

M7116 Maticové populační modely

Populace s interní variabilitou

11.5.2015

Populace strukturovaná podle plodnosti

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\begin{aligned} \lambda &= \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \\ &= \frac{1}{2} \left(\sigma_1(1-\gamma) + \sigma_2 + \sqrt{(\sigma_1(1-\gamma) - \sigma_2)^2 + 4\sigma_1\gamma\varphi} \right) \end{aligned}$$

$$\lambda > 1 \Leftrightarrow \sigma_1\gamma\varphi \geq (1-\sigma_2)(1-(\sigma_1(1-\gamma)))$$

Populace strukturovaná podle plodnosti

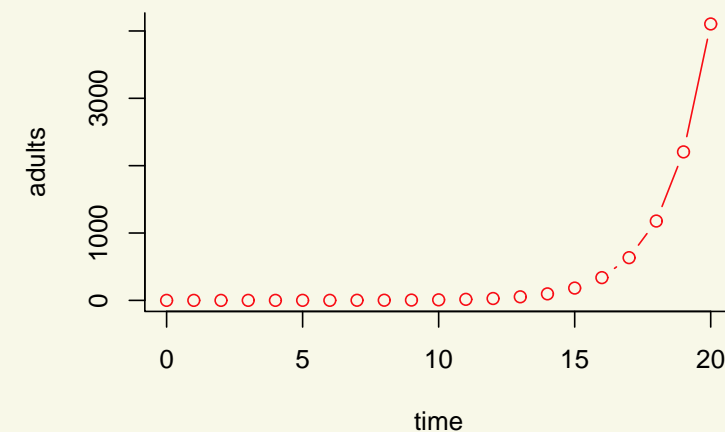
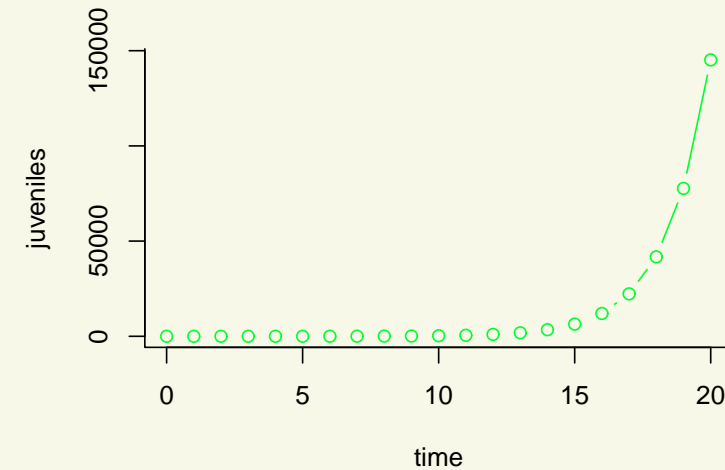
$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\begin{aligned} \lambda &= \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \\ &= \frac{1}{2} \left(\sigma_1(1 - \gamma) + \sigma_2 + \sqrt{(\sigma_1(1 - \gamma) - \sigma_2)^2 + 4\sigma_1\gamma\varphi} \right) \end{aligned}$$

$$\lambda > 1 \Leftrightarrow \sigma_1\gamma\varphi \geq (1 - \sigma_2)(1 - (\sigma_1(1 - \gamma)))$$

$$\sigma_1 = 0.5, \sigma_2 = 0.1, \gamma = 0.1, \varphi = 50$$

$$\lambda = 1.8658$$



Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

$$\lambda_0 = \lambda(\mathbf{o})$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n})$$

Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

$$\lambda_0 = \lambda(\mathbf{o})$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n})$$

$$\lim_{\sigma_1 \rightarrow 0} \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \sigma_2$$

$$\lim_{\sigma_2 \rightarrow 0} \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \frac{1}{2} \left(\sigma_1(1-\gamma) + \sqrt{\sigma_1^2(1-\gamma)^2 + 4\sigma_1\gamma\varphi} \right)$$

$$\lim_{\gamma \rightarrow 0} \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \sigma_1$$

$$\lim_{\varphi \rightarrow 0} \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \sigma_1(1-\gamma)$$

Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

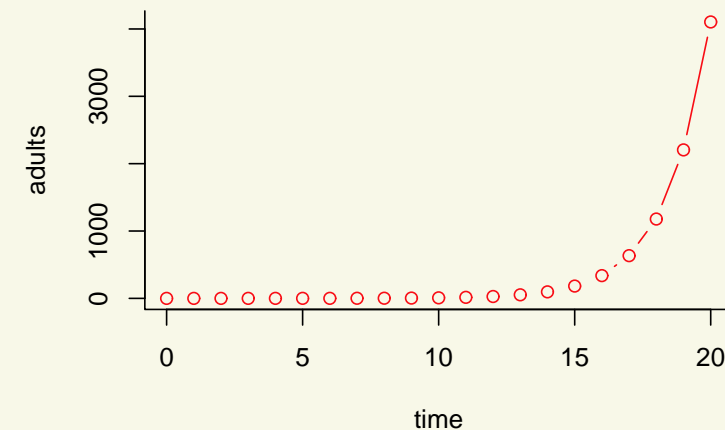
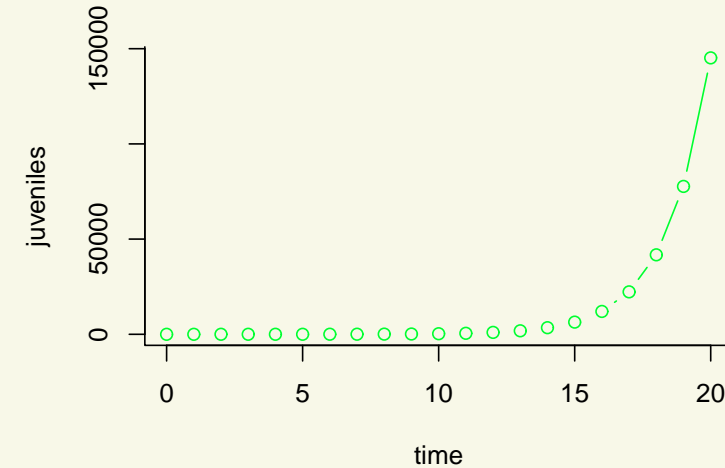
$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

$$\lambda_0 = \lambda(\mathbf{o}) = 1.8658$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n}) = 1.8658$$

$$\Sigma_1 = 0.5, \Sigma_2 = 0.1, \Gamma = 0.1, \Phi = 50$$

$$s_{11} = s_{12} = 0, s_{21} = s_{22} = 0, g_1 = g_2 = 0, f_1 = f_2 = 0$$



Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

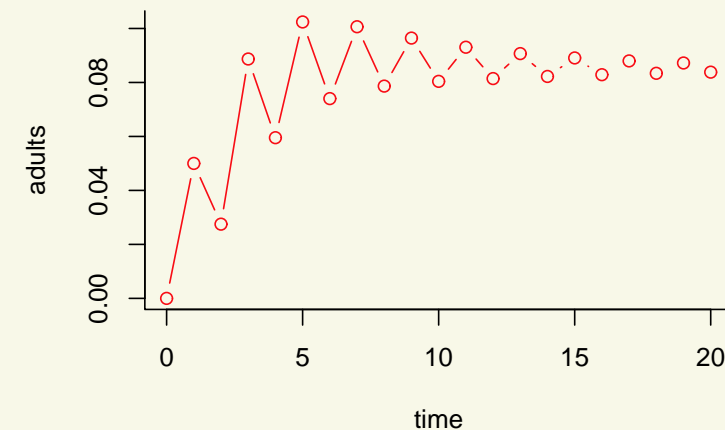
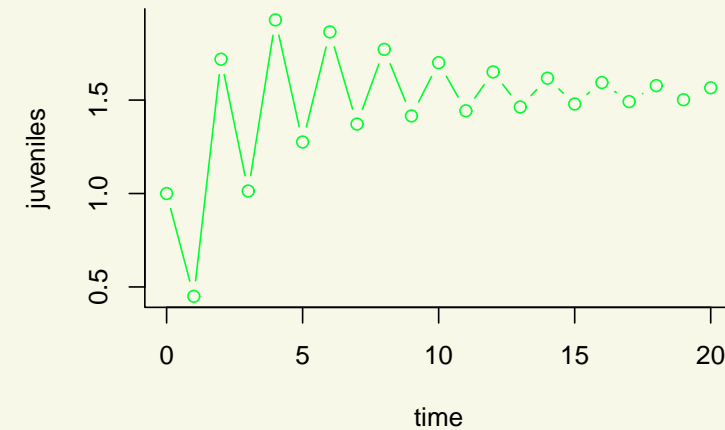
$$\lambda_0 = \lambda(\mathbf{o}) = 1.8658$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n}) = 0.45$$

$$\Sigma_1 = 0.5, \Sigma_2 = 0.1, \Gamma = 0.1, \Phi = 50$$

$$s_{11} = s_{12} = 0, s_{21} = s_{22} = 0, g_1 = g_2 = 0, f_1 = f_2 = 1$$

Stabilizace populace omezením plodnosti



Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

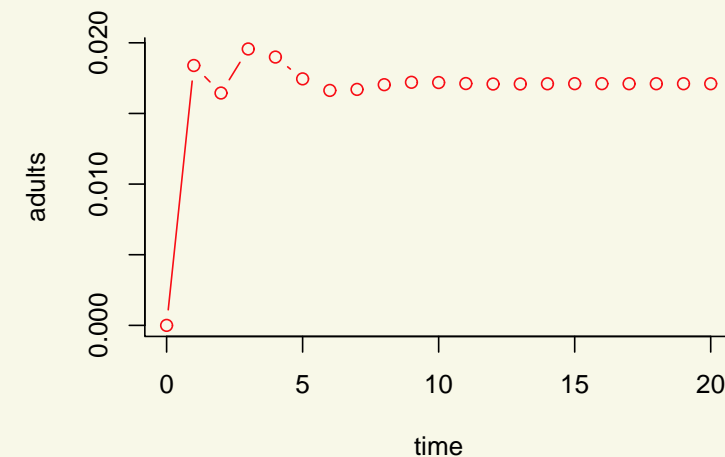
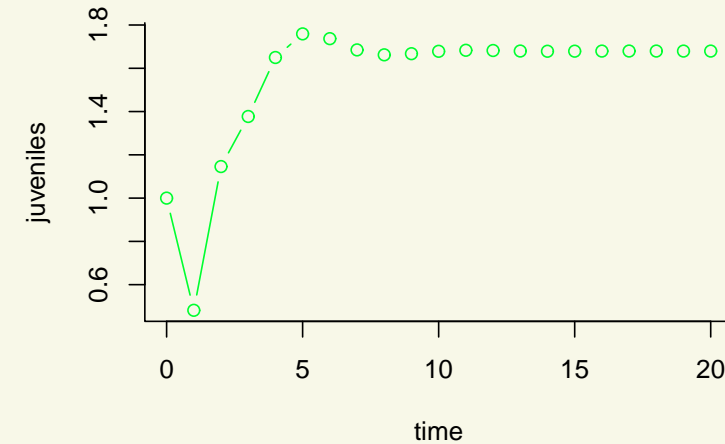
$$\lambda_0 = \lambda(\mathbf{o}) = 1.8658$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n}) = 0.5$$

$$\Sigma_1 = 0.5, \Sigma_2 = 0.1, \Gamma = 0.1, \Phi = 50$$

$$s_{11} = s_{12} = 0, s_{21} = s_{22} = 0, g_1 = g_2 = 1, f_1 = f_2 = 0$$

Stabilizace populace odložením reprodukce



Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

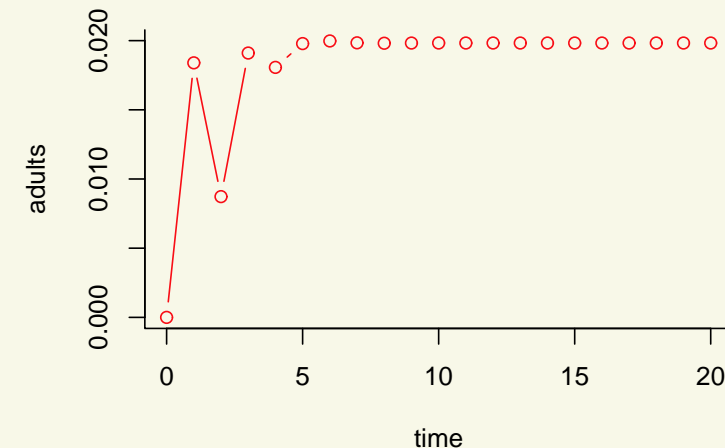
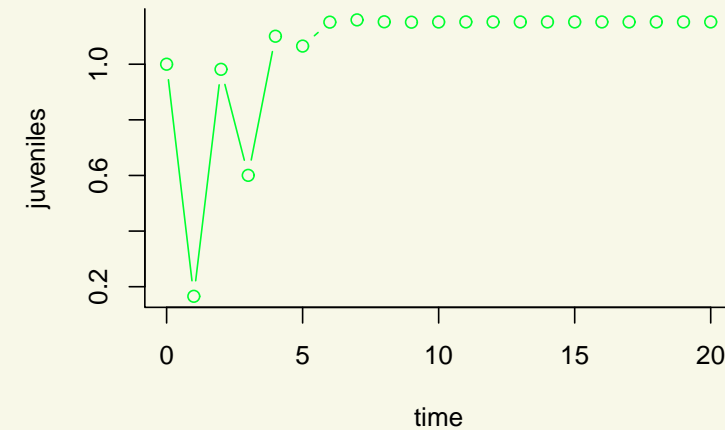
$$\lambda_0 = \lambda(\mathbf{o}) = 1.8658$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n}) = 0.1$$

$$\Sigma_1 = 0.5, \Sigma_2 = 0.1, \Gamma = 0.1, \Phi = 50$$

$$s_{11} = s_{12} = 1, s_{21} = s_{22} = 0, g_1 = g_2 = 0, f_1 = f_2 = 0$$

Stabilizace populace zvětšením úmrtnosti juvenilních jedinců (infanticidou)



Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

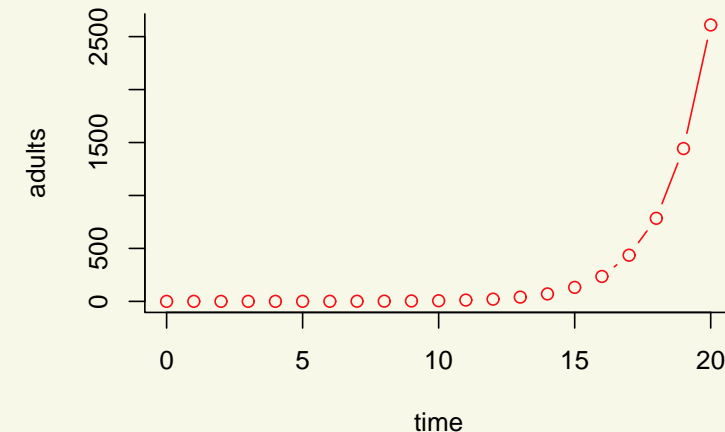
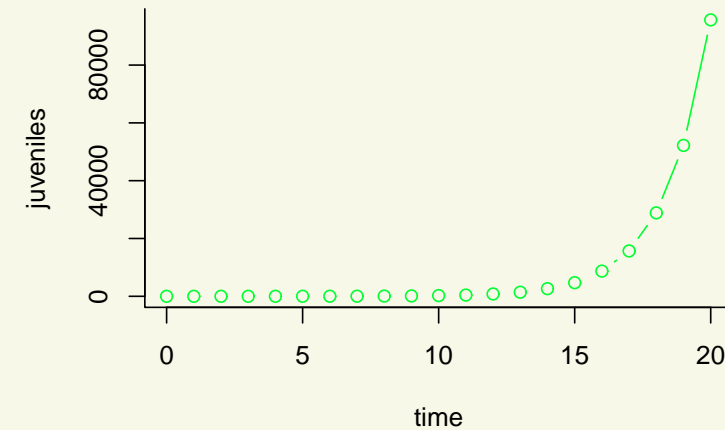
$$\lambda_0 = \lambda(\mathbf{o}) = 1.8658$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n}) = 1.8221$$

$$\Sigma_1 = 0.5, \Sigma_2 = 0.1, \Gamma = 0.1, \Phi = 50$$

$$s_{11} = s_{12} = 0, \mathbf{s}_{11} = \mathbf{s}_{12} = \mathbf{1}, g_1 = g_2 = 0, f_1 = f_2 = 0$$

Zpomalení růstu populace zvětšením úmrtnosti plodných jedinců (při velké plodnosti)



Parametry závislé na velikosti složek populace

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\lambda = \lambda(\sigma_1, \sigma_2, \gamma, \varphi) = \lambda(n_1, n_2) = \lambda(\mathbf{n})$$

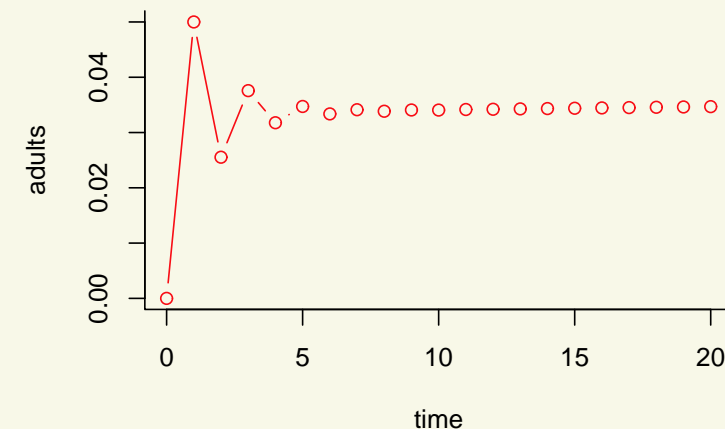
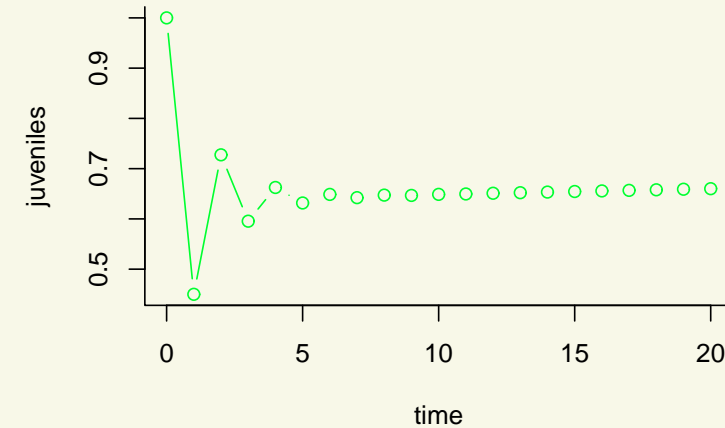
$$\lambda_0 = \lambda(\mathbf{o}) = 1.0204$$

$$\lambda_\infty = \lim_{\|\mathbf{n}\| \rightarrow \infty} \lambda(\mathbf{n}) = 0.9837$$

$$\Sigma_1 = 0.5, \Sigma_2 = 0.1, \Gamma = 0.1, \Phi = 10.5$$

$$s_{11} = s_{12} = 0, s_{21} = s_{22} = 1, g_1 = g_2 = 0, f_1 = f_2 = 0$$

Stabilizace populace zvětšením úmrtnosti plodných jedinců (při malé plodnosti)



Trajektorie a atraktory

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

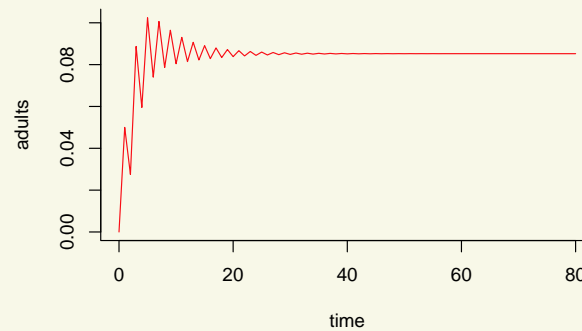
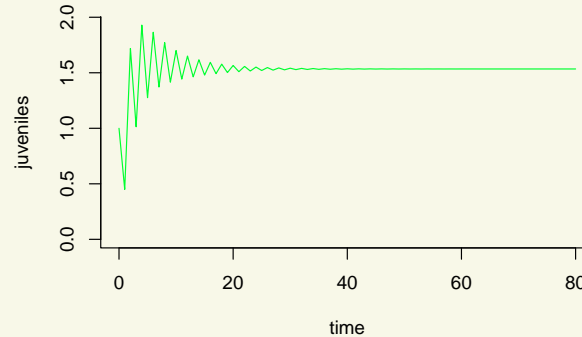
$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

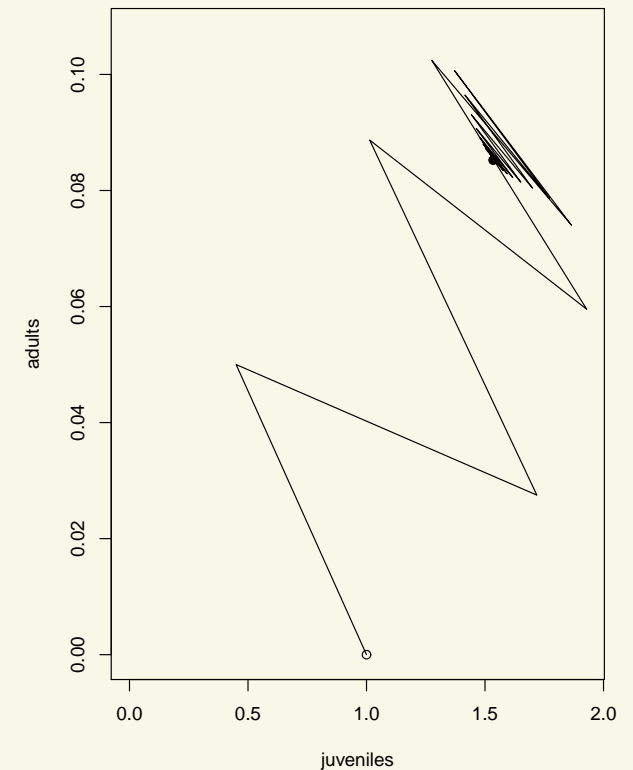
$$\Sigma_1 = 0.5, \quad \Sigma_2 = 0.1, \quad \Gamma = 0.1, \quad \Phi = 50,$$

$$s_{11} = s_{12} = s_{21} = s_{22} = 0, \quad g_1 = g_2 = 0, \quad f_1 = f_2 = 1$$

Population projection



Phase portrait



Trajektorie a atraktory

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

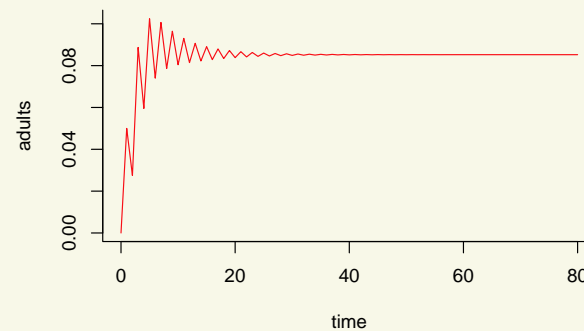
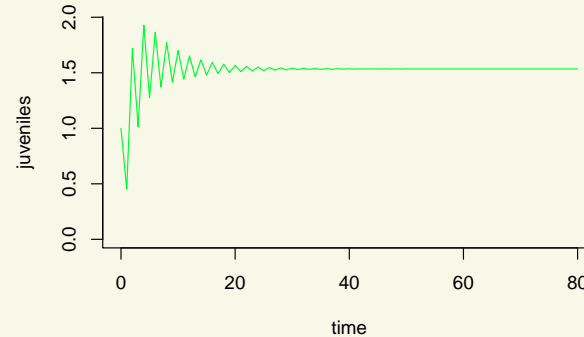
$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

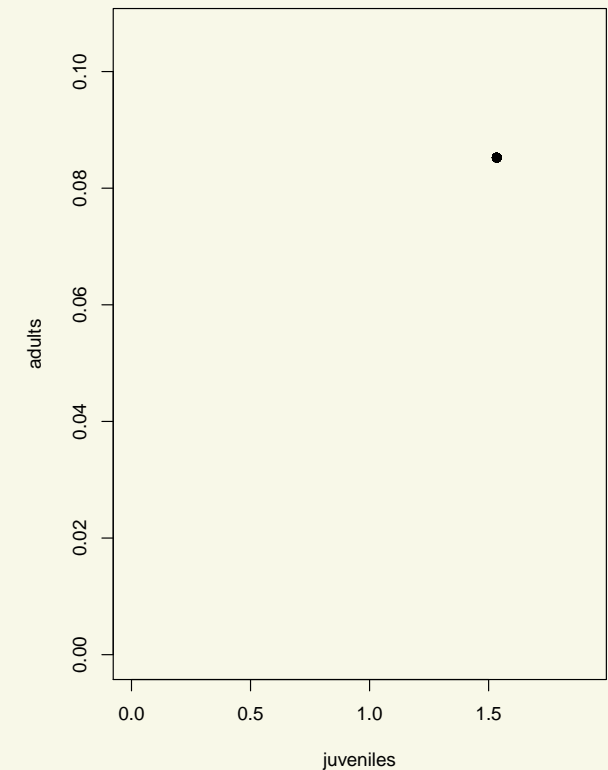
$$\Sigma_1 = 0.5, \quad \Sigma_2 = 0.1, \quad \Gamma = 0.1, \quad \Phi = 50,$$

$$s_{11} = s_{12} = s_{21} = s_{22} = 0, \quad g_1 = g_2 = 0, \quad f_1 = f_2 = 1$$

Population projection



Attractor



Rovnovážný bod

Trajektorie a atraktory

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

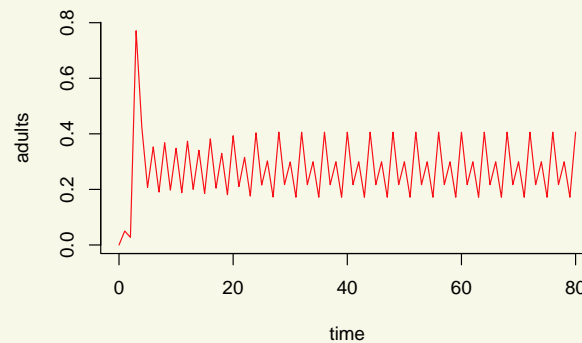
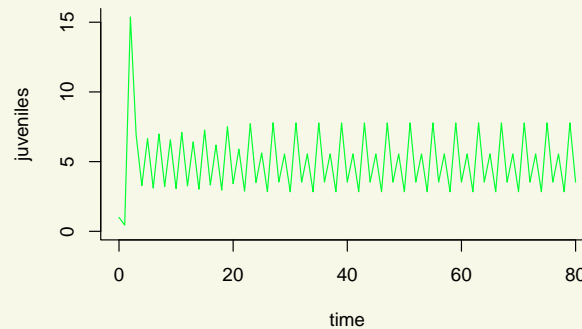
$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

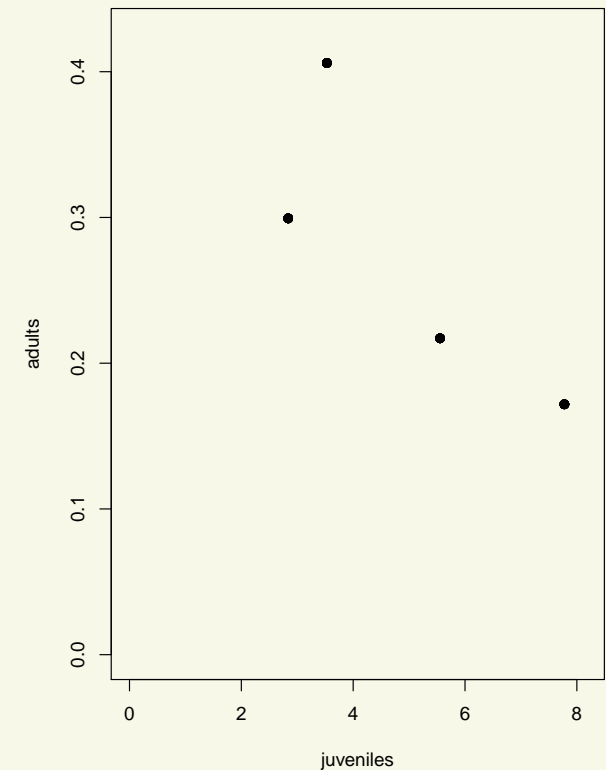
$$\Sigma_1 = 0.5, \quad \Sigma_2 = 0.1, \quad \Gamma = 0.1, \quad \Phi = 500,$$

$$s_{11} = s_{12} = s_{21} = s_{22} = 0, \quad g_1 = g_2 = 0, \quad f_1 = f_2 = 1$$

Population projection



Attractor



Trajektorie a atraktory

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

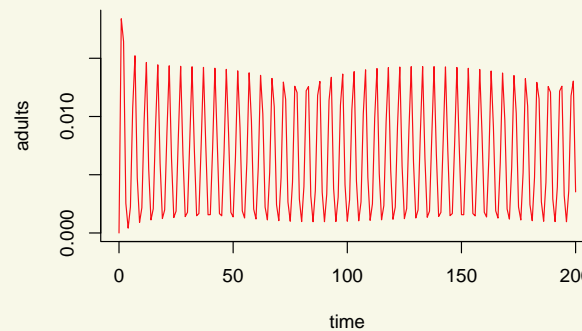
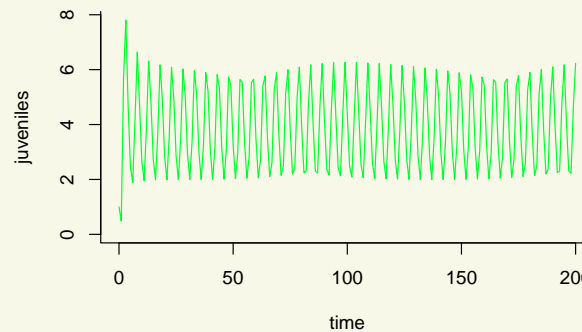
$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

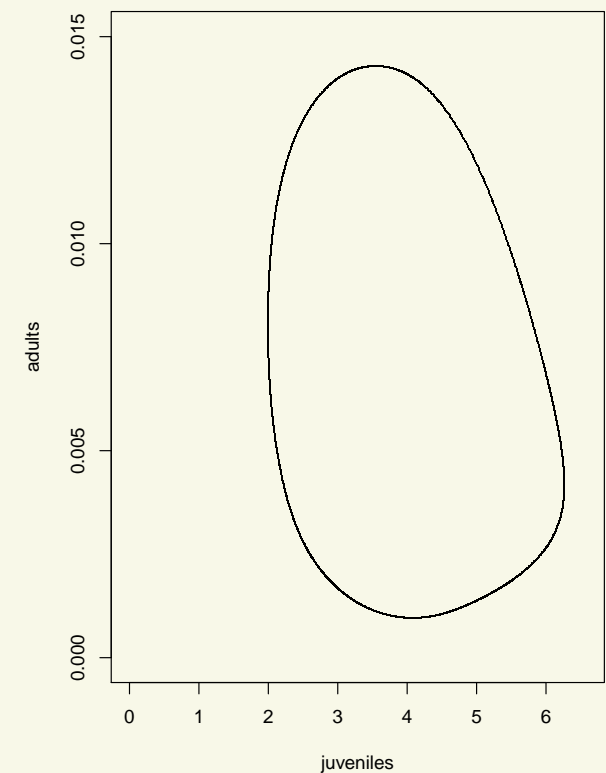
$$\Sigma_1 = 0.5, \quad \Sigma_2 = 0.1, \quad \Gamma = 0.1, \quad \Phi = 300,$$

$$s_{11} = s_{12} = s_{21} = s_{22} = 0, \quad g_1 = g_2 = 1, \quad f_1 = f_2 = 0$$

Population projection



Attractor



Invariantní smyčka

Trajektorie a atraktory

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t + 1) = \begin{pmatrix} \sigma_1(1 - \gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

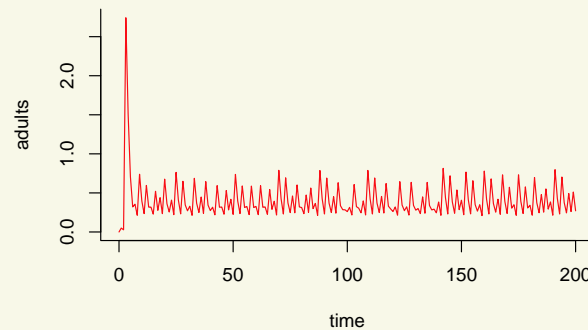
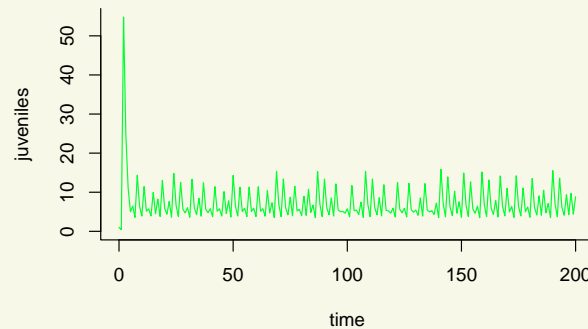
$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

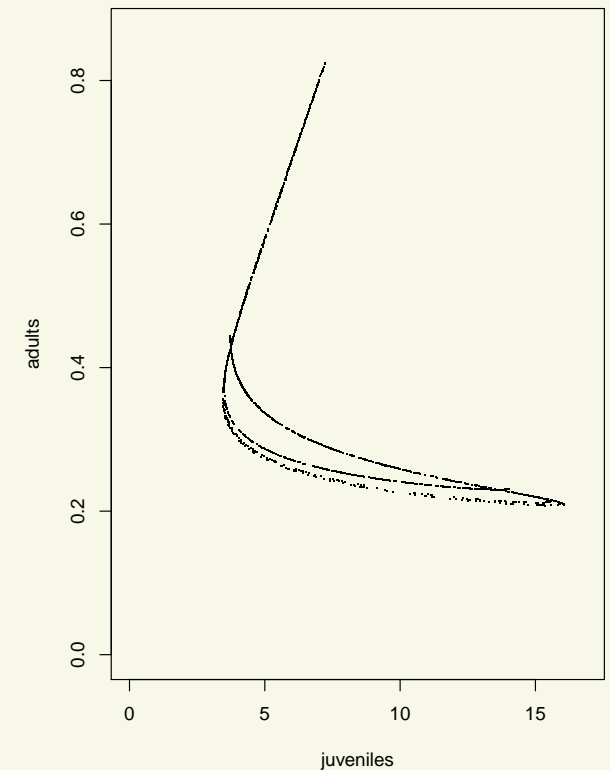
$$\Sigma_1 = 0.5, \quad \Sigma_2 = 0.1, \quad \Gamma = 0.1, \quad \Phi = 1800,$$

$$s_{11} = s_{12} = s_{21} = s_{22} = 0, \quad g_1 = g_2 = 0, \quad f_1 = f_2 = 1$$

Population projection



Attractor



Podivný atraktor

Trajektorie a atraktory

$$\begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t+1) = \begin{pmatrix} \sigma_1(1-\gamma) & \varphi \\ \sigma_1\gamma & \sigma_2 \end{pmatrix} \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (t), \quad \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} (0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$\sigma_1 = \sigma_1(n_1, n_2) = \Sigma_1 e^{-s_{11}n_1 - s_{12}n_2}$$

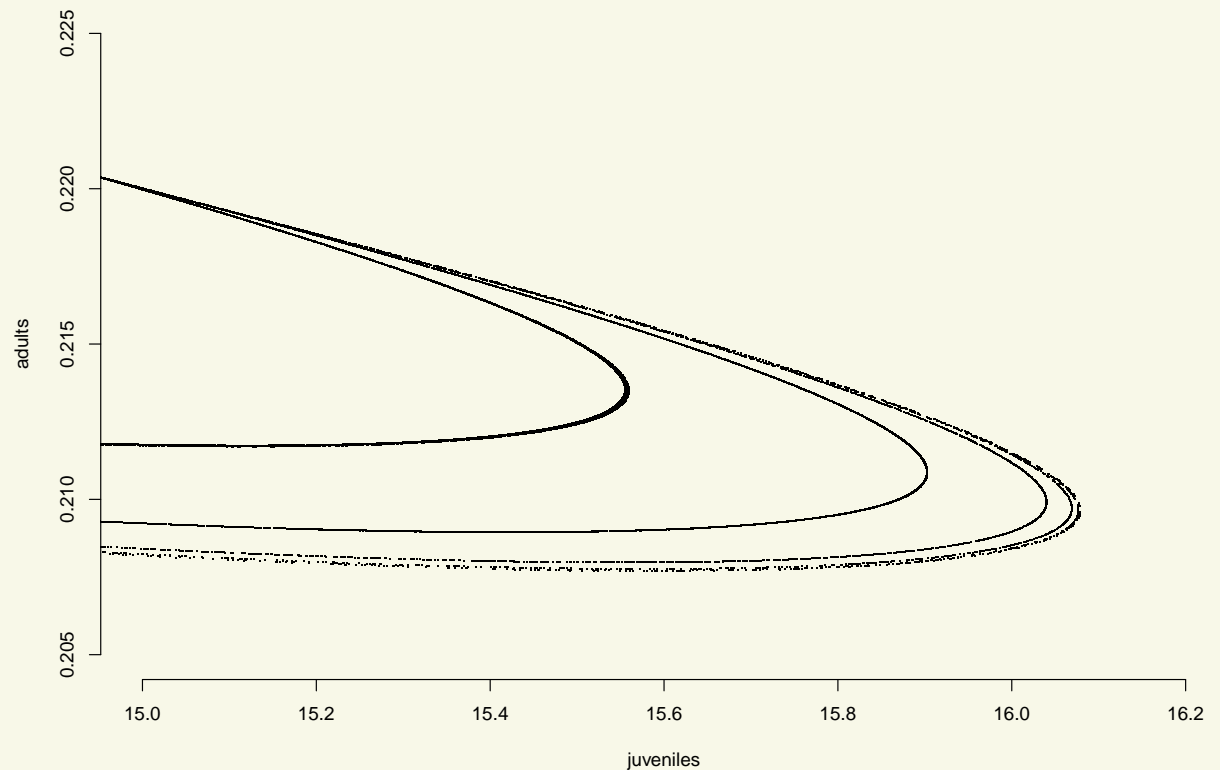
$$\gamma = \gamma(n_1, n_2) = \Gamma e^{-g_1n_1 - g_2n_2}$$

$$\sigma_2 = \sigma_2(n_1, n_2) = \Sigma_2 e^{-s_{21}n_1 - s_{22}n_2}$$

$$\varphi = \varphi(n_1, n_2) = \Phi e^{-f_1n_1 - f_2n_2}$$

$$\Sigma_1 = 0.5, \quad \Sigma_2 = 0.1, \quad \Gamma = 0.1, \quad \Phi = 1800,$$

$$s_{11} = s_{12} = s_{21} = s_{22} = 0, \quad g_1 = g_2 = 0, \quad f_1 = f_2 = 1$$



Podivný atraktor