# Detection of density dependence and adequate representation of parameter uncertainty in population dynamics of Elk (Alces alces)

**Ecological background & data**

The aim of this project is to infer population dynamics from an abundance time series, to detect density dependence and to assess the impact of model and parameter uncertainty on the prediction of future population dynamics.

The data is an annual time series of the abundance of Elk (Alces alces) in Bialowieza Primeval Forest at the border of Poland and Belarus (Jedrzejewska *et al.* 1997). The data was collected in 1946-1993 by a combination of snow tracking, hunting, drive censuses, and counts at baiting sites. While the original data had gaps of missing data for a few years, for this project the missing years were interpolated to facilitate the analysis.

**Exercises:**

1. Formulate a likelihood function according to the stochastic Ricker model:

$$N_{t+1} \sim NegBinom(\tilde{N}_{t+1}, S)$$
$$\tilde{N}_{t+1} = N_t \cdot \exp\left[ r_t \left( 1 - \frac{N_t}{K} \right) \right]$$

   and use a Maximum-Likelihood approach to estimate the parameters of the model (*r, K, S*) from the abundance time series.

2. Formulate an alternative model that does not include density-dependence (i.e. exponential growth) and compare the performance of both models.

3. Simulate the dynamics of the Elk population for the years 1994–2013 with both models using the respective Maximum-Likelihood parameters. Replicate the simulations 1000 times each to quantify the predictive uncertainty that result from model stochasticity.

4. Use the bootstrapping approach to estimate standard errors and 95% confidence intervals for the parameters of the Ricker model.

5. Run the same deterministic(!) simulation for each bootstrapped parameter sample and compare the variation in the predicted abundances to the results from (3.).

6. Summarize (also graphically) and discuss your results.

*Literature:*

Jędrzejewska, B., Jędrzejewski, W., Bunevich, A.N., Miłkowski, L. & Krasiński, Z.A. (1997) Factors shaping population densities and increase rates of ungulates in Białowieża Primeval Forest (Poland and Belarus) in the 19th and 20th centuries. *Acta Theriologica*, **42**, 399–451.