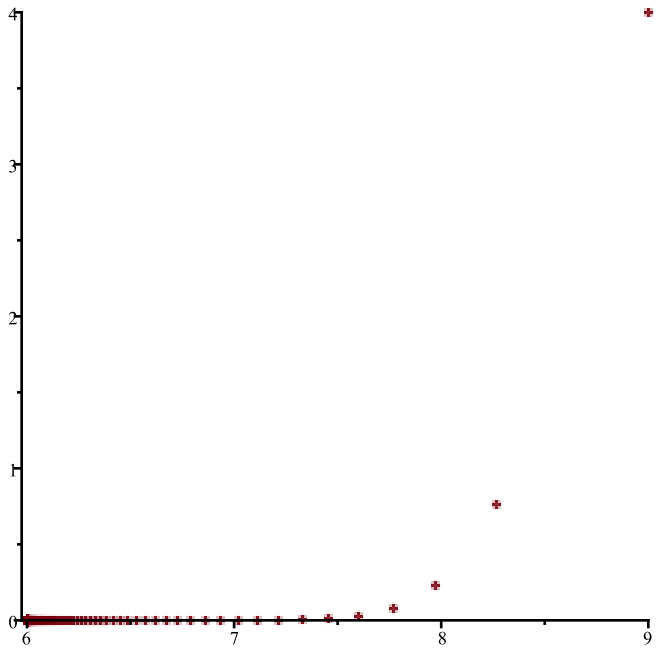
$$n1 := 9$$

$$n2 := 4$$

$$\{[-0.4000000000, 6.400000000], [6., 0.]\}$$







$$r1 := 4$$

$$r2 := 1$$

$$k1 := 4$$

$$k2 := 3$$

$$b12 := 5$$

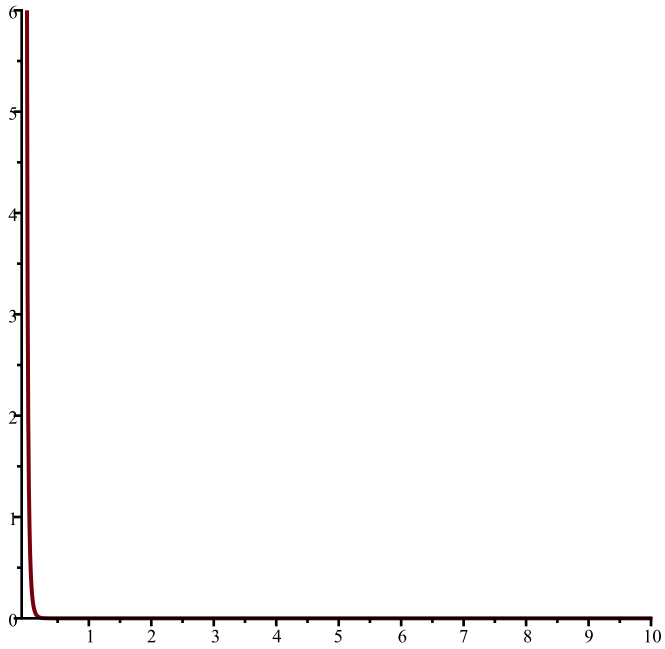
$$b21 := 6$$

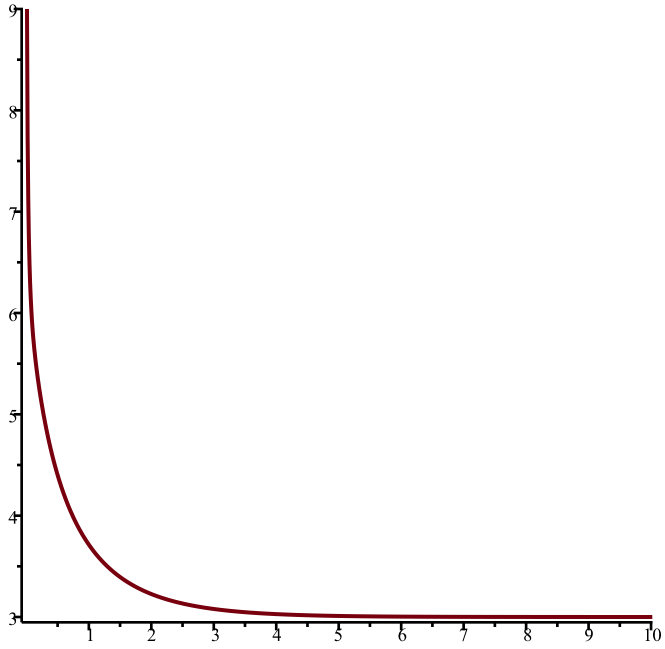
$$L := \left[N1\ (4 - N1 - 5\ N2),\ \frac{N2\ (3 - N2 - 6\ N1)}{3} \right]$$

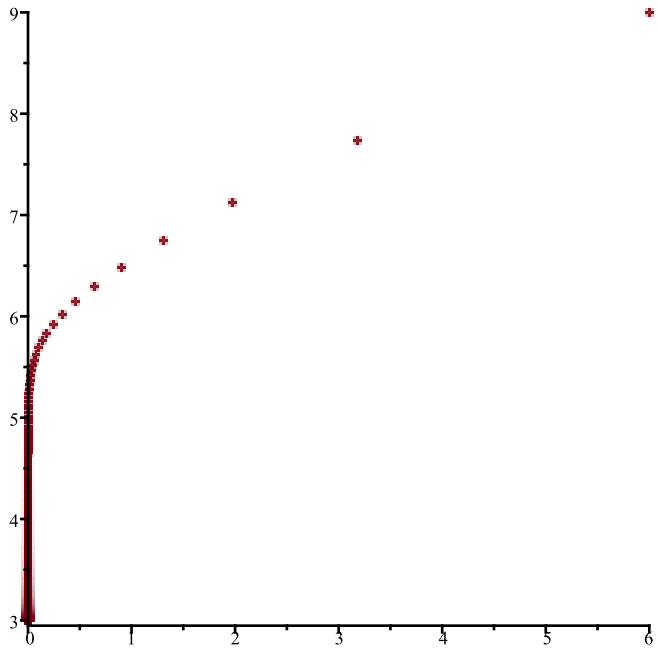
$$n1 := 6$$

$$n2 := 9$$

$$\{[0., 3.], [4., 0.]\}$$


6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10


9
8
7
6
5
4
3
1
2
3
4
5
6
7
8
9
10




```
> #Volterra
  a:=trunc(evalf(rand()*10^(-11)));
  b:=trunc(evalf(rand()*10^(-11)));
  c:=trunc(evalf(rand()*10^(-11)));
  d:=trunc(evalf(rand()*10^(-11)));
  V:=Volterra(a,b,c,d,x,y);
  x1:=trunc(evalf(rand()*10^(-11)));
  y2:=trunc(evalf(rand()*10^(-11)));
  SEquP(V,[x,y]);
  TimeSeries(V,[x,y],[x1,y2],0.01,1,1);
  TimeSeries(V,[x,y],[x1,y2],0.01,1,2);
  PhaseDiag(V,[x,y],[x1,y2],0.01,10);

  a:=trunc(evalf(rand()*10^(-11)));
  b:=trunc(evalf(rand()*10^(-11)));
  c:=trunc(evalf(rand()*10^(-11)));
  d:=trunc(evalf(rand()*10^(-11)));
  V:=Volterra(a,b,c,d,x,y);
  x1:=trunc(evalf(rand()*10^(-11)));
  y2:=trunc(evalf(rand()*10^(-11)));
  SEquP(V,[x,y]);
  TimeSeries(V,[x,y],[x1,y2],0.01,1,1);
  TimeSeries(V,[x,y],[x1,y2],0.01,1,2);
  PhaseDiag(V,[x,y],[x1,y2],0.01,10);

  a:=trunc(evalf(rand()*10^(-11)));
  b:=trunc(evalf(rand()*10^(-11)));
  c:=trunc(evalf(rand()*10^(-11)));
  d:=trunc(evalf(rand()*10^(-11)));
  V:=Volterra(a,b,c,d,x,y);
  x1:=trunc(evalf(rand()*10^(-11)));
  y2:=trunc(evalf(rand()*10^(-11)));
  SEquP(V,[x,y]);
  TimeSeries(V,[x,y],[x1,y2],0.01,1,1);
  TimeSeries(V,[x,y],[x1,y2],0.01,1,2);
  PhaseDiag(V,[x,y],[x1,y2],0.01,10);
```

Volterra(a,b,c,d,x,y): The (simple, original) Volterra predator-prey continuous-time dynamical system with parameters a,b,c,d

Given by Eqs. (7a) (7b) in Edelstein-Keshet p. 219 (section 6.2).

a,b,c,d may be symbolic or numeric

Try:

Volterra(a,b,c,d,x,y);

Volterra(1,2,3,4,x,y);

$a := 2$

$b := 6$

$c := 6$

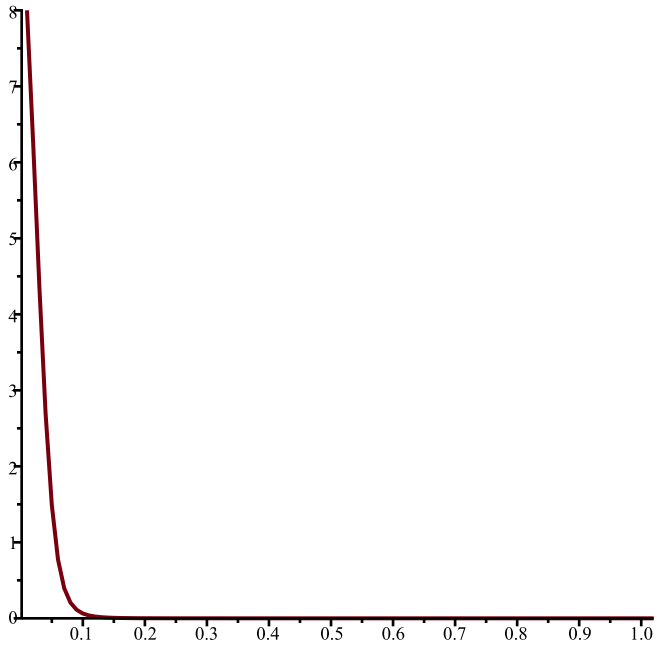
$d := 5$

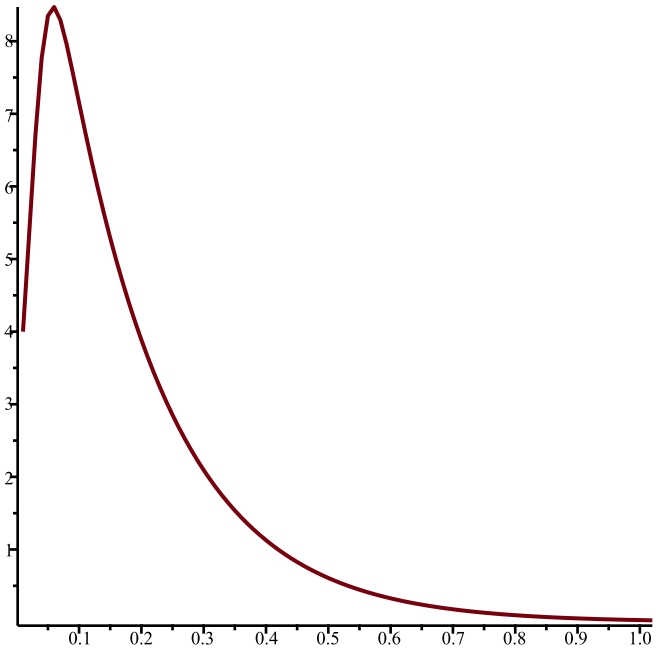
$V := [-6\,x\,y + 2\,x,\ 5\,x\,y - 6\,y]$

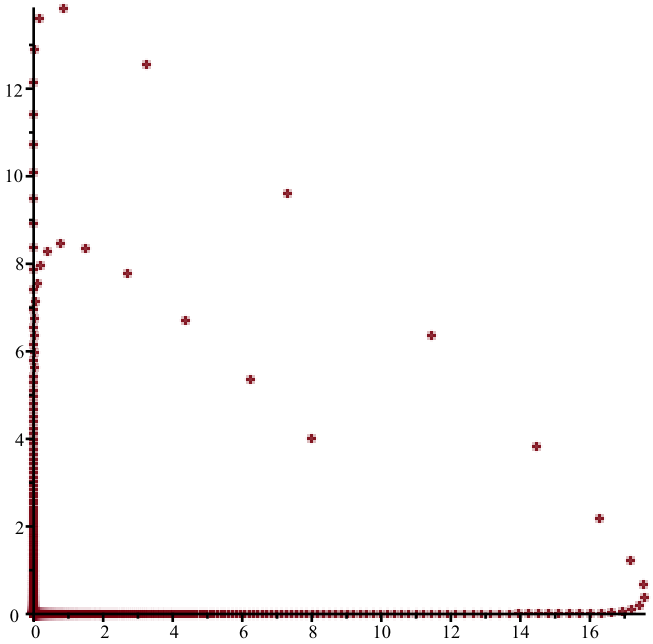
$x1 := 8$

$y2 := 4$

$\varnothing$







$$a := 0$$

$$b := 3$$

$$c := 8$$

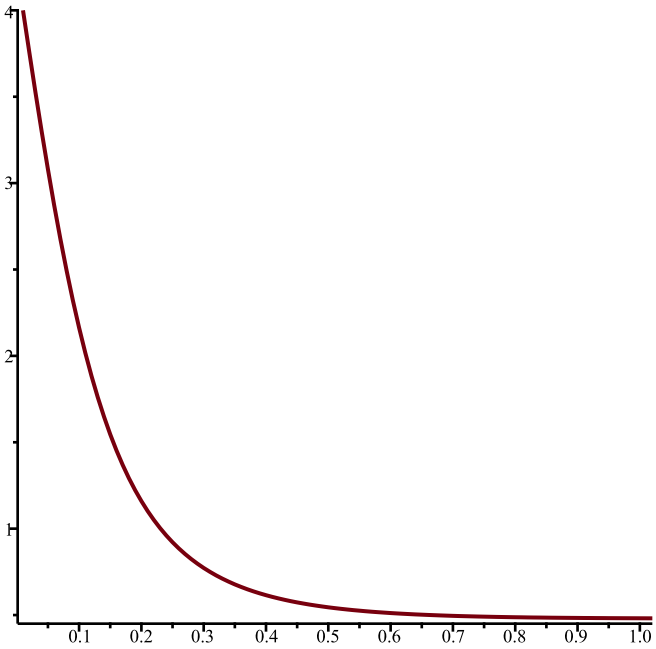
$$d := 3$$

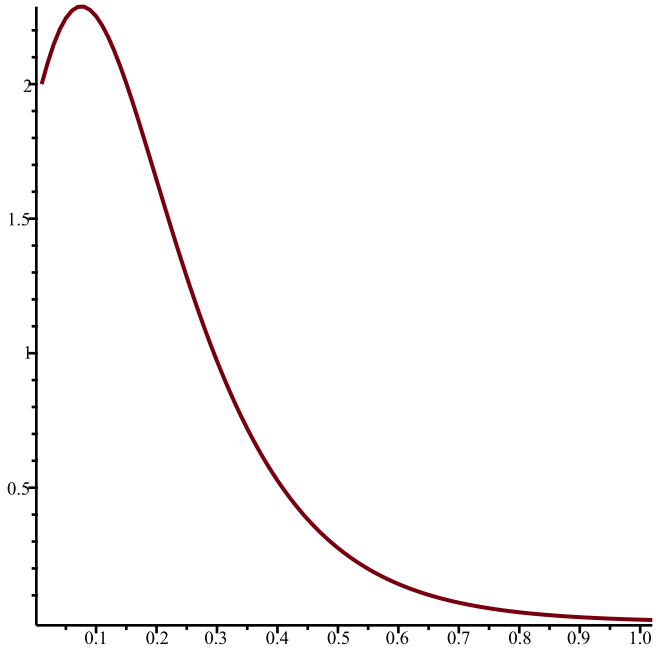
$$V := [-3\,x\,y,\ 3\,x\,y - 8\,y]$$

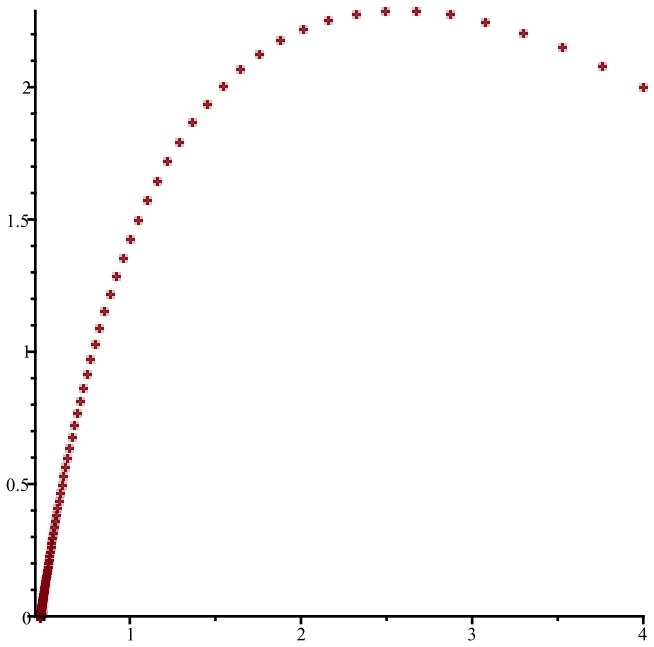
$$x1 := 4$$

$$y2 := 2$$

Error, (in SEquP) cannot determine if this expression is true or false: max(0, 3.*x-8.) < 0 |/Users/hb334/Documents/DMB.txt:639|


4
3
2
1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


2
1.5
1
0.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0



$$a := 1$$

$$b := 2$$

$$c := 2$$

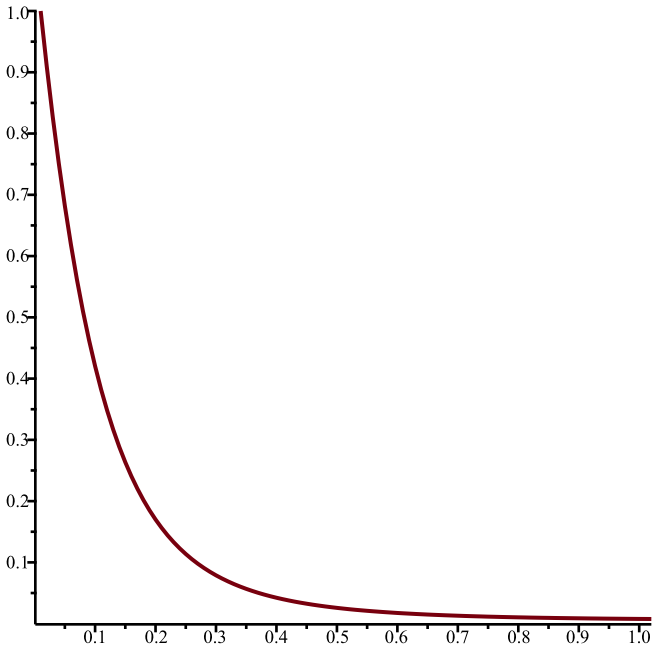
$$d := 3$$

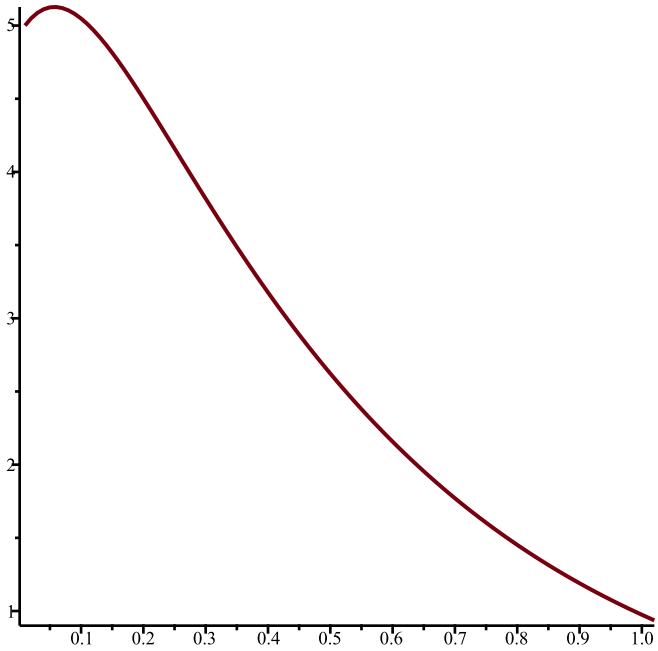
$$V := [-2\,x\,y + x,\ 3\,x\,y - 2\,y]$$

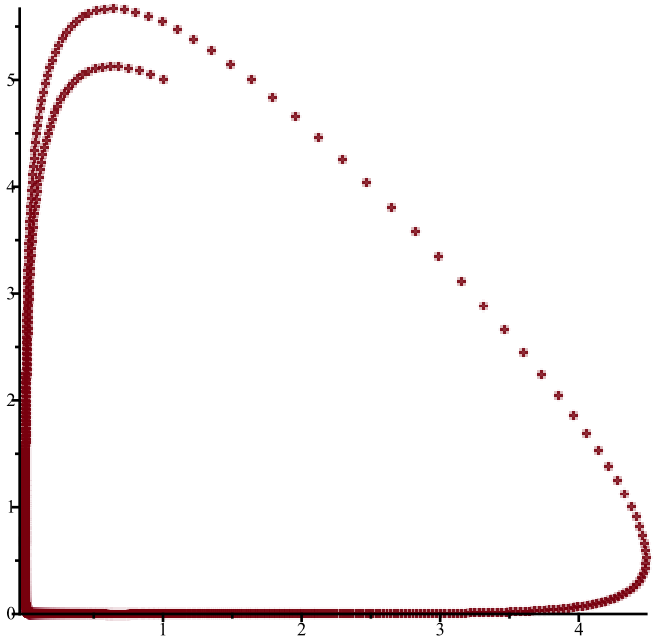
$$x1 := 1$$

$$y2 := 5$$

$$\varnothing$$








```
> #VolterraM
  a:=trunc(evalf(rand()*10^(-11)));
  b:=trunc(evalf(rand()*10^(-11)));
  c:=trunc(evalf(rand()*10^(-11)));
  d:=trunc(evalf(rand()*10^(-11)));
  K:=trunc(evalf(rand()*10^(-11)));
  V2:=VolterraM(a,b,c,d,K,x,y);
  x1:=trunc(evalf(rand()*10^(-11)));
  y2:=trunc(evalf(rand()*10^(-11)));
  SEquP(V2,[x,y]);
  TimeSeries(V2,[x,y],[x1,y2],0.01,10,1);
  TimeSeries(V2,[x,y],[x1,y2],0.01,1,2);
  PhaseDiag(V2,[x,y],[x1,y2],0.01,10);

  a:=trunc(evalf(rand()*10^(-11)));
```

```
b:=trunc(evalf(rand()*10^(-11)));
c:=trunc(evalf(rand()*10^(-11)));
d:=trunc(evalf(rand()*10^(-11)));
K:=trunc(evalf(rand()*10^(-11)));
V2:=VolterraM(a,b,c,d,K,x,y);
x1:=trunc(evalf(rand()*10^(-11)));
y2:=trunc(evalf(rand()*10^(-11)));
SEquP(V2,[x,y]);
TimeSeries(V2,[x,y],[x1,y2],0.01,10,1);
TimeSeries(V2,[x,y],[x1,y2],0.01,1,2);
PhaseDiag(V2,[x,y],[x1,y2],0.01,10);

a:=trunc(evalf(rand()*10^(-11)));
b:=trunc(evalf(rand()*10^(-11)));
c:=trunc(evalf(rand()*10^(-11)));
d:=trunc(evalf(rand()*10^(-11)));
K:=trunc(evalf(rand()*10^(-11)));
V2:=VolterraM(a,b,c,d,K,x,y);
x1:=trunc(evalf(rand()*10^(-11)));
y2:=trunc(evalf(rand()*10^(-11)));
SEquP(V2,[x,y]);
TimeSeries(V2,[x,y],[x1,y2],0.01,10,1);
TimeSeries(V2,[x,y],[x1,y2],0.01,1,2);
PhaseDiag(V2,[x,y],[x1,y2],0.01,10);
```

VolterraM(a,b,c,d,x,K,y): The MODIFIED Volterra predator-prey continuous-time dynamical system with parameters a,b,c,d,K

Given by Eqs. (8a) (8b) in Edelstein-Keshet p. 220 (section 6.2).

a,b,c,d ,Kmay be symbolic or numeric

Try:

VolterraM(a,b,c,d,K,x,y);

VolterraM(1,2,3,4,3,x,y);

$$a := 1$$

$$b := 8$$

$$c := 4$$

$$d := 8$$

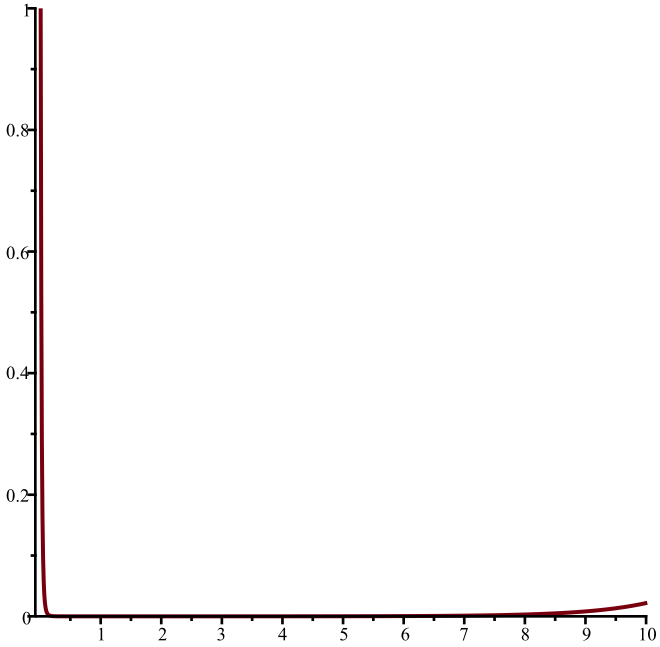
$$K := 0$$

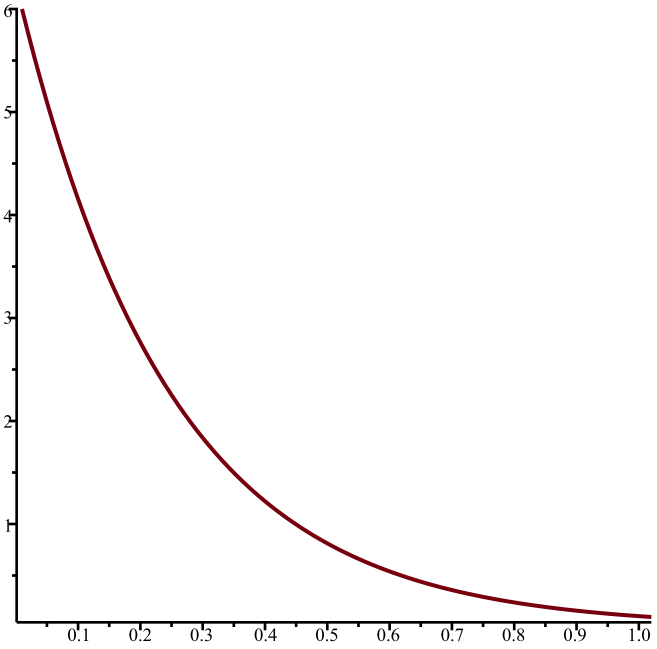
$$V2 := \left[x\left(1 - \frac{x}{8}\right) - 8\,x\,y,\ -4\,y\right]$$

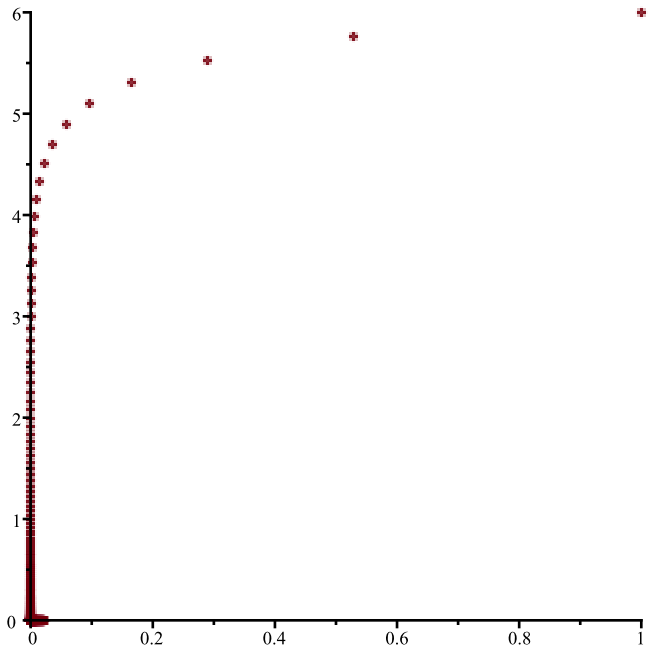
$$x1 := 1$$

$$y2 := 6$$

$$\{[8., 0.]\}$$


1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10


6
5
4
3
2
1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0



$$a := 1$$

$$b := 0$$

$$c := 9$$

$$d := 8$$

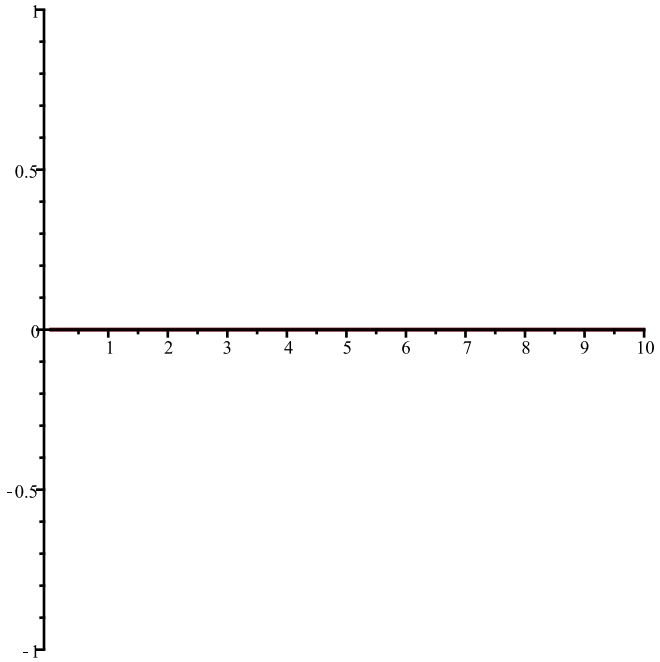
$$K := 8$$

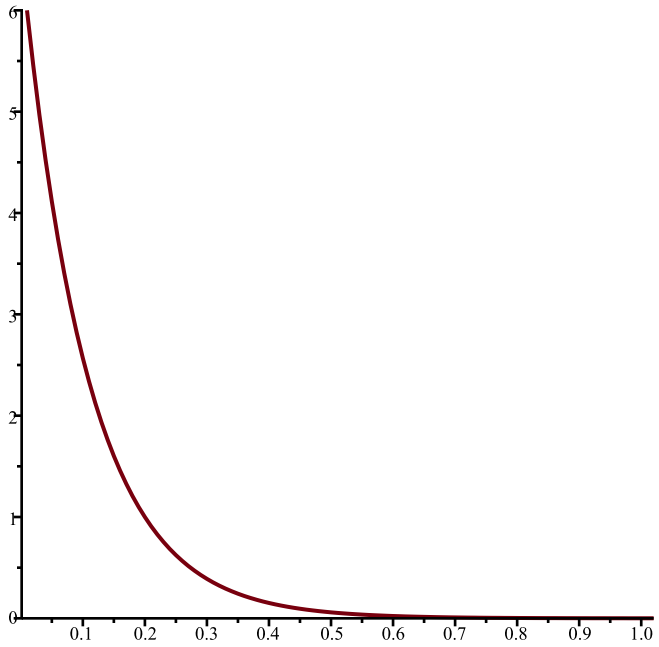
$$V2 := \left[x\left(1 - \frac{x}{8}\right), 8\,x\,y - 9\,y\right]$$

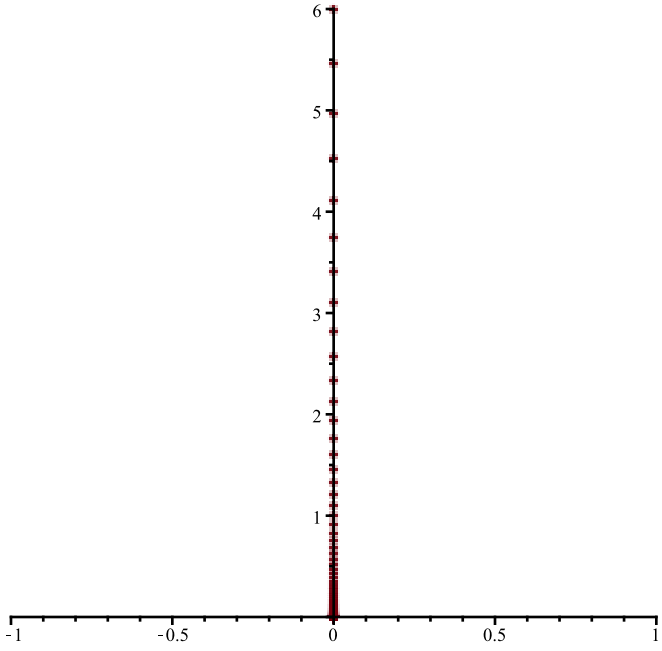
$$x1 := 0$$

$$y2 := 6$$

$$\varnothing$$







$$a := 6$$

$$b := 2$$

$$c := 9$$

$$d := 8$$

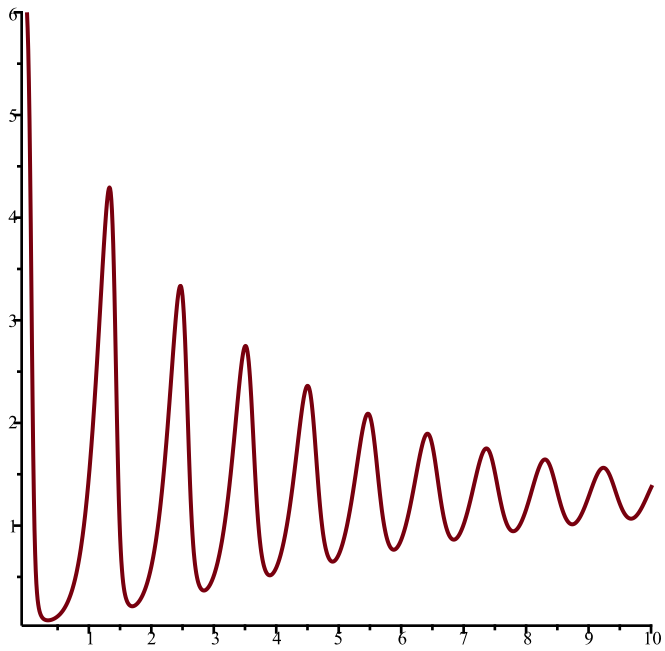
$$K := 7$$

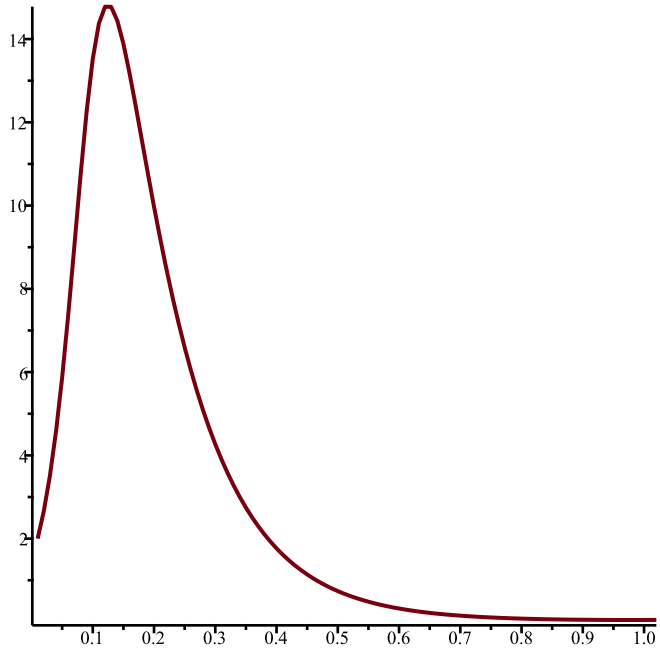
$$V2 := \left[6\,x\left(1 - \frac{x}{8}\right) - 2\,x\,y,\ 7\,x\,y - 9\,y\right]$$

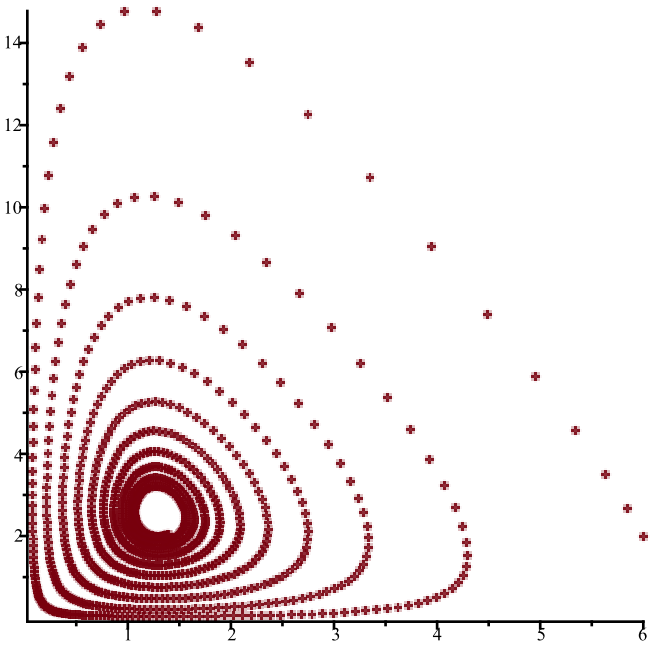
$$x1 := 6$$

$$y2 := 2$$

$$\{[1.285714286,\ 2.517857143]\}$$


6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10


14
12
10
8
6
4
2
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


14
12
10
8
6
4
2
1
2
3
4
5
6