```
> #OK to post
>
> #Anne Somalwar, hw21, 11.15.2021
>
> read "C:/Users/aks238/OneDrive - Rutgers University/Documents/DMB.txt"
```

First Written: Nov. 2021

This is DMB.txt, A Maple package to explore Dynamical models in Biology (both discrete and continuous)
accompanying the class Dynamical Models in Biology, Rutgers University. Taught by Dr. Z. (Doron Zeilbeger)

The most current version is available on WWW at:
http://sites.math.rutgers.edu/~zeilberg/tokhniot/DMB.txt .
Please report all bugs to: DoronZeil at gmail dot com .

For general help, and a list of the MAIN functions,
type "Help();". For specific help type "Help(procedure_name);"

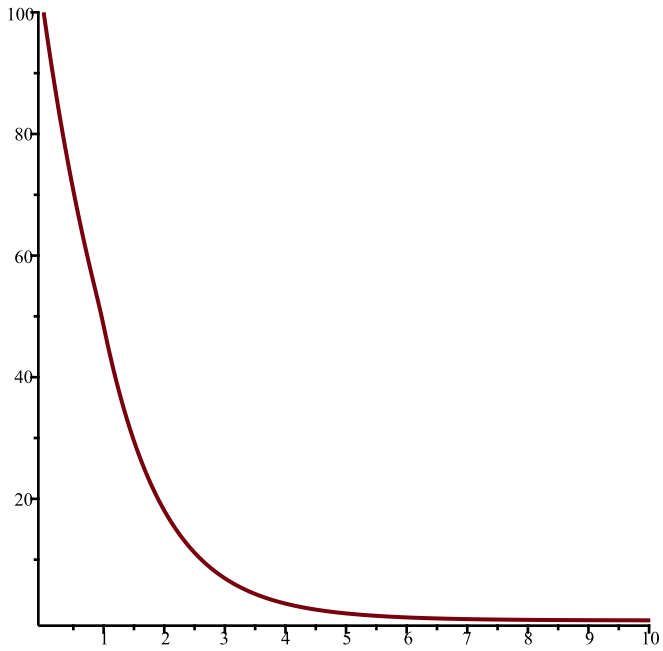
For a list of the supporting functions type: Help1();
For help with any of them type: Help(ProcedureName);

For a list of the functions that give examples of Discrete-time dynamical systems (some famous), type: HelpDDM();
For help with any of them type: Help(ProcedureName);

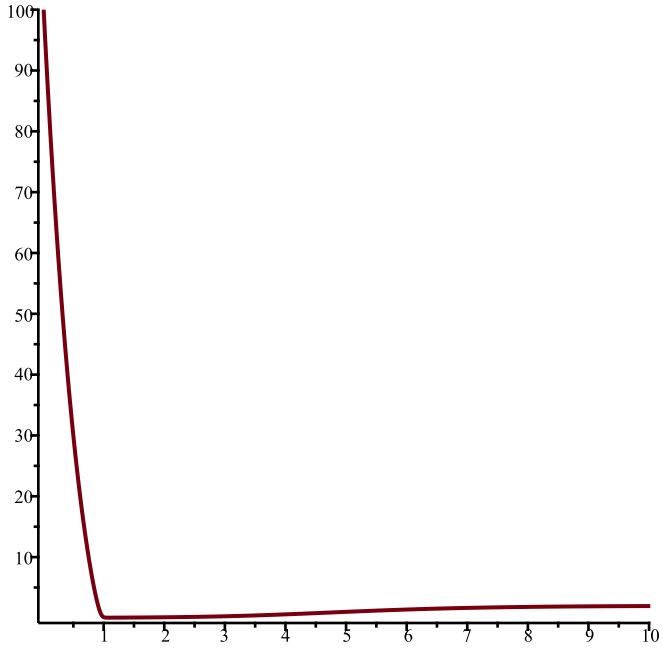
For a list of the functions continuous-time dynamical systems (some famous) type: HelpCDM();
For help with any of them type: Help(ProcedureName);

--- **(1)**

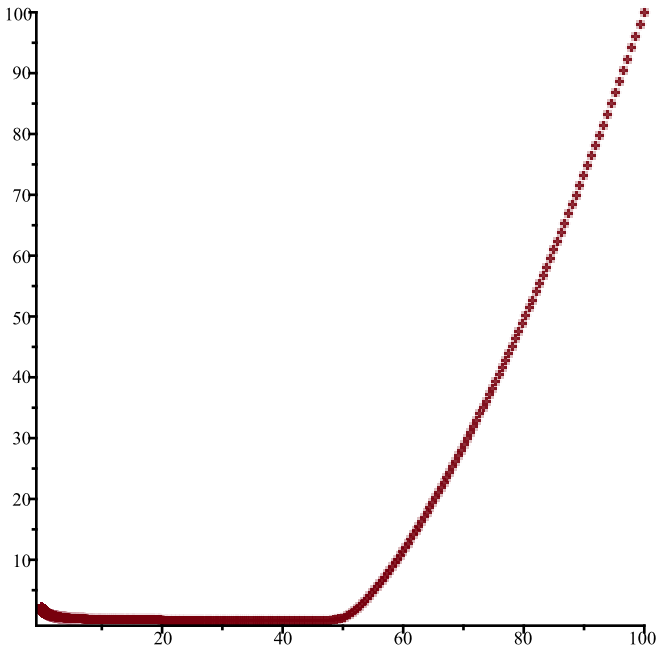
```
> #1
>
>
>
> TimeSeries(ChemoStat(N, C, 0.3, 2), [N, C], [100, 100], 0.01, 10, 1)
```




```
> TimeSeries(ChemoStat(N, C, 0.3, 2), [N, C], [100, 100], 0.01, 10, 2)
```




```
>
> PhaseDiag(ChemoStat(N, C, 0.3, 2), [N, C], [100, 100], 0.01, 10)
```

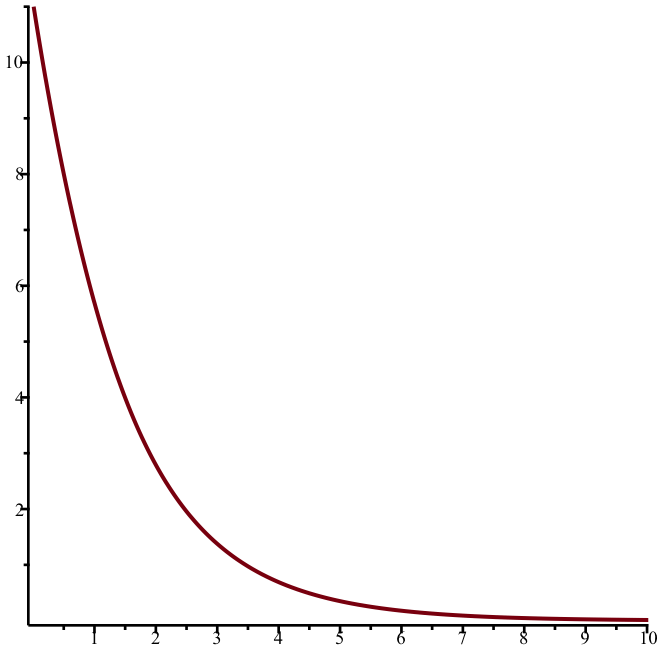


> $SEquP(ChemoStat(N, C, 0.3, 2), [N, C])$

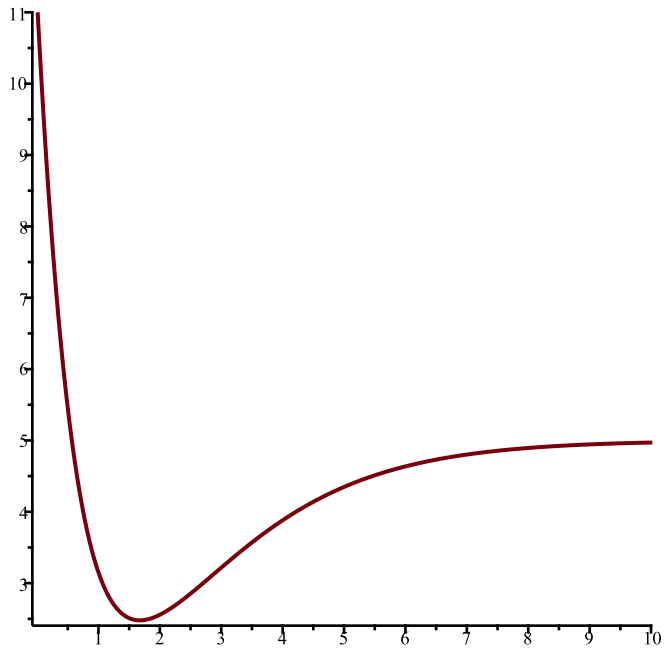
$$\{[0., 2.], [1.028571429, -1.428571429]\} \quad \textbf{(2)}$$

>

> $TimeSeries(ChemoStat(N, C, 0.4, 5), [N, C], [11, 11], 0.01, 10, 1)$



> $TimeSeries(ChemoStat(N, C, 0.4, 5), [N, C], [11, 11], 0.01, 10, 2)$



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>
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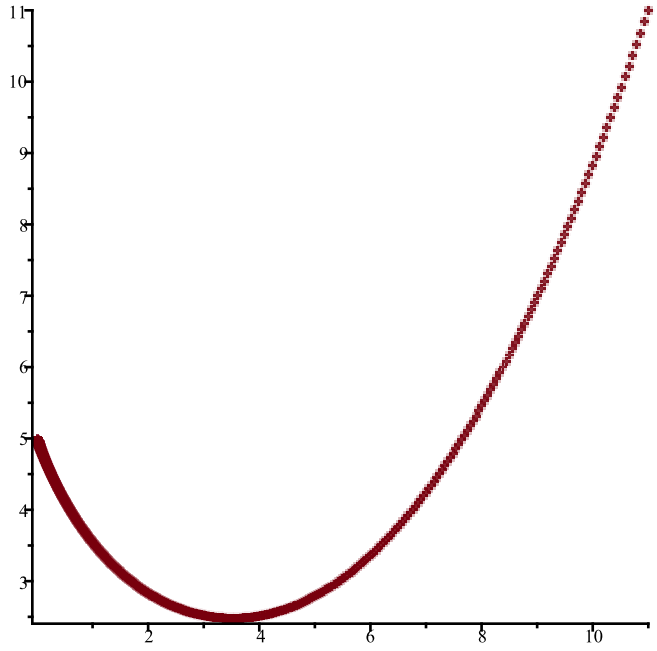
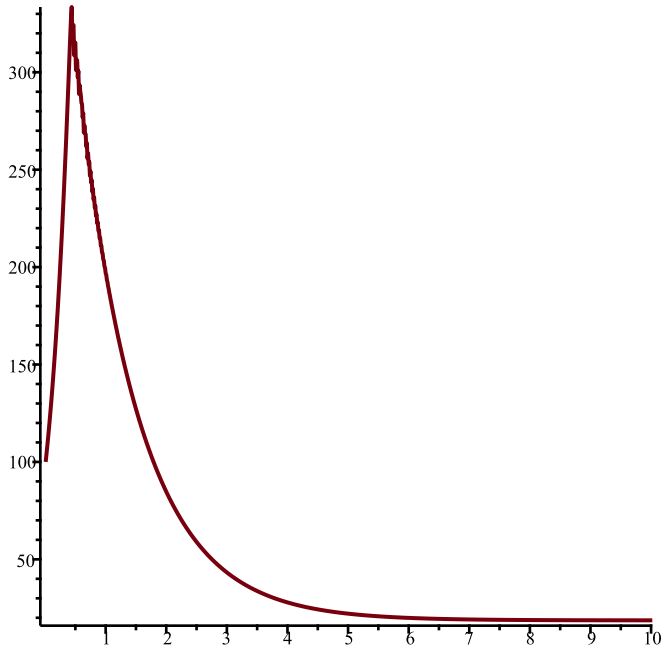
```
> PhaseDiag(ChemoStat(N, C, 0.4, 5), [N, C], [11, 11], 0.01, 10)
```



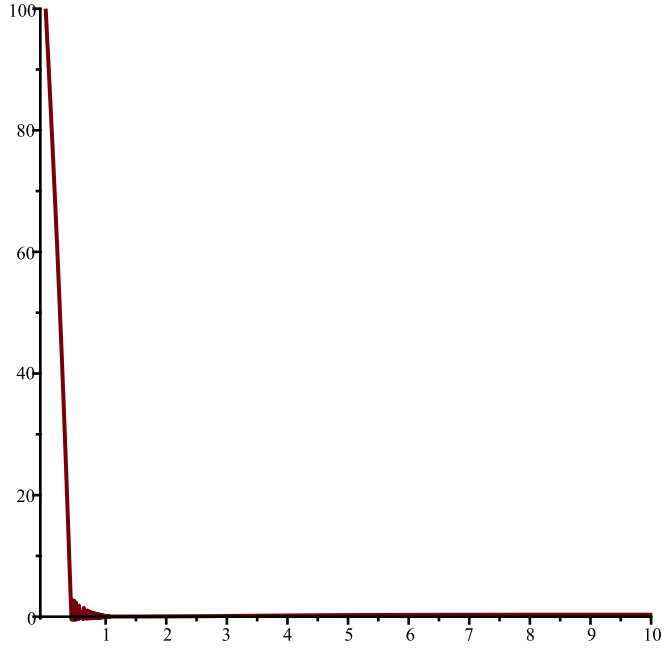
```
> SEquP(ChemoStat(N, C, 0.4, 5), [N, C])
```

$$\{[0., 5.], [2.666666667, -1.666666667]\} \quad \textbf{(3)}$$

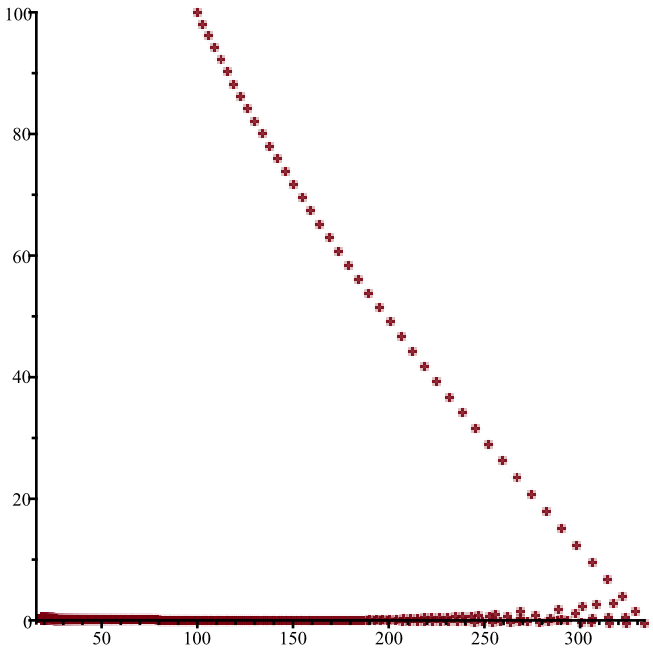
```
> TimeSeries(ChemoStat(N, C, 4, 5), [N, C], [100, 100], 0.01, 10, 1)
```



> $TimeSeries(ChemoStat(N, C, 4, 5), [N, C], [100, 100], 0.01, 10, 2)$



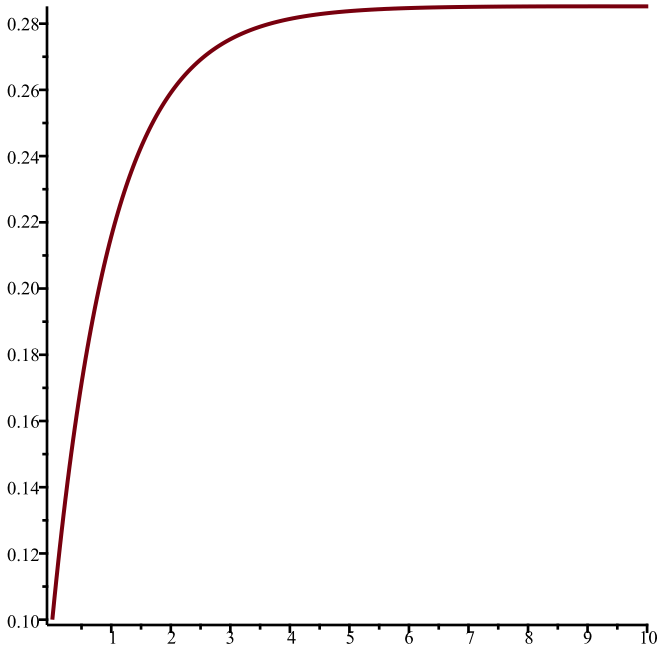
> $PhaseDiag(ChemoStat(N, C, 4, 5), [N, C], [100, 100], 0.01, 10)$



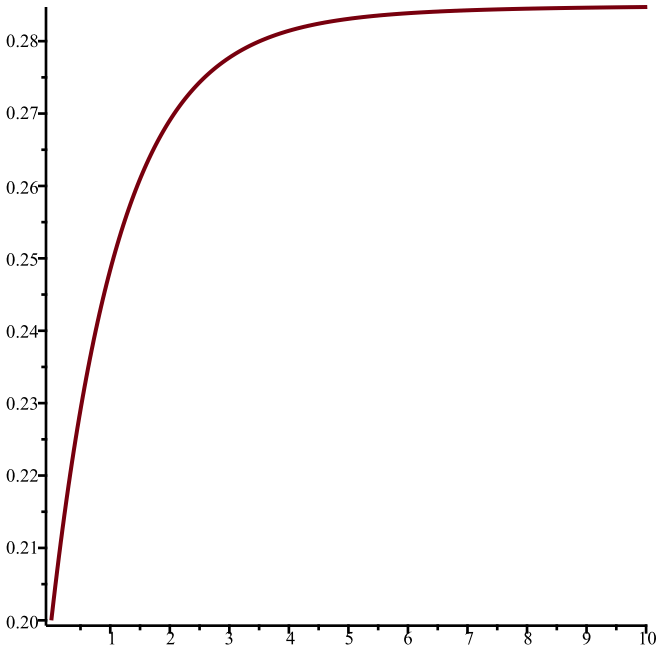

```
> SEquP(ChemoStat(N, C, 4, 5), [N, C])
```

$$\{[18.66666667, 0.3333333333]\} \quad \textbf{(4)}$$

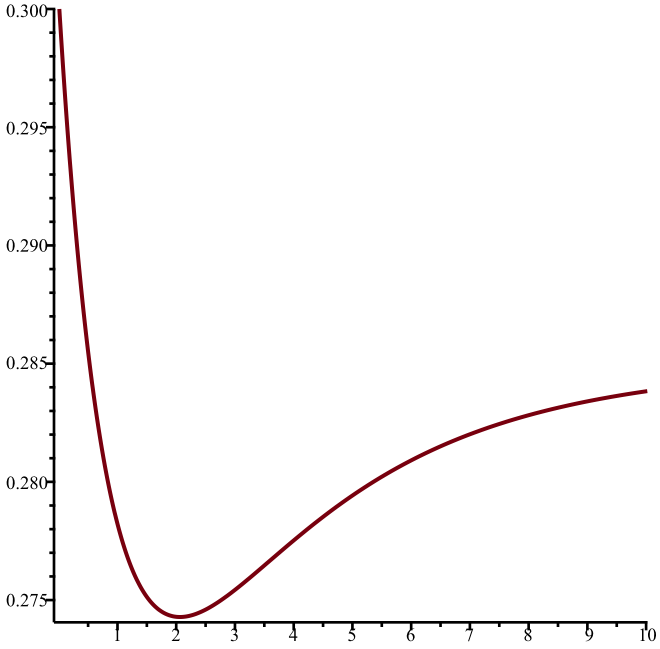
```
>
>
>
> TimeSeries(GeneNet(0.1, 0.2, 0.3, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.1,
      0.2, 0.3, 0.4, 0.5, 0.3], 0.01, 10, 1)
```



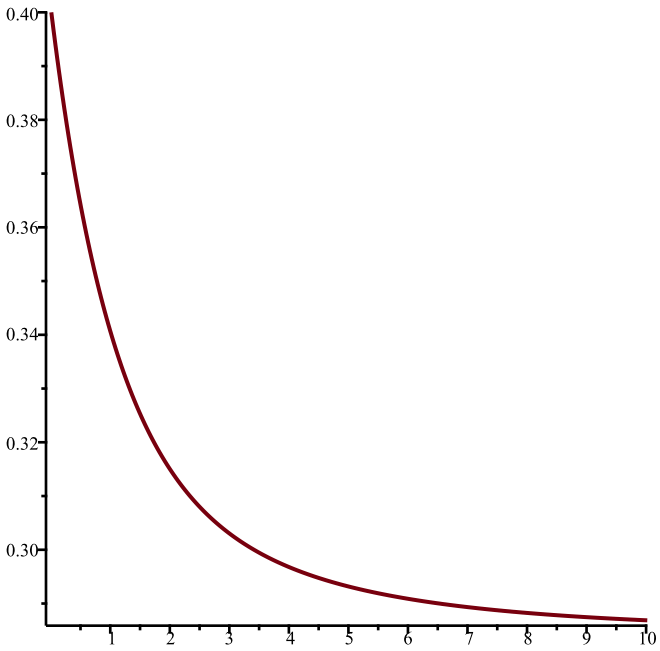

```
> TimeSeries(GeneNet(0.1, 0.2, 0.3, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.1,
      0.2, 0.3, 0.4, 0.5, 0.3], 0.01, 10, 2)
```



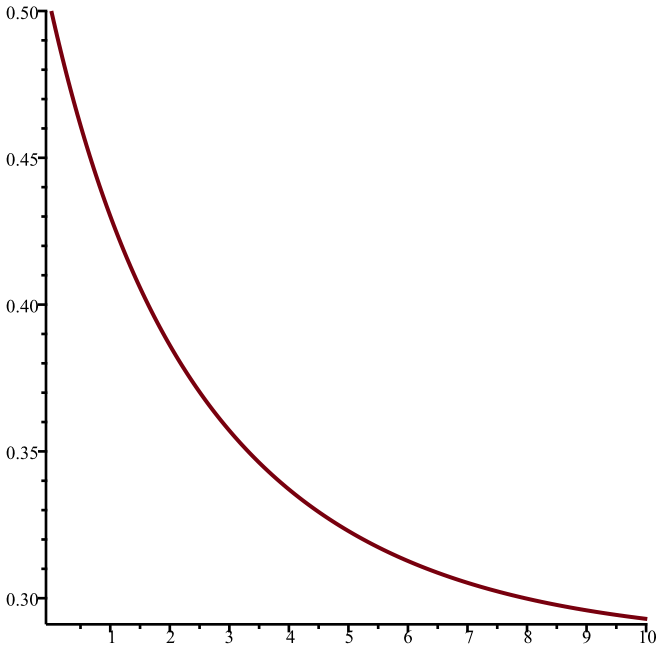
> *TimeSeries*(*GeneNet*(0.1, 0.2, 0.3, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.1, 0.2, 0.3, 0.4, 0.5, 0.3], 0.01, 10, 3)



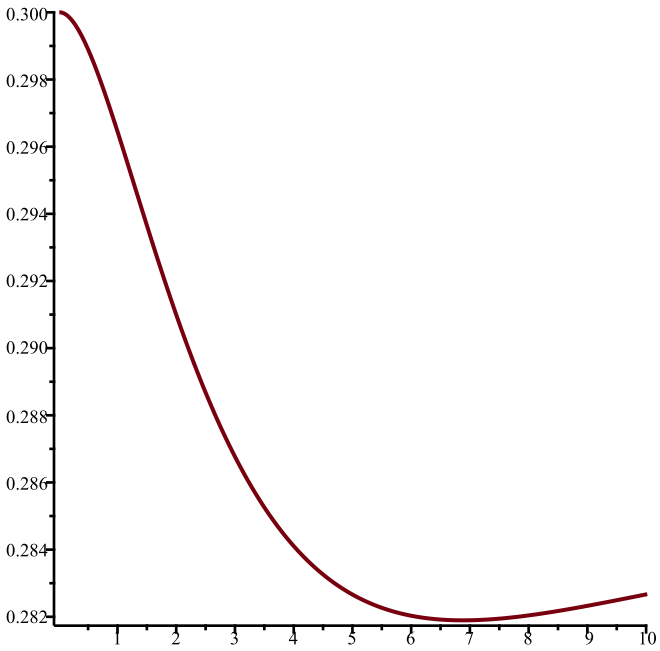
> *TimeSeries*(*GeneNet*(0.1, 0.2, 0.3, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.1, 0.2, 0.3, 0.4, 0.5, 0.3], 0.01, 10, 4)



> $TimeSeries(GeneNet(0.1, 0.2, 0.3, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.1, 0.2, 0.3, 0.4, 0.5, 0.3], 0.01, 10, 5)$



> $TimeSeries(GeneNet(0.1, 0.2, 0.3, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.1, 0.2, 0.3, 0.4, 0.5, 0.3], 0.01, 10, 6)$



> *SEquP*(*GeneNet*(0.1, 0.2, 0.3, 2, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*])

{[0.2849775630, 0.2849775630, 0.2849775630, 0.2849775630, 0.2849775630, 0.2849775630]} **(5)**

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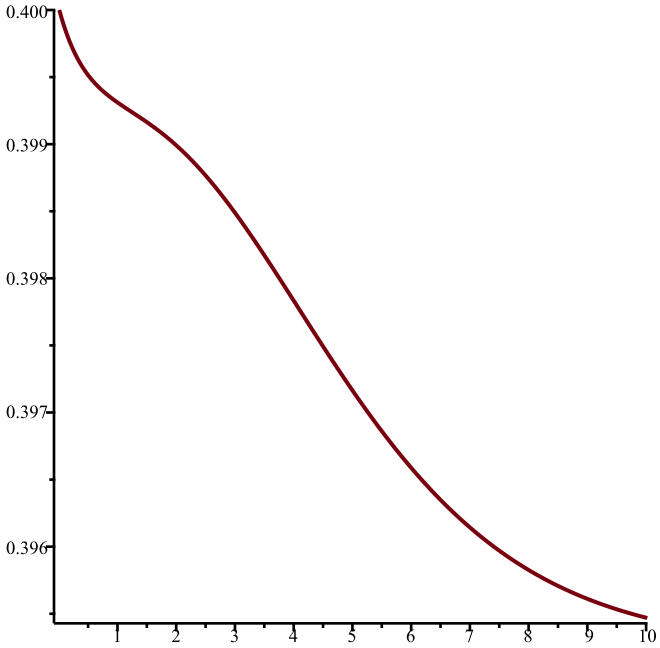
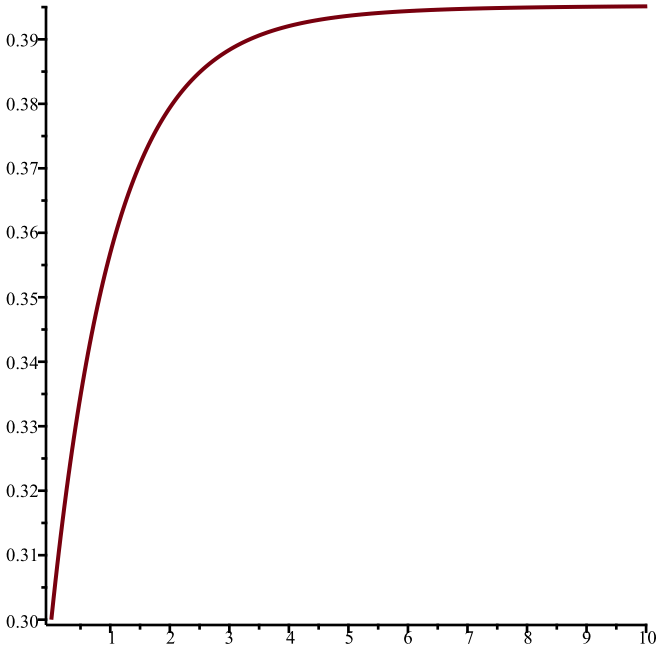
> *TimeSeries*(*GeneNet*(0.2, 0.2, 0.5, 4, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.4, 0.3, 0.1, 0.5, 0.5, 0.3], 0.01, 10, 1)

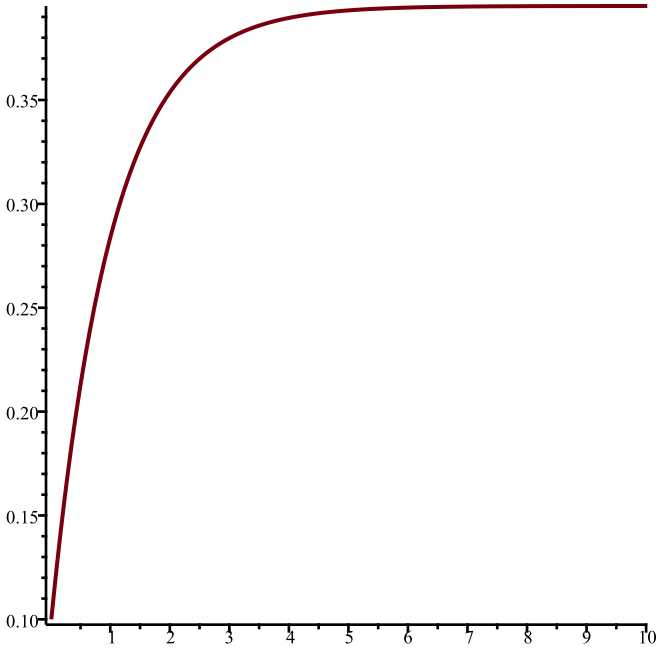


> *TimeSeries*(*GeneNet*(0.2, 0.2, 0.5, 4, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.4,

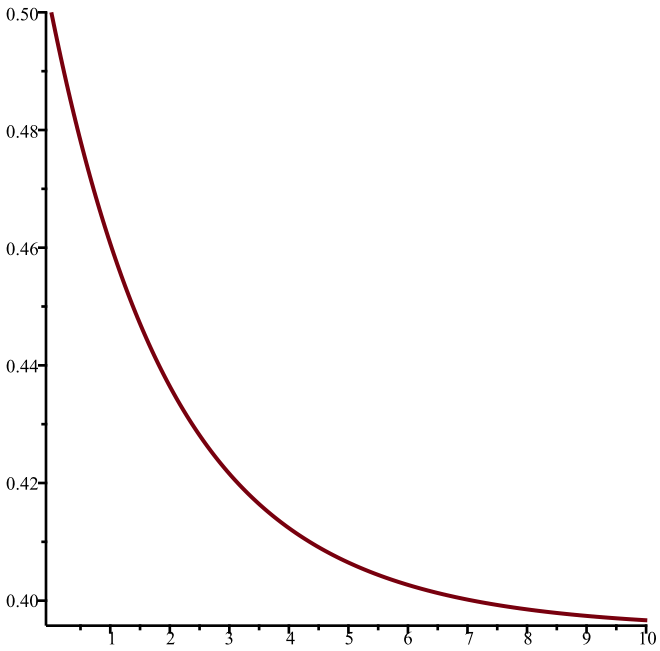
0.3, 0.1, 0.5, 0.5, 0.3], 0.01, 10, 2)



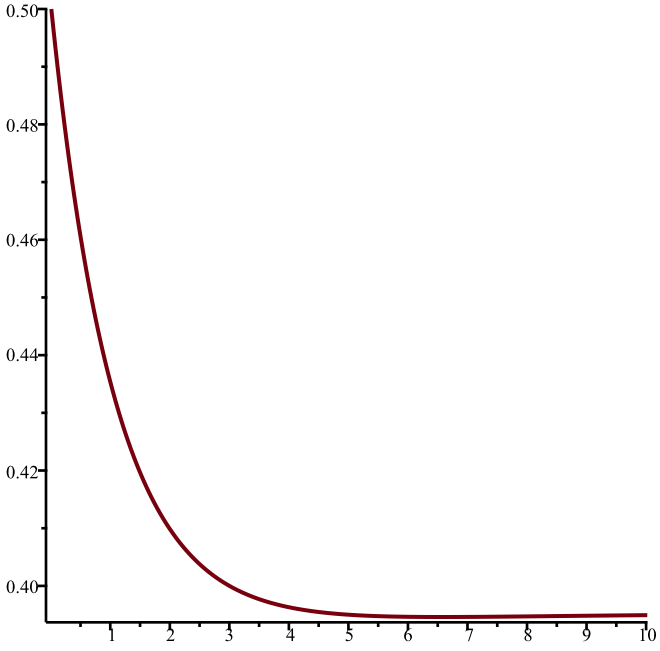
> *TimeSeries*(*GeneNet*(0.2, 0.2, 0.5, 4, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.4, 0.3, 0.1, 0.5, 0.5, 0.3], 0.01, 10, 3)



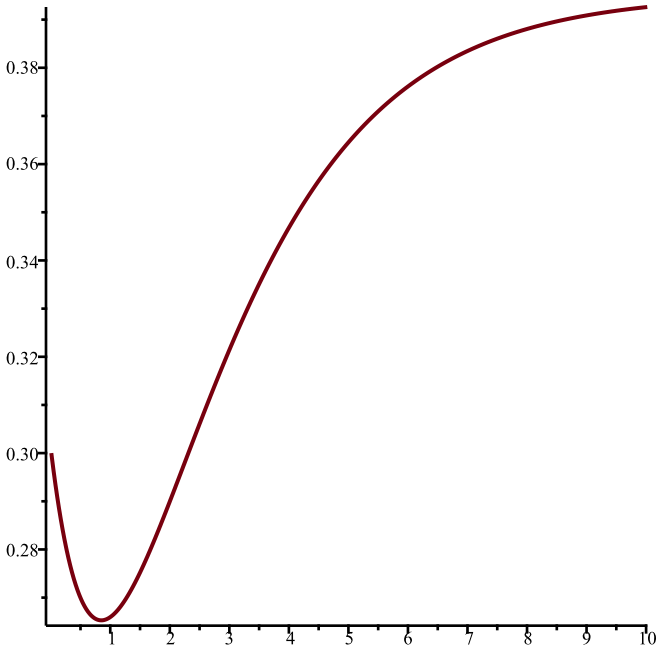
> *TimeSeries*(*GeneNet*(0.2, 0.2, 0.5, 4, *m1*, *m2*, *m3*, *p1*, *p2*, *p3*), [*m1*, *m2*, *m3*, *p1*, *p2*, *p3*], [0.4, 0.3, 0.1, 0.5, 0.5, 0.3], 0.01, 10, 4)



> $TimeSeries(GeneNet(0.2, 0.2, 0.5, 4, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.4, 0.3, 0.1, 0.5, 0.5, 0.3], 0.01, 10, 5)$



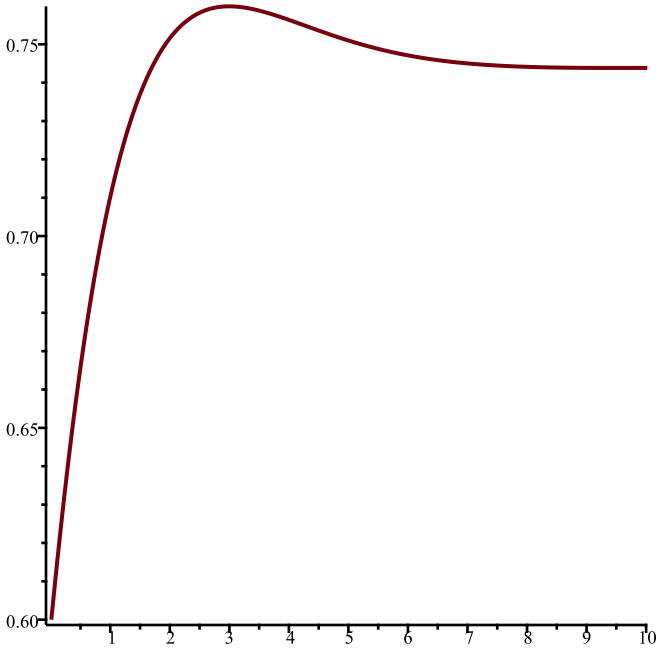
> $TimeSeries(GeneNet(0.2, 0.2, 0.5, 4, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.4, 0.3, 0.1, 0.5, 0.5, 0.3], 0.01, 10, 6)$



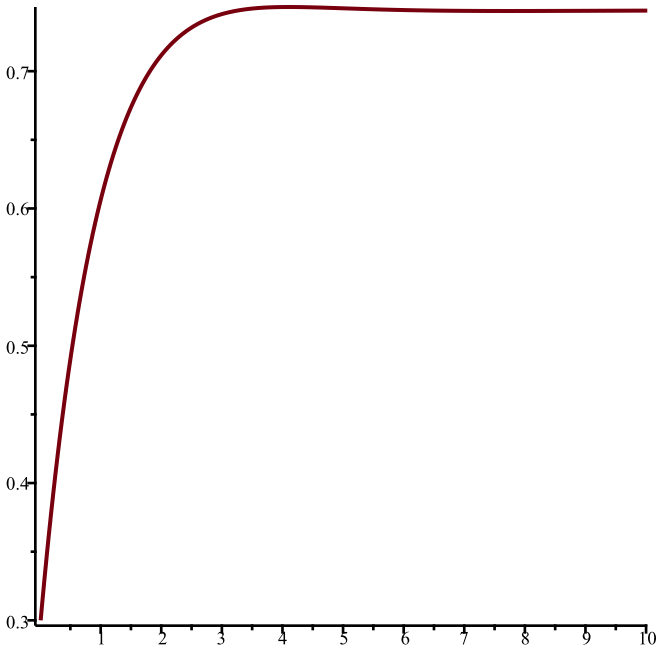

```
> SEquP(GeneNet(0.1, 0.2, 0.3, 2, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3])
```

{[0.2849775630, 0.2849775630, 0.2849775630, 0.2849775630, 0.2849775630, 0.2849775630]} **(6)**

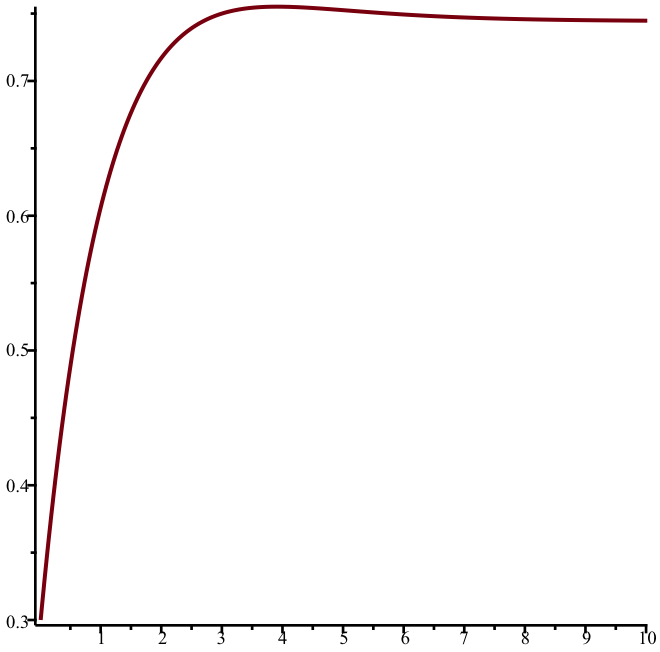
```
>
>
>
> TimeSeries(GeneNet(0.5, 0.3, 0.7, 5, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.6,
      0.3, 0.3, 0.5, 0.6, 0.7], 0.01, 10, 1)
```



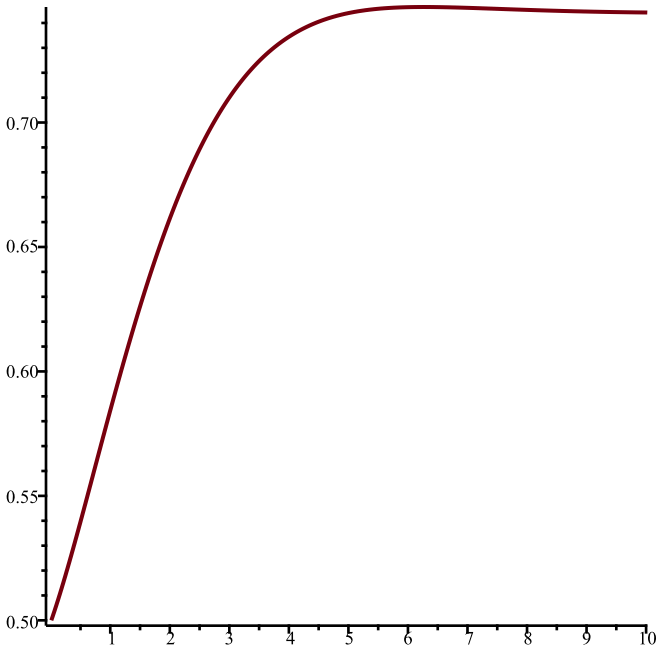

```
> TimeSeries(GeneNet(0.5, 0.3, 0.7, 5, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.6,
      0.3, 0.3, 0.5, 0.6, 0.7], 0.01, 10, 2)
```



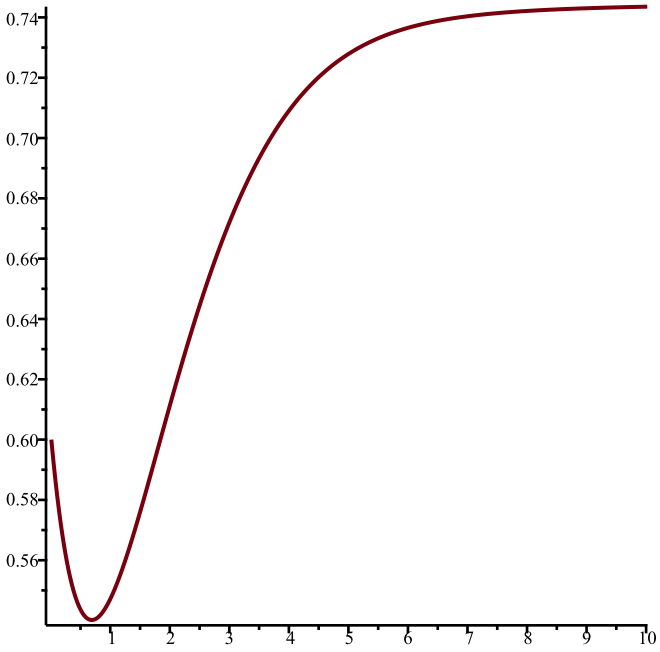
> $TimeSeries(GeneNet(0.5, 0.3, 0.7, 5, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.6, 0.3, 0.3, 0.5, 0.6, 0.7], 0.01, 10, 3)$



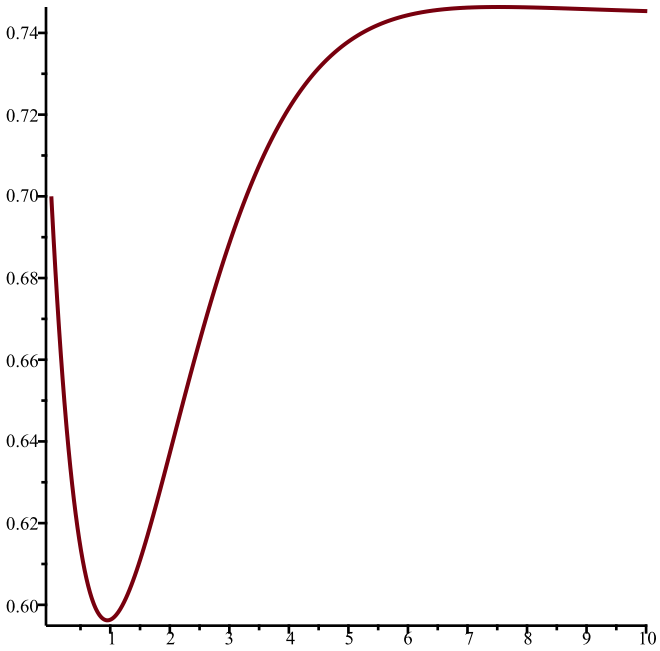
> $TimeSeries(GeneNet(0.5, 0.3, 0.7, 5, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.6, 0.3, 0.3, 0.5, 0.6, 0.7], 0.01, 10, 4)$



> $TimeSeries(GeneNet(0.5, 0.3, 0.7, 5, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.6, 0.3, 0.3, 0.5, 0.6, 0.7], 0.01, 10, 5)$



> $TimeSeries(GeneNet(0.5, 0.3, 0.7, 5, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3], [0.6, 0.3, 0.3, 0.5, 0.6, 0.7], 0.01, 10, 6)$



> $SEquP(GeneNet(0.5, 0.3, 0.7, 5, m1, m2, m3, p1, p2, p3), [m1, m2, m3, p1, p2, p3])$ **(7)**

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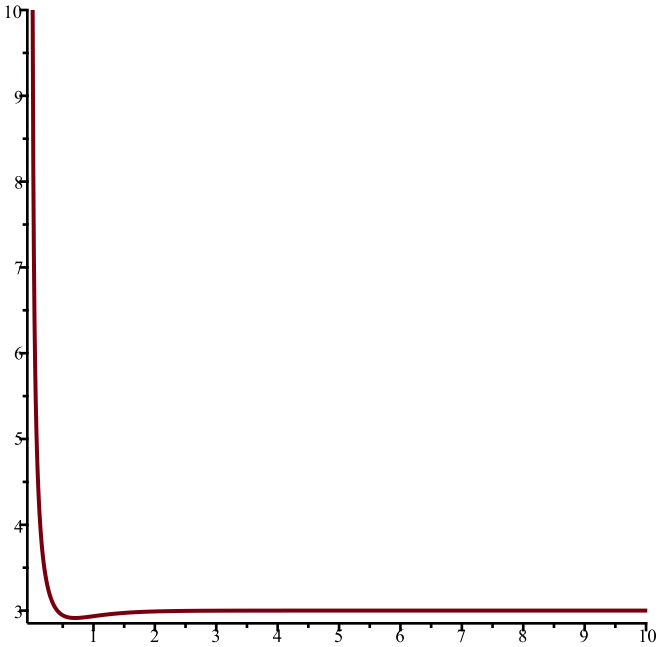
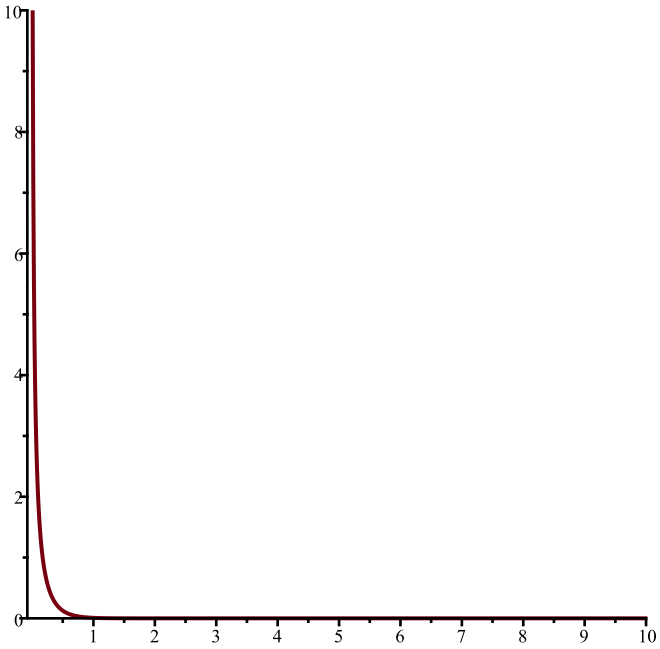
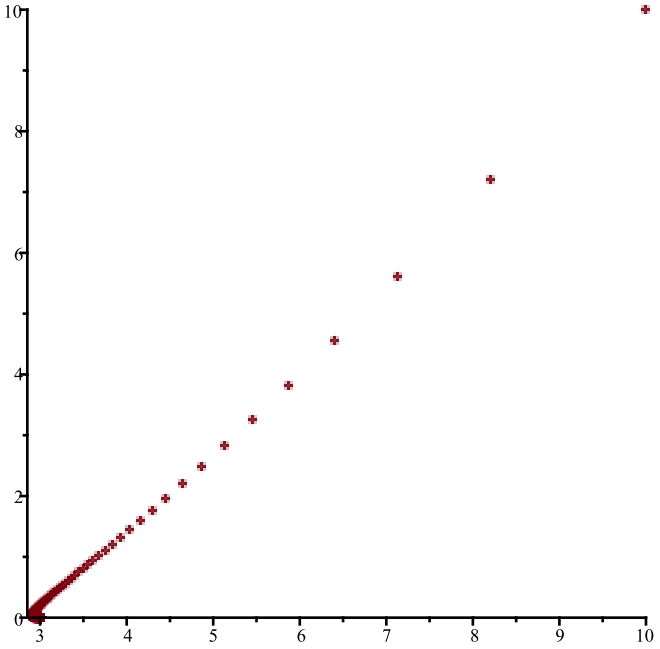
> $TimeSeries(Lotka(2, 3, 2, 4, 2, 5, N1, N2), [N1, N2], [10, 10], 0.01, 10, 1)$



> $TimeSeries(Lotka(2, 3, 2, 4, 2, 5, N1, N2), [N1, N2], [10, 10], 0.01, 10, 2)$



> $PhaseDiag(Lotka(2, 3, 2, 4, 2, 5, N1, N2), [N1, N2], [10, 10], 0.01, 10)$



> $SEquP(Lotka(2, 3, 2, 4, 2, 5, N1, N2), [N1, N2])$

$$\{[0., 4.], [3., 0.]\} \quad \textbf{(8)}$$

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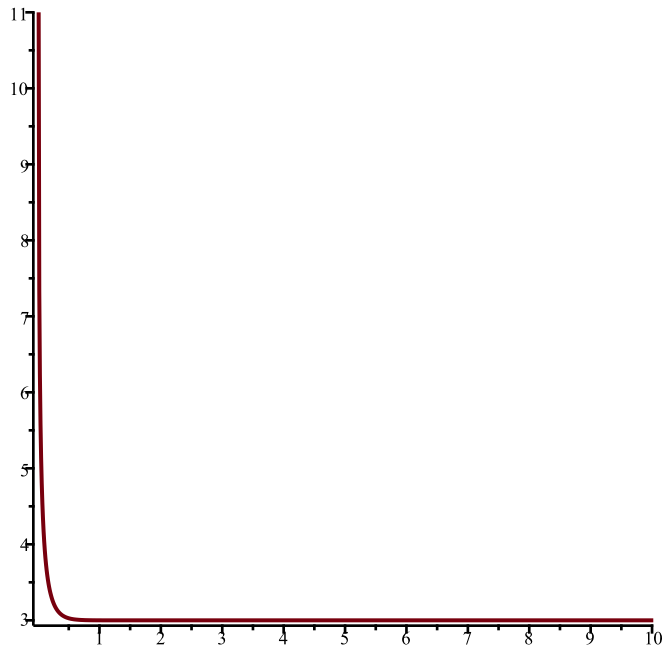
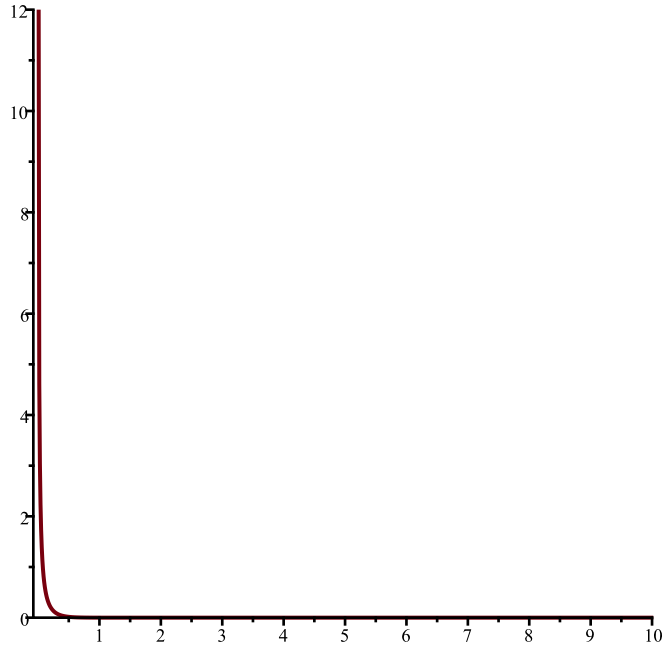
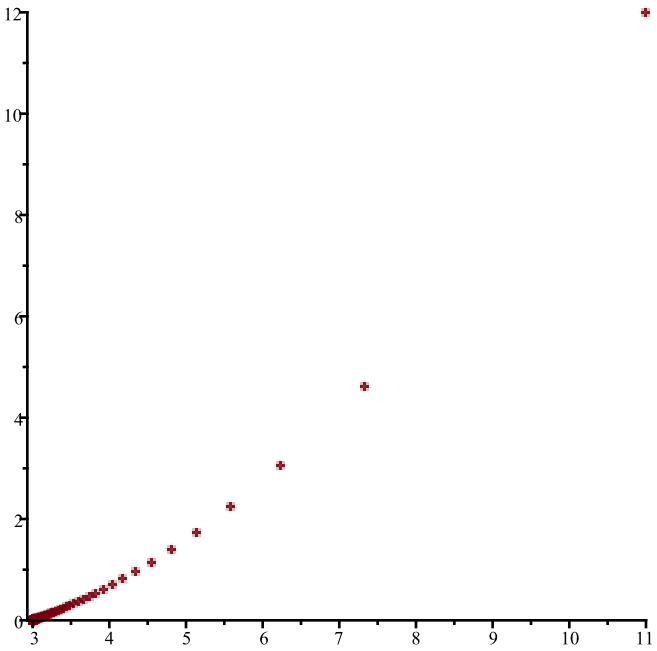
> $TimeSeries(Lotka(5, 3, 6, 4, 1, 3, N1, N2), [N1, N2], [11, 12], 0.01, 10, 1)$



> $TimeSeries(Lotka(5, 3, 6, 4, 1, 3, N1, N2), [N1, N2], [11, 12], 0.01, 10, 2)$



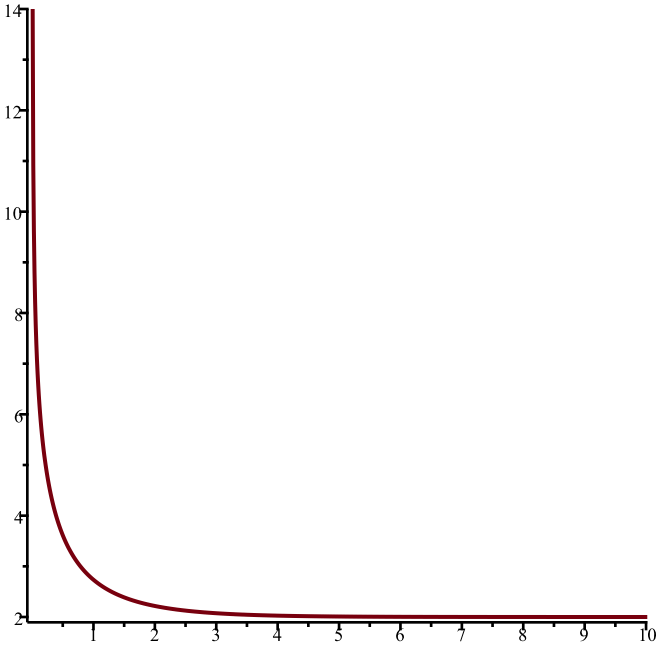
> $PhaseDiag(Lotka(5, 3, 6, 4, 1, 3, N1, N2), [N1, N2], [11, 12], 0.01, 10)$



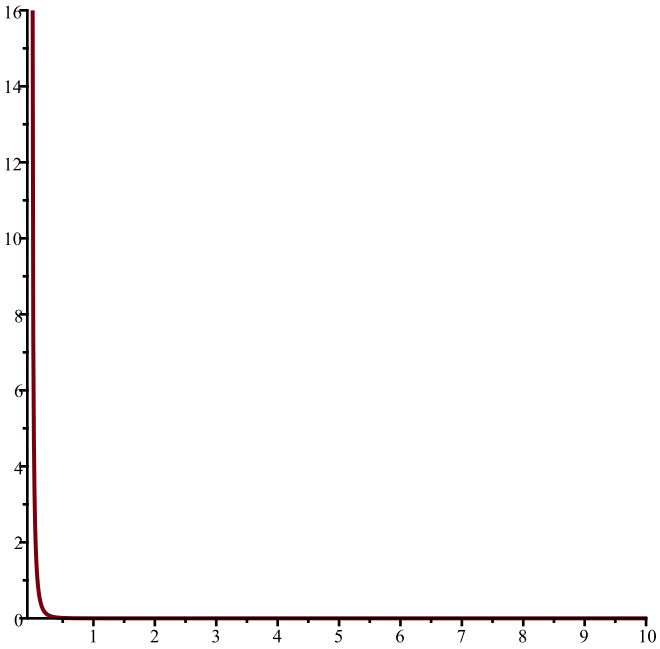

```
> SEquP(Lotka(5, 3, 6, 4, 1, 3, N1, N2), [N1, N2])
```

$$\{[0., 4.], [3., 0.]\} \quad \textbf{(9)}$$

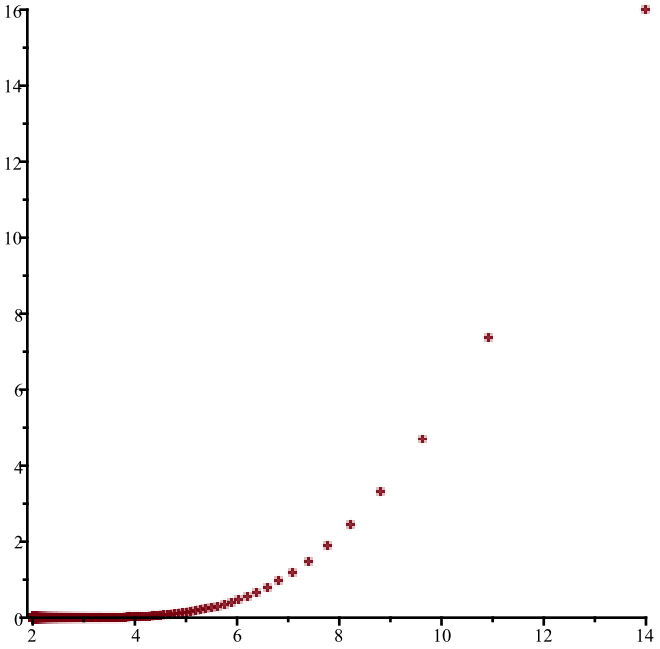
```
>
>
>
>
> TimeSeries(Lotka(1, 2, 4, 4, 2, 3, N1, N2), [N1, N2], [14, 16], 0.01, 10, 1)
```




```
> TimeSeries(Lotka(1, 2, 4, 4, 2, 3, N1, N2), [N1, N2], [14, 16], 0.01, 10, 2)
```



> $PhaseDiag(Lotka(1, 2, 4, 4, 2, 3, N1, N2), [N1, N2], [14, 16], 0.01, 10)$



> $SEquP(Lotka(1, 2, 4, 4, 2, 3, N1, N2), [N1, N2])$

$$\{[0., 4.], [2., 0.]\} \quad \textbf{(10)}$$

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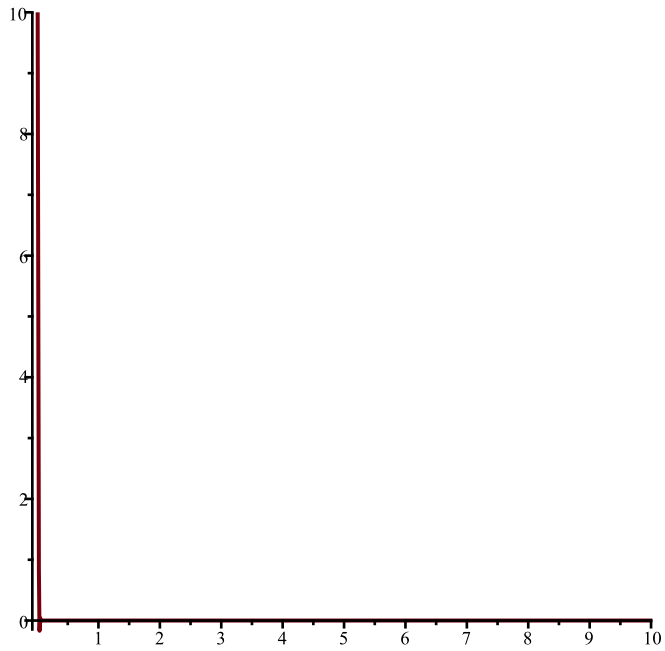
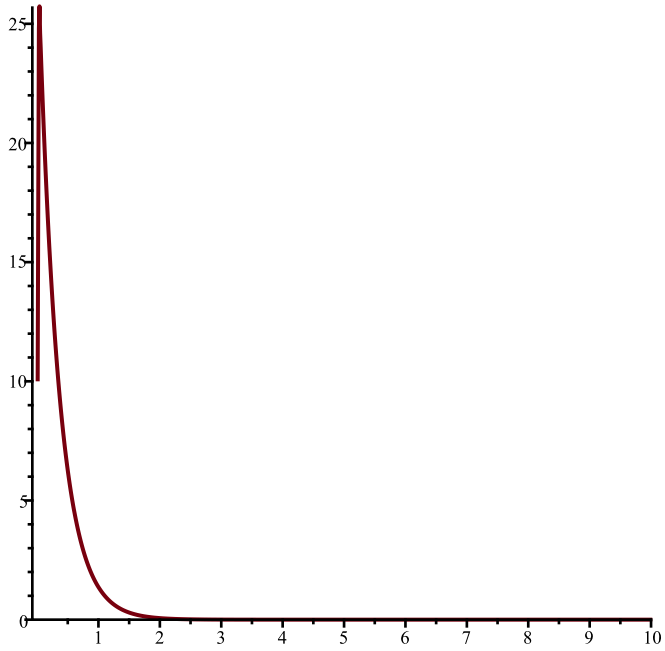
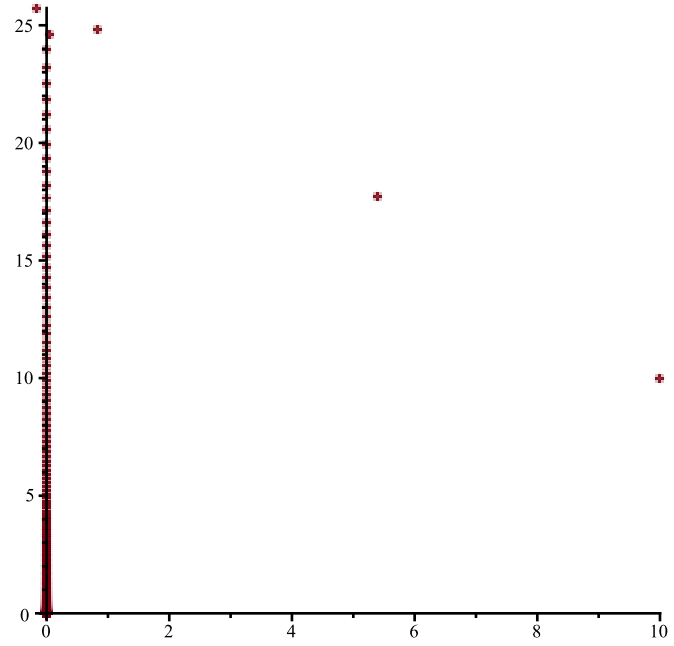
> $TimeSeries(Volterra(4, 5, 3, 8, x, y), [x, y], [10, 10], 0.01, 10, 1)$



> $TimeSeries(Volterra(4, 5, 3, 8, x, y), [x, y], [10, 10], 0.01, 10, 2)$



> $PhaseDiag(Volterra(4, 5, 3, 8, x, y), [x, y], [10, 10], 0.01, 10, 1)$



> $SEquP(Volterra(4, 5, 3, 8, x, y), [x, y])$

$\varnothing$ **(11)**

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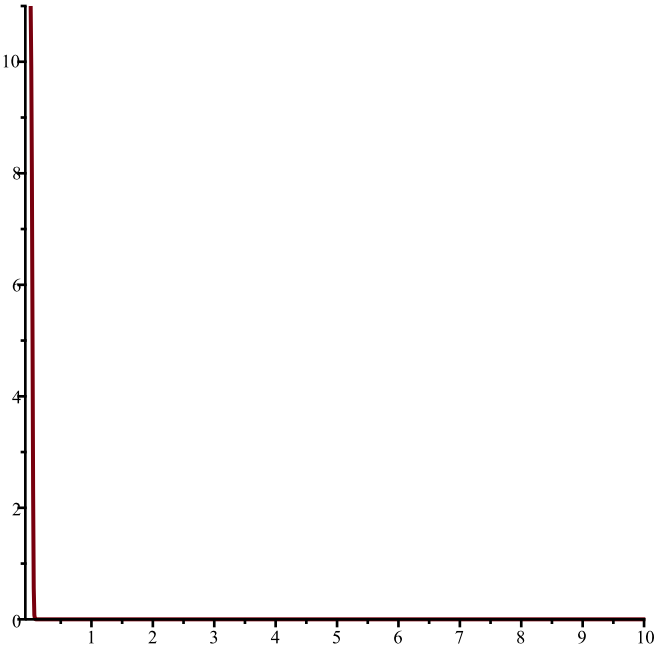
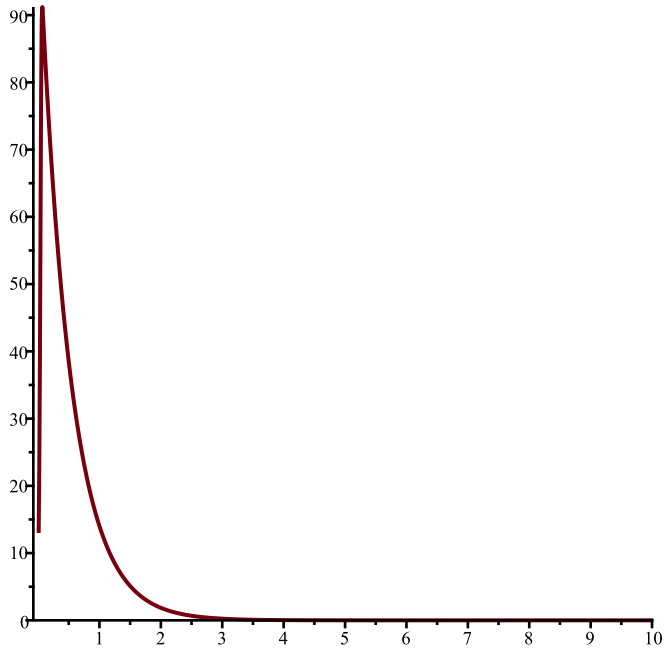
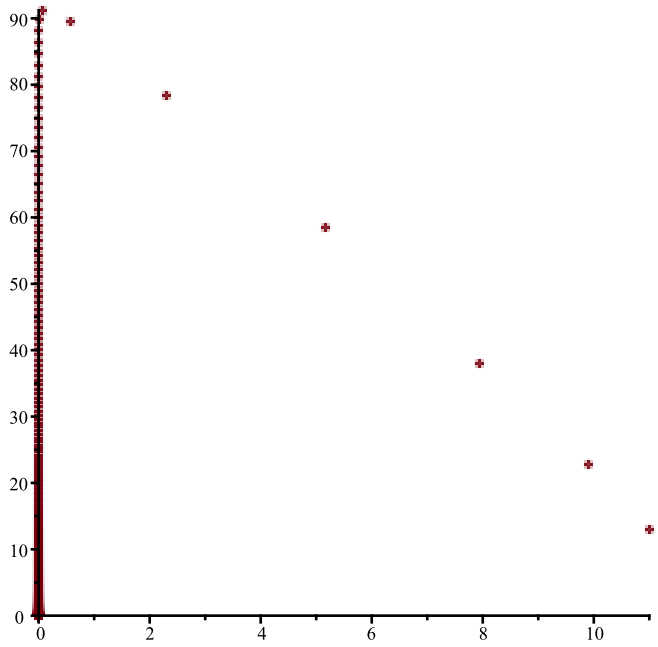
> $TimeSeries(Volterra(3, 1, 2, 7, x, y), [x, y], [11, 13], 0.01, 10, 1)$



> $TimeSeries(Volterra(3, 1, 2, 7, x, y), [x, y], [11, 13], 0.01, 10, 2)$



> $PhaseDiag(Volterra(3, 1, 2, 7, x, y), [x, y], [11, 13], 0.01, 10)$



> $SEquP(Volterra(3, 1, 2, 7, x, y), [x, y])$

$\varnothing$ **(12)**

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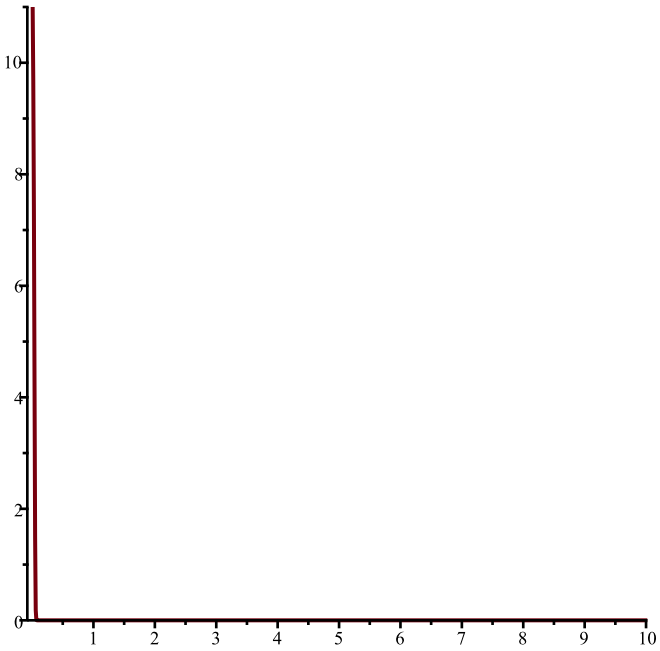
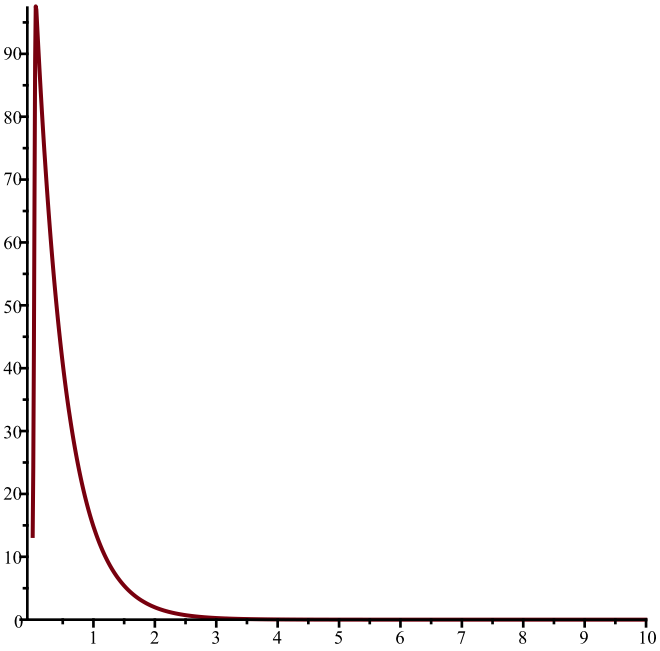
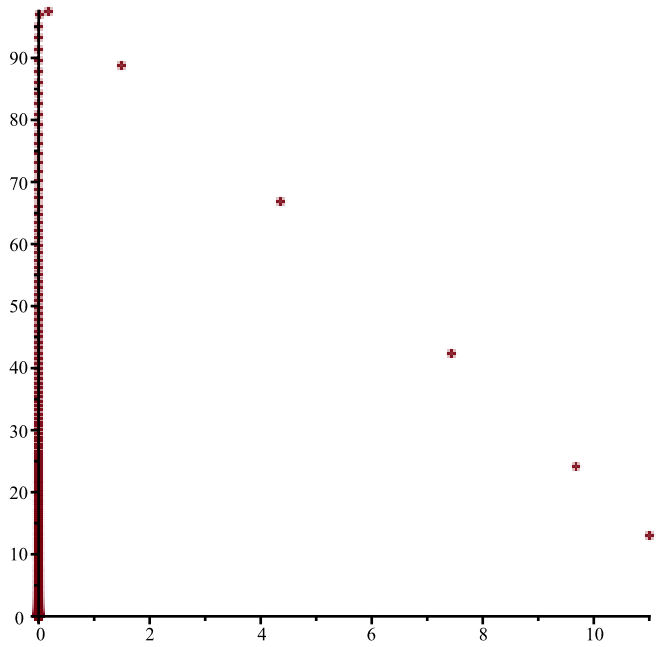
> $TimeSeries(Volterra(1, 1, 2, 8, x, y), [x, y], [11, 13], 0.01, 10, 1)$



> $TimeSeries(Volterra(1, 1, 2, 8, x, y), [x, y], [11, 13], 0.01, 10, 2)$



> $PhaseDiag(Volterra(1, 1, 2, 8, x, y), [x, y], [11, 13], 0.01, 10)$



> $SEquP(Volterra(1, 1, 2, 8, x, y), [x, y])$

$\varnothing$ **(13)**

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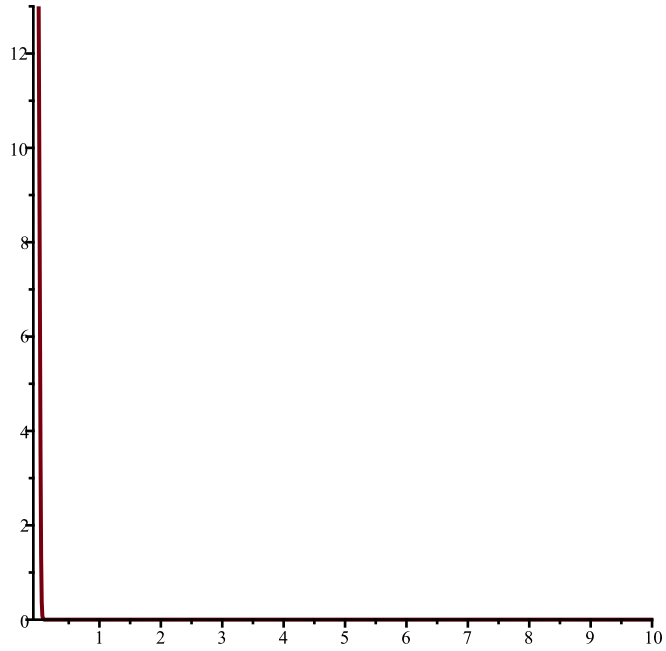
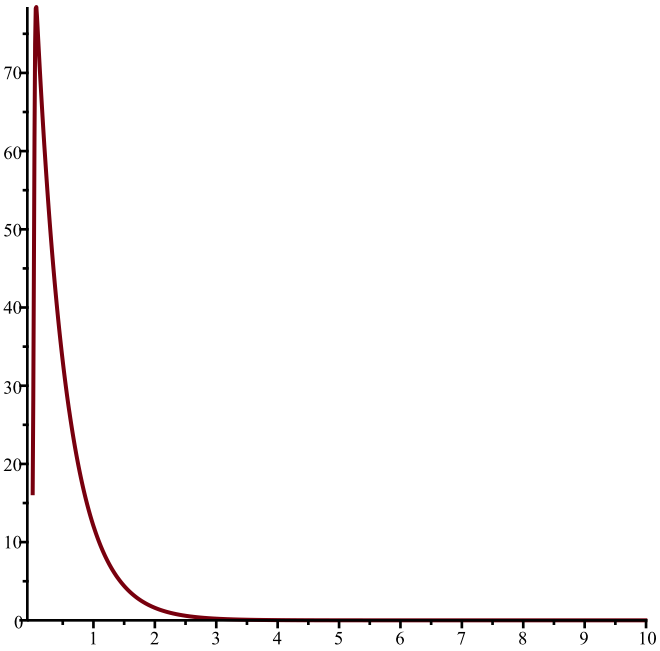
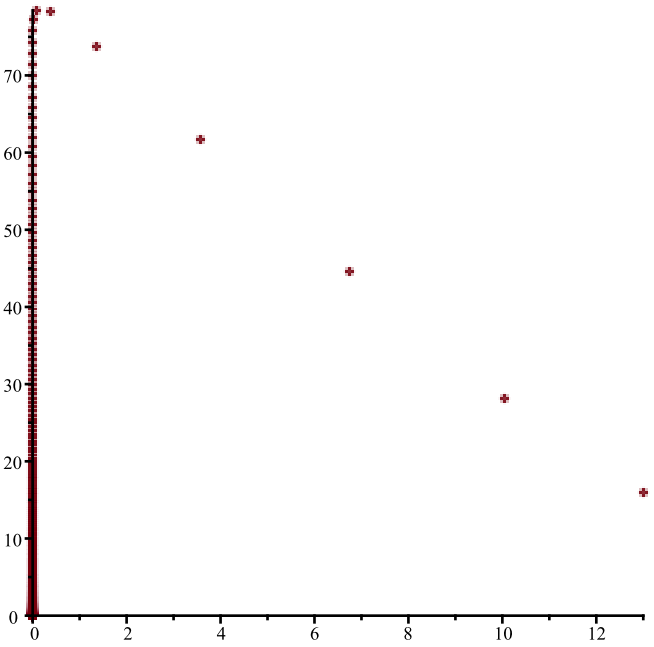
> $TimeSeries(VolterraM(2, 1, 2, 3, 6, x, y), [x, y], [13, 16], 0.01, 10, 1)$



> $TimeSeries(VolterraM(2, 1, 2, 3, 6, x, y), [x, y], [13, 16], 0.01, 10, 2)$



> $PhaseDiag(VolterraM(2, 1, 2, 3, 6, x, y), [x, y], [13, 16], 0.01, 10)$



> $SEquP(VolterraM(2, 1, 2, 3, 6, x, y), [x, y])$

$\{[0.3333333333, 1.777777778]\}$ **(14)**

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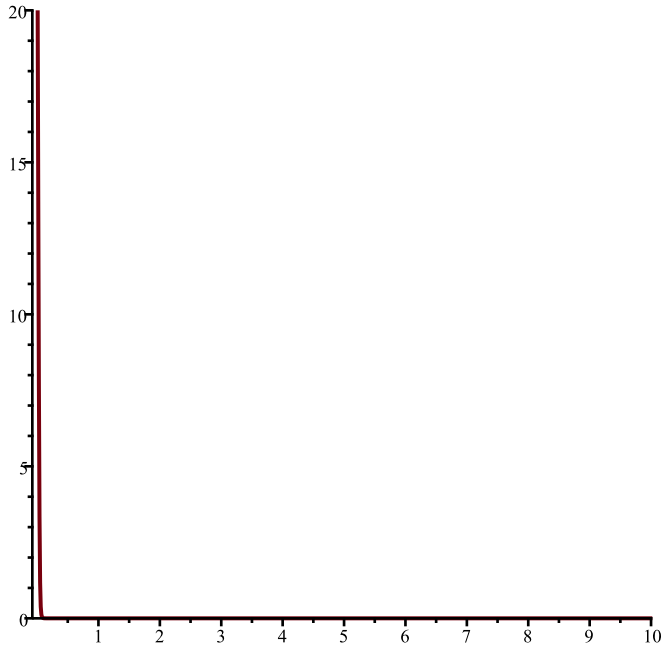
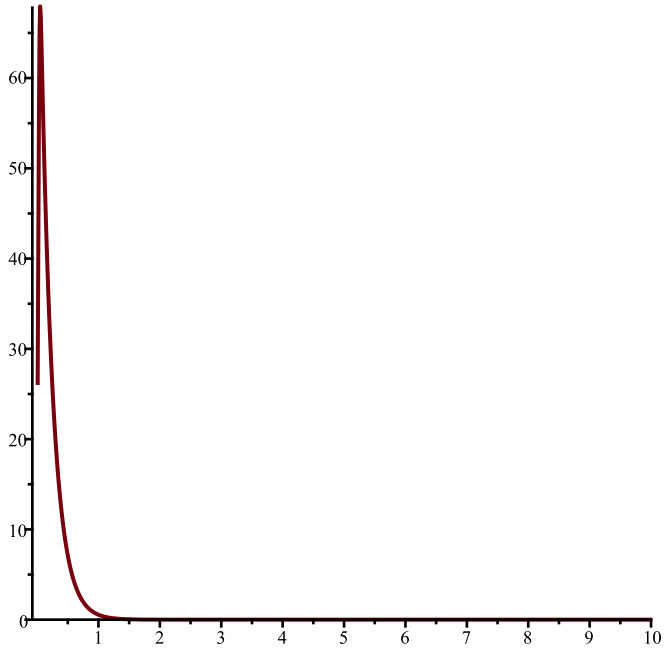
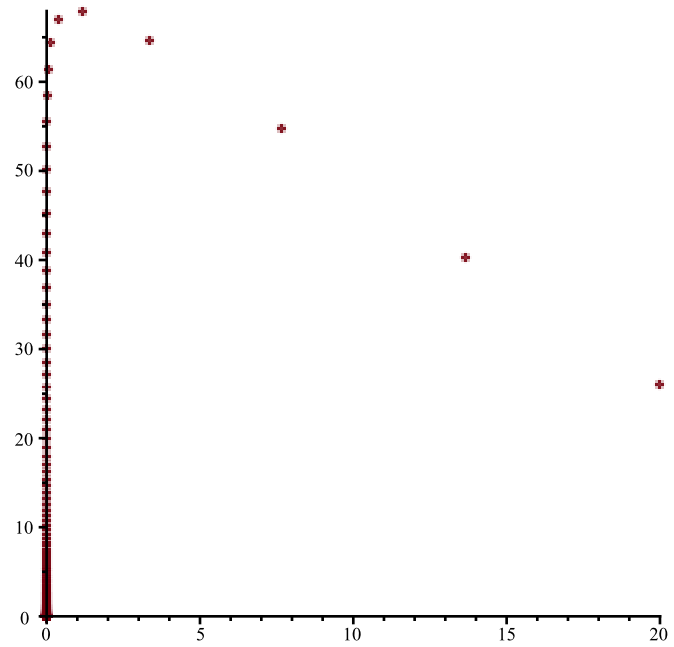
> $TimeSeries(VolterraM(1, 1, 5, 3, 3, x, y), [x, y], [20, 26], 0.01, 10, 1)$



> $TimeSeries(VolterraM(1, 1, 5, 3, 3, x, y), [x, y], [20, 26], 0.01, 10, 2)$



> $PhaseDiag(VolterraM(1, 1, 5, 3, 3, x, y), [x, y], [20, 26], 0.01, 10)$




```
> SEquP(VolterraM(1, 1, 5, 3, 3, x, y), [x, y])
```

$$\{[1.666666667, 0.4444444444]\} \quad \textbf{(15)}$$

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>
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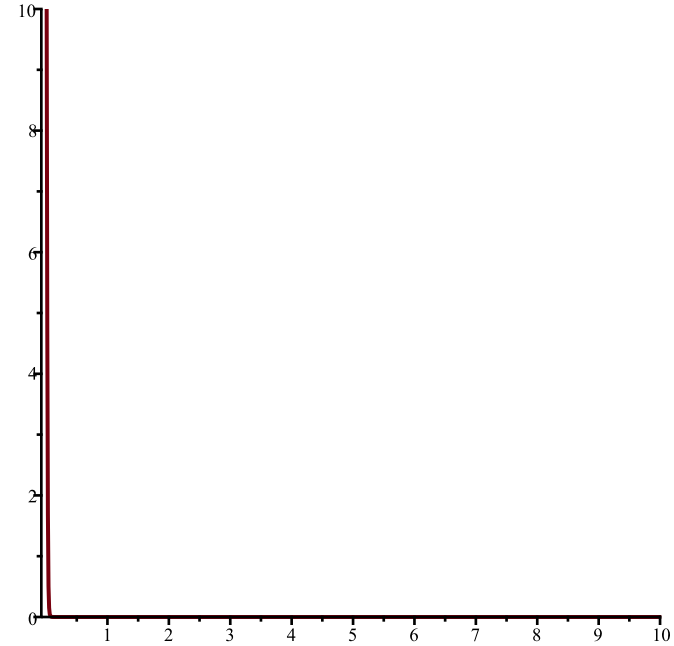
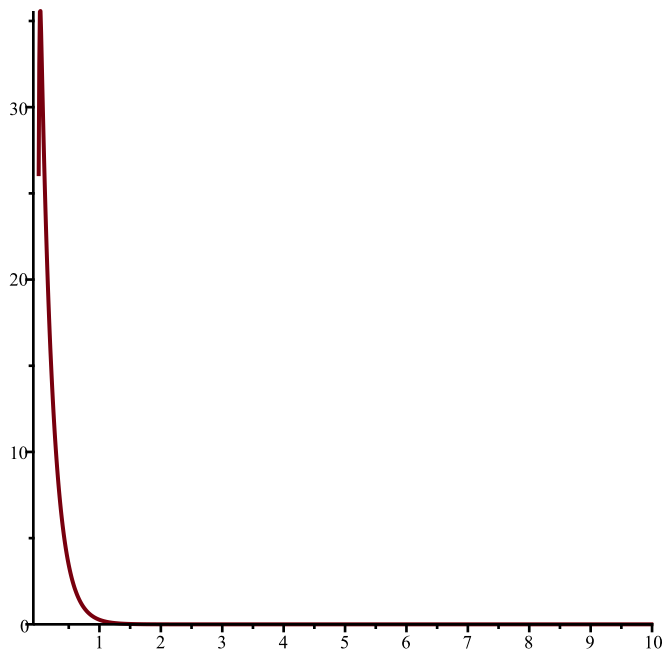
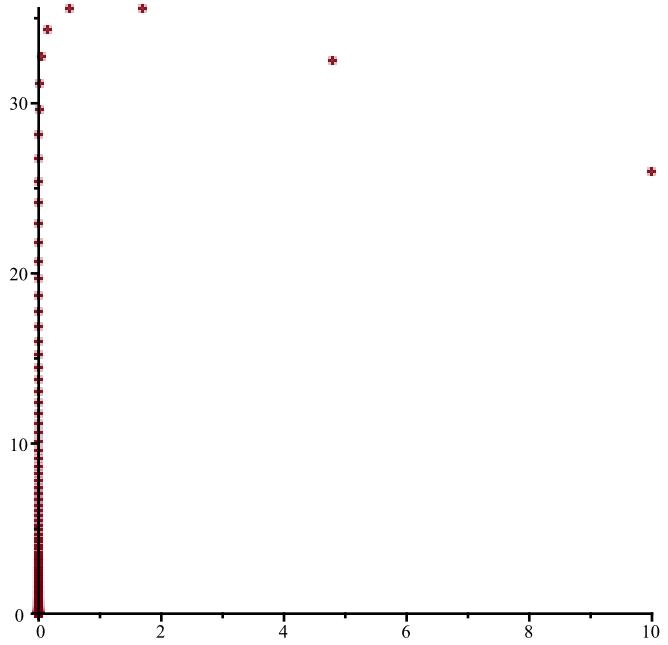
>
> TimeSeries(VolterraM(1, 2, 5, 9, 3, x, y), [x, y], [10, 26], 0.01, 10, 1)
```




```
> TimeSeries(VolterraM(1, 2, 5, 9, 3, x, y), [x, y], [10, 26], 0.01, 10, 2)
```



> $PhaseDiag(VolterraM(1, 2, 5, 9, 3, x, y), [x, y], [10, 26], 0.01, 10)$



> $SEquP(VolterraM(1, 2, 5, 9, 3, x, y), [x, y])$

$$\{[1.666666667, 0.4074074074]\} \quad \textbf{(16)}$$

>