Biomass models

1. Introduction

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Outline

Data required

landings, biomass index

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Biomass model

assumptions, parameters, variations

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assumptions, parameters, variations

Estimation

least squares, likelihood, quantities of interest

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assumptions, parameters, variations

Estimation

least squares, likelihood, quantities of interest

Diagnostics

convergence, residuals, uncertainty, model comparison

Goals

After this three-day module, you should:

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1. **Understand** how biomass models work
2. Be able to **fit biomass models to data**
3. Be able to **interpret the results** as a basis for advice

Data required

Landed **catch** (usually in tonnes)

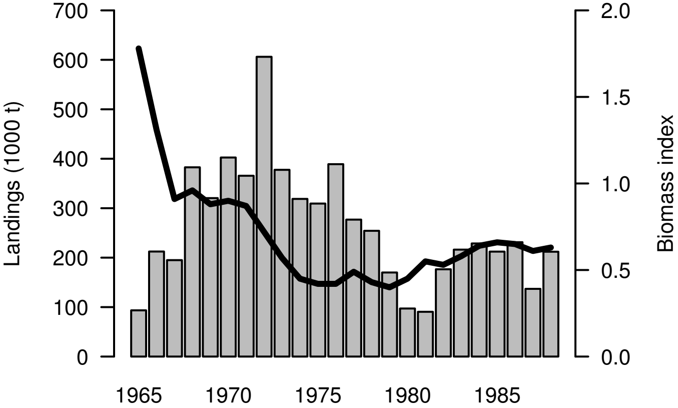
Biomass **index** (CPUE or survey)

Data required

Landed **catch** (usually in tonnes) $= C_t$

Biomass **index** (CPUE or survey) $= I_t$

Namibian hake



Model dynamics

$$B_{t+1} \quad = \quad B_t \quad + \quad g(B_t) \quad - \quad C_t$$

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Schaefer (1954):

$$B_{t+1} \quad = \quad B_t \quad + \quad r\,B_t\left(1-\frac{B_t}{K}\right) \quad - \quad C_t$$

Model parameters

r	maximum growth rate
K	carrying capacity

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r	maximum growth rate
K	carrying capacity
B_{init}	initial population
q	catchability coefficient

Construct a biomass model

Three columns in a spreadsheet: year, biomass, and catch

t	B	C
1950	100	0
1951	= formula	0
...	...	0
2000	= formula	0

$$B_{t+1} = B_t + r B_t \left(1 - \frac{B_t}{K}\right) - C_t$$

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Experiment with different r and K values

Fit model to data

1. Get **data**
   ...and plot

   $t \quad B \quad C \quad I \quad \mathit{Ifit} \quad \mathit{res2}$

2. Define **parameters**
   ...and consider transforming

   $B_{\text{init}} \quad r \quad K \quad q$

3. Calculate **predictions**
   ...and fit by eye

   $$B_{t+1} = B_t + rB_t\left(1-\frac{B_t}{K}\right) - C_t$$
   $$\hat{I}_t = qB_t$$

4. Calculate **RSS**
   ...and optimize

   $$RSS = \sum\left(\log I_t - \log \hat{I}_t\right)^2$$

Interpreting the results

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But the fisheries manager may also ask:

- what harvest rate will maximize the long-term catch?
- what level of biomass leads to high surplus production?

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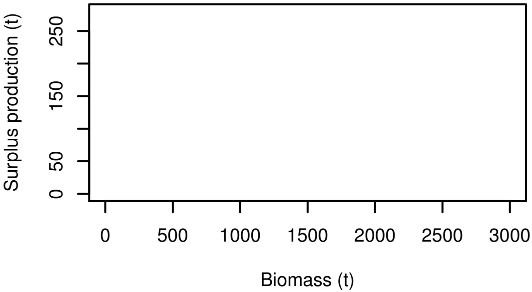

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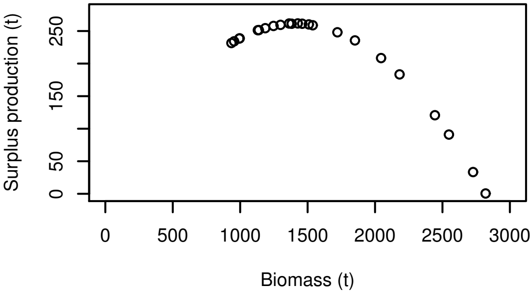

Surplus production

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$$B_{t+1} \quad = \quad B_t \quad + \quad r\,B_t\left(1-\frac{B_t}{K}\right) \quad - \quad C_t$$

Surplus production $g(B)$ is a quadratic function of B:

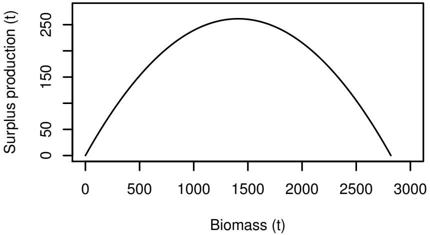
$$g(B) \quad = \quad r\,B\left(1-\frac{B}{K}\right) \quad = \quad r\,B \;-\; \frac{r}{K}B^2$$

Reference points

$$B_{\text{MSY}} = \frac{K}{2}$$

$$MSY = \frac{r\,K}{4}$$

$$u_{\text{MSY}} = \frac{r}{2} = \frac{MSY}{B_{\text{MSY}}}$$



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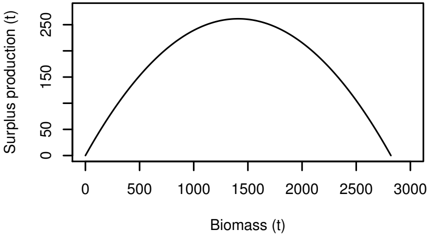

Experiment with different harvest rates, projecting 20 years or more

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- Deterministic, with no recruitment events

  In reality, small or large cohorts cause populations to fluctuate