A length-structured mark-recapture model

Estimation of humpback chub abundance in the Grand Canyon using LSMR

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Motivation

Why a length-structured model?

- Assigning age from length implies growth is known.
- ASMR is an observation error only model; uncertainty under-estimated.
- Information on individuals < 150mm (100mm) is discarded.

Introduction

- Majority of HBC captured, tagged, and recaptured are sampled by hoop nets.
- Since 1989, there have been 81,812 capture & recapture records of HBC.
- 67,296 captured in hoop nets, 4,306 in tramel nets, and 9,043 detections.
- Catch from hoop and tramel nets were disaggregated due to differences in sampling effort.
- Minimum size of tagging was 150mm TL, and in recent years reduced to 100mm TL.

Introduction

Model Structure

- Data: catch-at-length (marked & unmarked), annual growth increments.
- Parameters: Initial lengths, length & abundance of new recruits, capture probability, natural mortality.
- Psuedocode:
  1. Construct size-transition matrixes from growth increment data.
  2. Initialize No.-at-length & annual recruits-at-length.
  3. Survive & grow fish each year.
  4. Compute marked & unmarked catch-at-length.
  5. Minimize -log negative binomial likelihood.
  6. Use Metropolis-Hastings to sample joint posterior distribution.

Size transition probabilities

Psuedocode:

1. Extract annual growth increments for individuals capture & recaptured in subsequent year.
2. Estimate annual growth parameters in a Bayesian hierarchical model.
3. Construct size-transition matrix using parametric uncertainty and measurement error with $\sigma = 9.4$mm.

Size transition probabilities

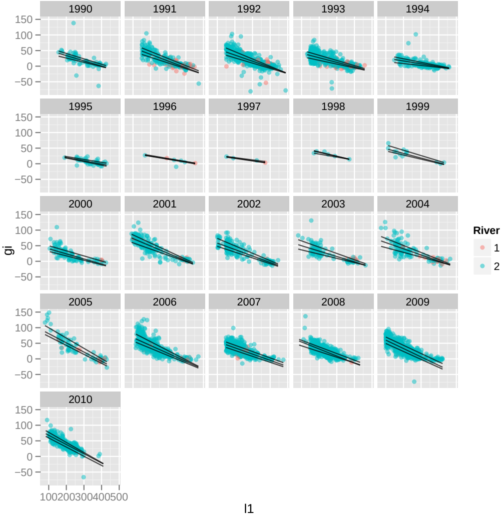

Figure: Annual growth increments for individuals marked in year t and recaptured in year $t + 1$ in LCR (blue) and COL (red).

Size transition probabilities

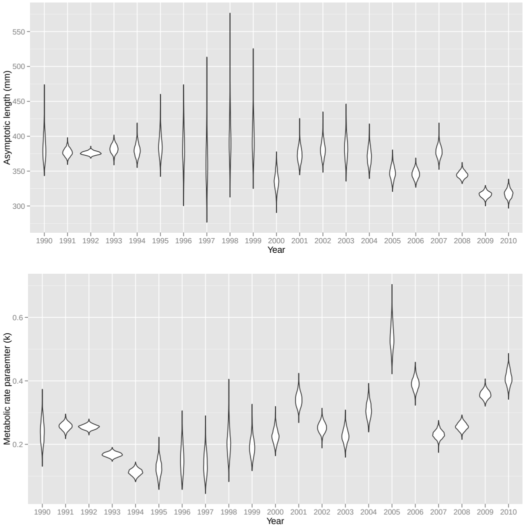

Figure: Marginal posterior distributions for growth parameters l_∞ and k.

Size transition probabilities

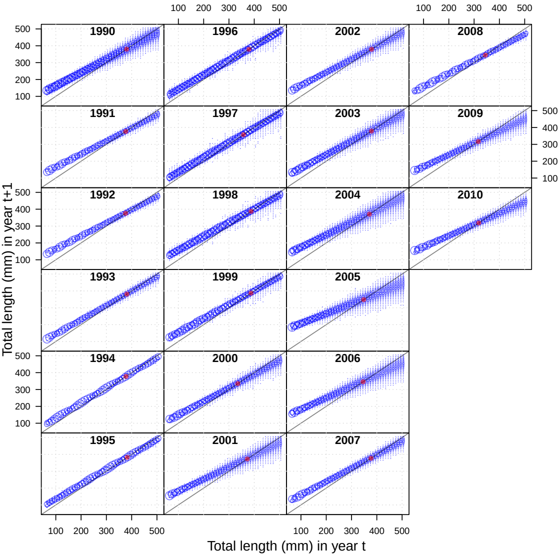

Figure: Annual size transition matrix based on annual growth increments

Catch-at-length

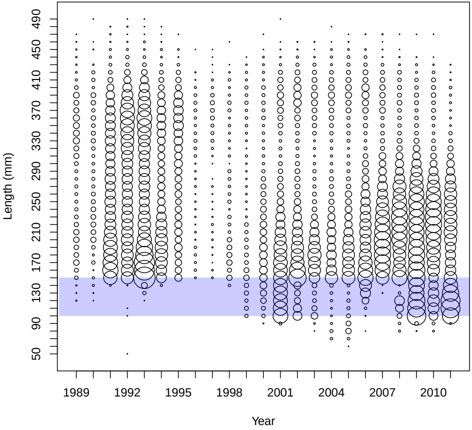

Figure: Length frequencies for all gear types. Area of circle is proportional to abundance of measured fish, shaded region represents the 100-150 mm size interval.

Catch-at-length: hoop nets

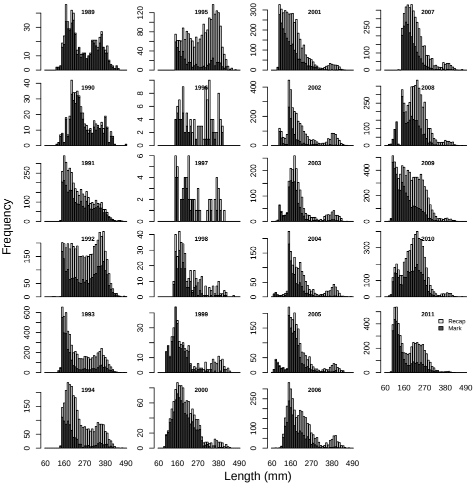

Figure: New marks (dark bars) and recapture marks (light bars) of HBC using hoop nets (all sizes & bait) in the LCR and COR.

Catch-at-length: tramel nets

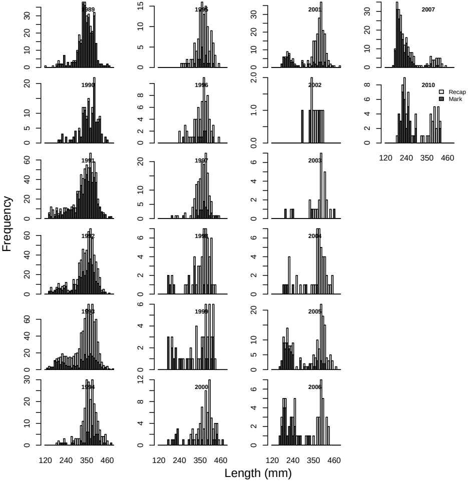

Figure: New marks (dark bars) and recapture marks (light bars) of HBC using tramel nets (all sizes & bait) in the LCR and COR.

Length-structured mark-recapture model

Objective

Fit a length-based model to capture and recapture-at-length data, while jointly estimating abundance, growth and survival rates.

Difference between LSMR and ASMR

- Forward reconstruction of unmarked individuals.
- Estimate size-based capture probabilities.

Length-structured mark-recapture model

Dynamics of numbers-at-length

- Let $\vec{N}$ = vector of individuals at length intervals l,
- let $\vec{M}$ = vector of size l specific survival rates,
- let P = a size transition matrix from size l to l', and
- let $\vec{R}$ = vector of new recruits at length intervals l.

Then the number of individuals at the next time step is given by:

$$\vec{N}_{t+\Delta t} = \vec{N}_t \vec{M} P_{l,l'} + \vec{R}_t$$

Length-structured mark-recapture model

Predicted catch-at-length

- Let $\vec{\pi}$ = a vector of size-specific capture probabilities,
- let $\vec{N}$ = vector of individuals at length intervals l

Then the predicted catch-at-length in year t is given by:

$$\vec{C}_t = \vec{\pi}_t \vec{N}_t$$

Simulation testing

Objective

Use simulated data to demonstrate estimability of model parameters.

Scenarios

1. Perfect information (no observation errors).
2. Mixed error: error in size-specific capture probabilities.

Simulation

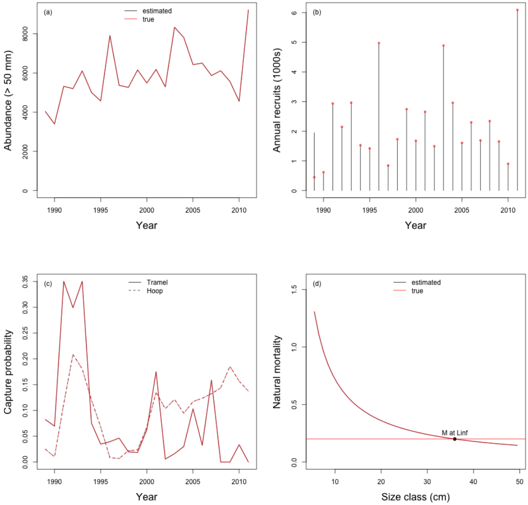

Figure: MLE results with perfect information.

Simulation

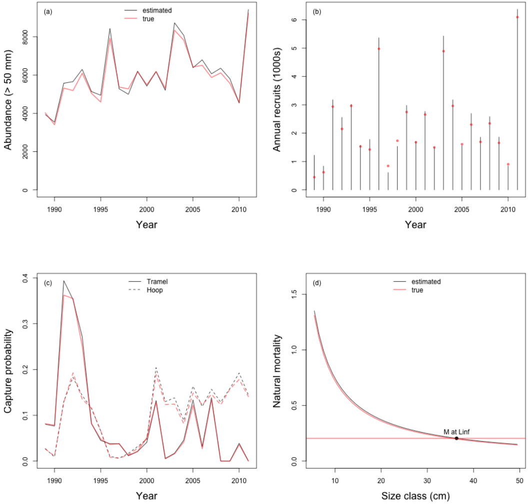

Figure: MLE results with $\sigma_\delta = 0.2$.

More details ...

Code @: `https://github.com/smartell/LSMR`

The End