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Simulation and R

Fish 559; Lecture 12

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Problem Statement-I

- Compare alternative harvest strategies using simulation.
- The true dynamics are governed by the Pella-Tomlinson model, the parameters of which are uncertain.
- The output statistic of interest is the percentage increase in the time to recover to 80% of the carrying capacity under a harvest compared to under no harvest, i.e: starting sims in year 15:

$$V = 100 \sum_i L_i \frac{Y_i^h - Y_i^0}{Y_i^0 - 15} / \sum_j L_j$$

Y_i^0 – time to recover to $0.8K$ in the absence of exploitation (simulation i);

Y_i^h – time to recover to $0.8K$ for harvest strategy h (simulation i); and

L_i – likelihood for simulation i.

Problem Statement-II N_MPL =

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The true dynamics of the population are governed by: z=1 is a Schaeffer model. z can change shape of production fxn.
0.6 for Nmsy/K is magic # for cetaceans. The MSY/Nmsy is production and is very low. You shouldn't have more priors than params

N_t – population size at the start of year t;

r – intrinsic rate of growth;

K – carrying capacity;

z – degree of compensation; and

C_t – catch during year t.

$$N_{t+1} = N_t + rN_t(1-(N_t/K)^z) - C_t$$

$$\boxed{\begin{array}{ll} K \sim U[1000, 2000]; & N_1 = N(500, 50^2) \\ N_{MSY}/K \sim U[0.5, 0.7]; & MSY/N_{MSY} \sim U[0.01, 0.05] \end{array}}$$

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Problem Statement-III

- The harvest strategies:
  - Constant catch of 1 animal each year
  - Catch of 1 then 2 animals each year
  - Catch of 1 animal for ten years then 2 thereafter.
  - Use of the PBR (potential biological removal) catch control rule.

- The catch for years 1 to 15 (when the harvest strategies are first applied) is assumed to be 1 animal and the projections are continued for 100 years.

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The PBR-I

- The basic formulation:
  - $PBR = N_{MIN}\ \frac{1}{2}\ R_{MAX}\ F_R$
- N_{MIN} – Minimum population estimate. Uncertainty adjusted population estimate
- R_{MAX} – Maximum theoretical (or estimated) net productivity rate.
- F_R – A recovery factor (between 0.1 and 1). “fiddle factor”. Without F_r this is the F_msy under a Schaeffer model)
- If N > N_msy & < K is OSP Optimum Sustained Population

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The PBR-II

- N_{MIN} – accounts for imprecision in abundance estimation (the lower 20th percentile of the estimate).

$$N_{\min} = \hat{N} \exp(-0.84\, CV_N)$$

- ½ R_{MAX} – an approximation to the harvest rate at N_{MSY} (assumed to be 0.01, i.e. R_{MAX}=0.02)
- F_{R} – addresses factors such as biases when estimating abundance (assumed to be 0.5).

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The PBR-III

- It is necessary to generate future survey estimates to apply the PBR. We assume that survey estimates of abundance are available every 5th year (starting in year 1) with a CV of 0.2, i.e.:

$$\hat{N}_y = N_y \exp(\varepsilon_y); \qquad \varepsilon_y \sim N(0; 0.2^2)$$

- The PBR catch limit for year *y* is "carried over" to year *y*+1 if there is no abundance estimate for year *y*+1.

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Problem Statement-IV

- Information is available on the population size at the start of year 15 in the form of a normally distributed estimate with a mean of 625 (s.d. 75).
- Notes:
  - This is essentially a Bayesian problem because we have a model and a set of priors and some data which will update these priors.
  - We are interested in the posteriors for the parameters and for the increase in the time to recover to 80% of the carrying capacity under a harvest compared to under no harvest.

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Parameterization of The Model-I

Distributions are placed on N_{MSY}/K and MSY/N_{MSY}. It is therefore necessary to convert from N_{MSY}/K and MSY/N_{MSY} to *r* and *z*.

The relationship between catch and population in equilibrium is given by $C = rN(1-(N/K)^z)$

i.e.: $$MSY = r\,N_{MSY}(1-(N_{MSY}/K)^z)$$

Differentiating with respect to *N* gives:

$$\left.\frac{dC}{dN}\right|_{N=N_{MSY}} = r(1-(z+1)(N_{MSY}/K)^z)$$

We solve this using uniroot

Parameterization of The Model-II

The process of setting up a simulation is therefore:

1. Generate the parameters from their prior distributions.
2. Compute *r* and *z* from the equations that relate them to N_{MSY}/K and MSY/N_{MSY}.
3. Project the model from year 1 to year 15 under a catch of 1 animal.
4. Calculate the likelihood of the current set of parameters and find the normalized likelihood.

$$L_i = C\exp\left(-\frac{(N_{15,i}-625)^2}{2(75)^2}\right)$$

Solution-I

- Setting up the simulation:
  - generate values for the parameters from their priors;
  - compute the values for *r* and *z*;
  - project ahead 15 years under zero harvest; and
  - compute the normalized likelihood
- We will make this code fairly generic.

Solution-II

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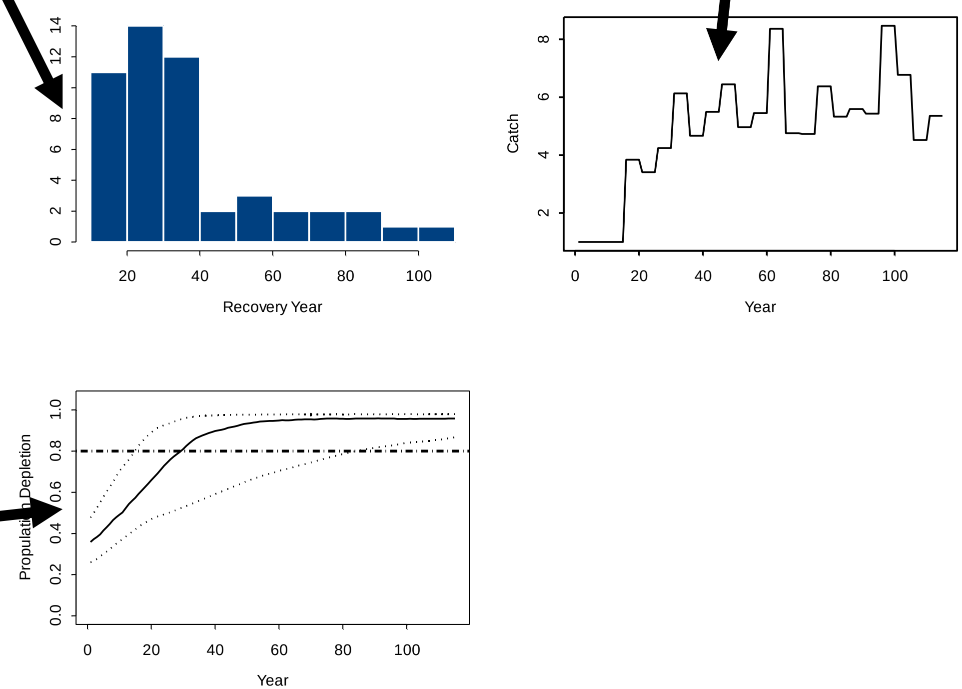
- Projecting the strategies ahead 100 years:
  - project from year -14 to year 1 under a harvest of 1 animal each year;
  - project from year 1 to year 101 under the pre-specified harvest strategy;
  - identify the year in which the population (first) reaches $0.8K$ and store it; and
  - for the PBR harvest strategy it is necessary to generate future survey estimates of abundance (years 1, 6, ..).
- Compute the change in the time to recovery.

Solution III

Single catch trajectory

Recovery year distribution

5th, median and 95th percentiles of population size



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Extensions

- Compute a distribution for the ratio of the recovery time with a harvest to that without a harvest.
- See how the output statistics change with increased numbers of simulations.
- Plot the posteriors for the model parameters (and the corresponding priors).
- What happens when you change the CV