**Question 1**

Pacific salmon spawn once and are harvested as adults when they return to their natal stream. Therefore, their population dynamics can be described by a stock-recruit relationship. Management reference points can be derived from such stock recruit-relationships, often assumed to be stationary in time. The most common stock-recruit relationship used for Pacific salmon is the Ricker stock-recruit relationship:

where is the number returning salmon born in year *y*,



is spawning numbers (or a proxy thereof) for year *y*,



are the parameters of the stock-recruitment relationship (density-independent and density-dependent, respectively).



DeFilippo (2019; *Evolutionary Applications* 12:214–229) used a Ricker stock-recruitment model to understand recruitment of sockeye salmon in Frazer Lake, Kodiak Island. The data are stored in the file DeFilippo\_data.csv (format: BroodYear, Spawners, Return, Bosmina, and Daphnia).

1. Reparametrize the Ricker model the model so that it becomes a linear model with the response variable as log(). This assumes that the noise about the stock-recruitment relationship is log-normal.
2. Use R to fit a linear model to data and evaluate the hypothesis that there is density-dependent growth. What are your estimates of ?
3. In the Ricker model, the spawning numbers that produces the maximum return is . Use a bootstrap approach to derive the 95% CI of .
4. Defilippo (2019) also developed indices of the average seasonal biomass of the main zooplankton genera comprising the diets of juvenile Frazer Lake sockeye salmon (Daphnia and Bosmina; seasonal mean biomass (mg/m2)) and annual climate indices related to [NPGO](https://www.psl.noaa.gov/gcos_wgsp/Timeseries/NPGO/). It is often hypothesized that survival at early life stages are linked to environmental factors. The linear Ricker function can be generalized to include environmental covariates. See if either are significantly linked to parameters of the stock recruit curve.

Extra credit: fit the non-linear model in RTMB and estimate using the delta methods.