

Trends and Status of the Little Colorado River population of Humpback Chub: 1989-2011

Scott Vanderkooi on behalf of Steven Martell

University of British Columbia

s.martell@mail.ubc.ca

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Introduction to ASMR

Mark-recapture information between 1989 and 2011 is used to estimate the abundance and recruitment of Humpback Chub (HBC).

Catch-at-length data are transformed into catch-at-age data using length-age relationship developed from a bioenergetics model.

The unmarked population is reconstructed using Virtual Population Analysis (VPA) with and assumed value of natural mortality rate.

The fate of marked individuals is tracked using an age-structured model, and the capture-recapture probability is assumed to be a Poisson sampling process.

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ASMR-3 Analytical details

Age Structure Mark Recapture (ASMR-3)

Data: Marks & Recaptures $m_{t,a}, r_{t,a}$ (1)

Estimate unmarked numbers $\Theta = \hat{U}_{t=2012, a=2:14}$ (2)

Survival rate $S_a = \exp(-Ml_{\infty}/I_a)$ (3)

Unmarked animals $\hat{U}_{t,a} = \frac{\hat{U}_{t+1, a+1}}{S_a} + m_{t,a}$ (4)

Marked animals $\hat{M}_{a+1, t+1} = S_a(\hat{M}_{t,a} + m_{t,a})$ (5)

Predicted new marks $\hat{m}_{t,a} = \hat{p}_{t,a} \hat{U}_{t,a}$ (6)

Predicted recaps $\hat{r}_{t,a} = \hat{p}_{t,a} \hat{M}_{t,a}$ (7)

Capture probability $\hat{p}_{t,a} = \frac{m_{t,a} + r_{t,a}}{\hat{U}_{t,a} + \hat{M}_{t,a}}$ (8)

Negative log likelihood $\ell_{t,a} = (-\hat{m}_{t,a} + m_{t,a} \ln(\hat{m}_{t,a}))$
 $+ (-\hat{r}_{t,a} + r_{t,a} \ln(\hat{r}_{t,a}))$ (9)

ASMR-3 Analytical details

Age Structure Mark Recapture (ASMR-3)

Assumptions:

- Natural mortality is a function of length.
- Natural mortality is constant over time.
- Marked & unmarked fish have same capture probability & survival.
- Observation error only.
- Growth is time invariant.
- Age is a function of length (slicing).
- Walters & Martell are never wrong!

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Marks released

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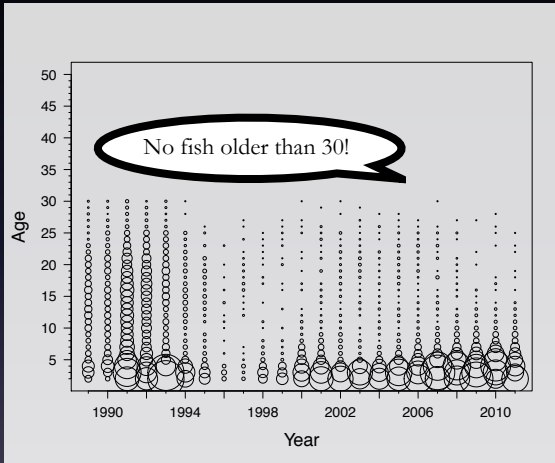


Figure: Number of marks released by age-year. Area of bubble is proportional to the number of marks released.

Marks recaptured

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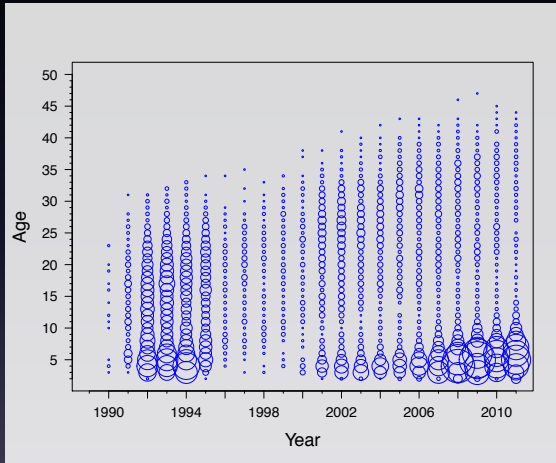


Figure: Number of marks recaptured by age-year. Area of bubble is proportional to the number of marks released.

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Marks recaptured

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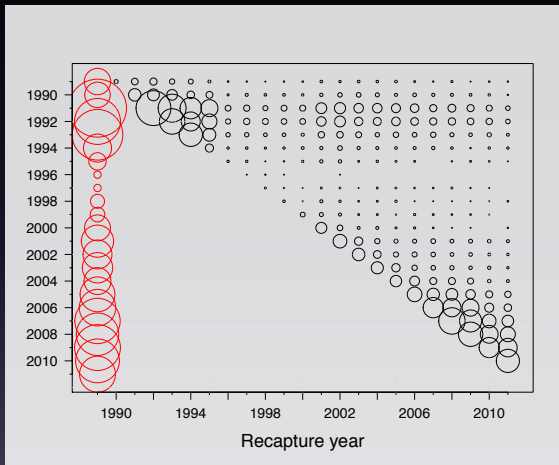


Figure: Tags released each year (red circles) and number recaptured by tag-year (row of black circles).

Age-4+ abundance

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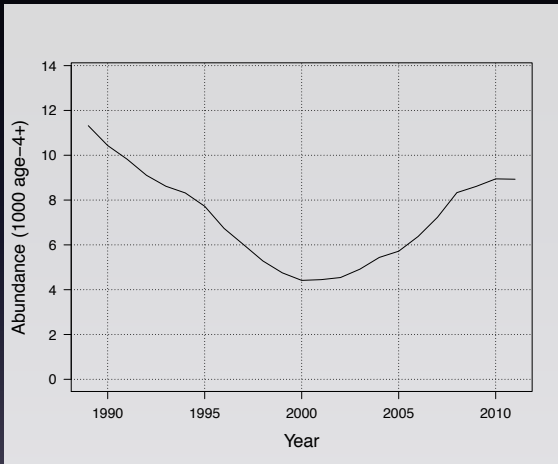


Figure: Maximum likelihood estimates of age-4+ abundance.

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Age-2 Recruits

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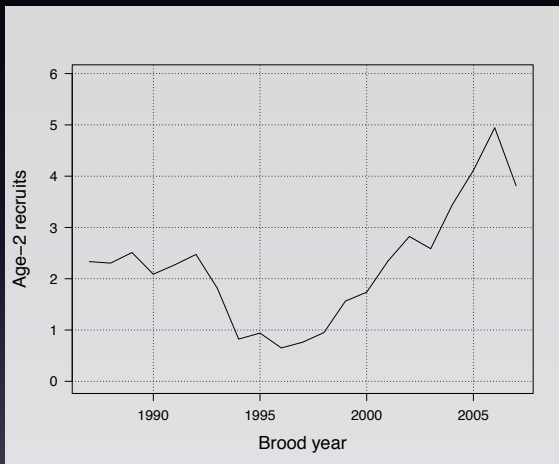


Figure: Maximum likelihood estimates of age-2 recruits.

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Capture probability

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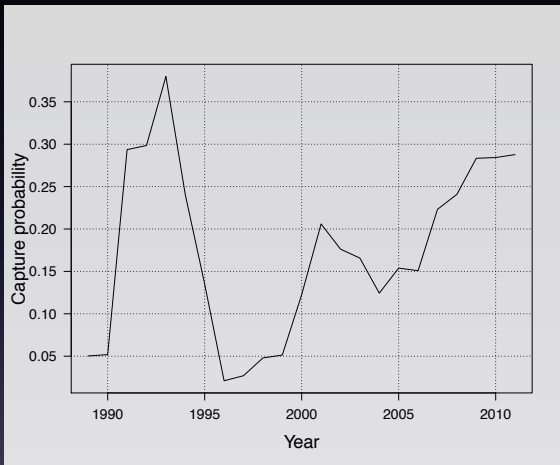


Figure: Maximum likelihood estimates of annual capture probability.

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Residuals (released marks)

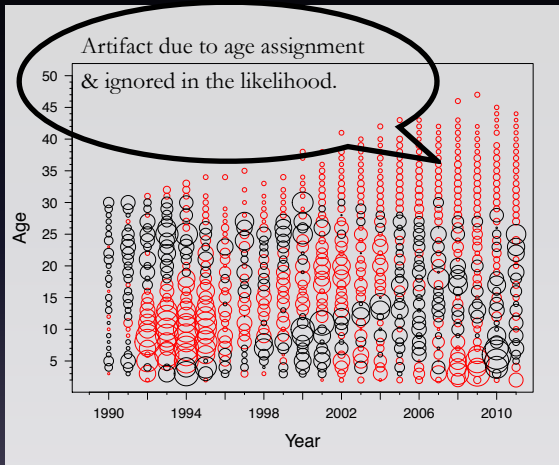


Figure: Pearson residuals (observed - expected) for new marks released (black=positive).

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Residuals (recaptured marks)

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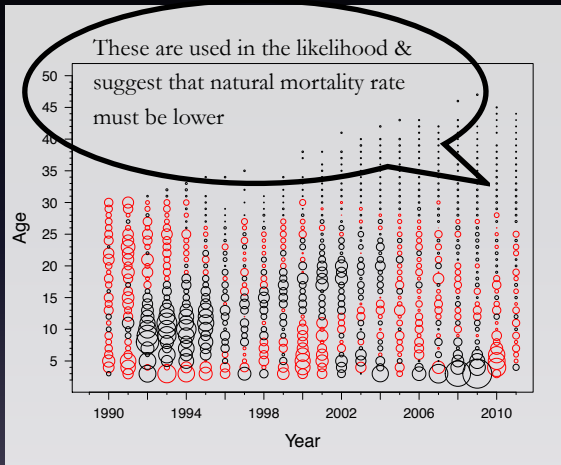


Figure: Pearson residuals (observed - expected) for recaptured marks (black=positive).

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Retrospective age-4+ abundance

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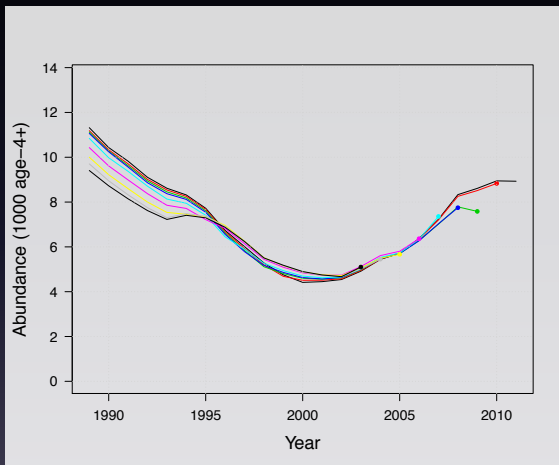


Figure: Retrospective estimates of age-4+ abundance.

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Retrospective age-2 recruits

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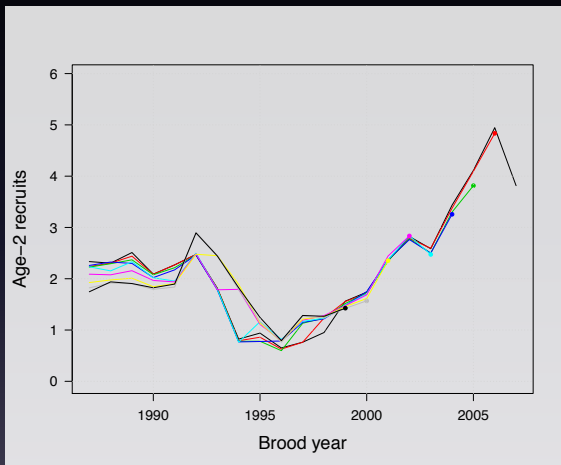


Figure: Retrospective estimates of age-2 recruits.

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Uncertainty: Age-4+ & Age-2

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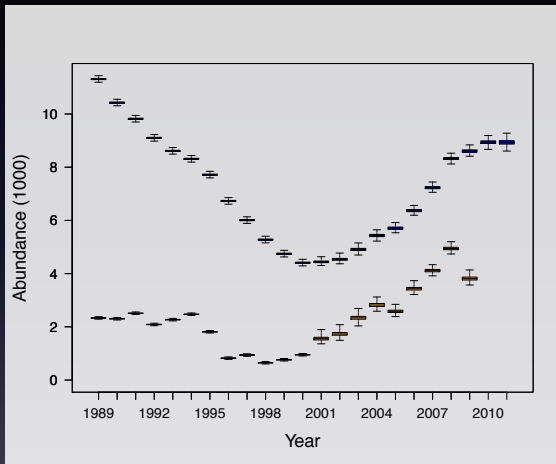


Figure: Marginal distributions for age-4+ (blue) abundance and age-2 recruits (orange).

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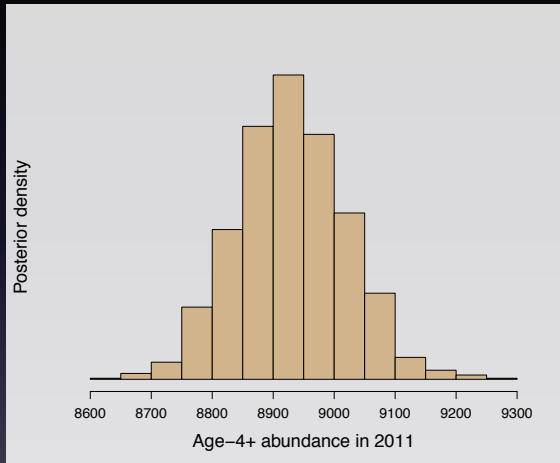
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Age-4+ abundance in 2011

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Figure: Marginal posterior density for age-4+ abundance in 2011.

Sensitivity to natural mortality (M)

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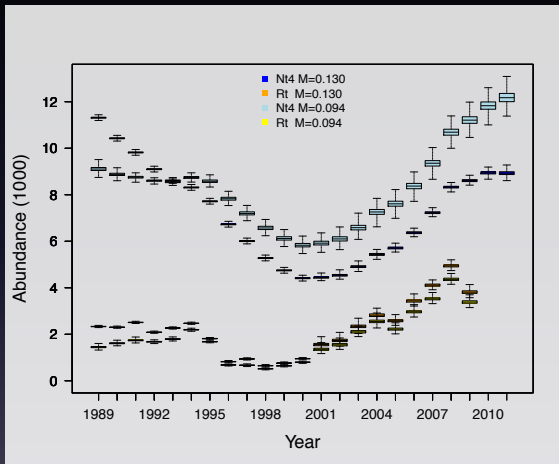


Figure: Freely estimating natural mortality results in increased estimates of age-4 abundance and fewer age-2 recruits.

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Sensitivity to natural mortality (M)

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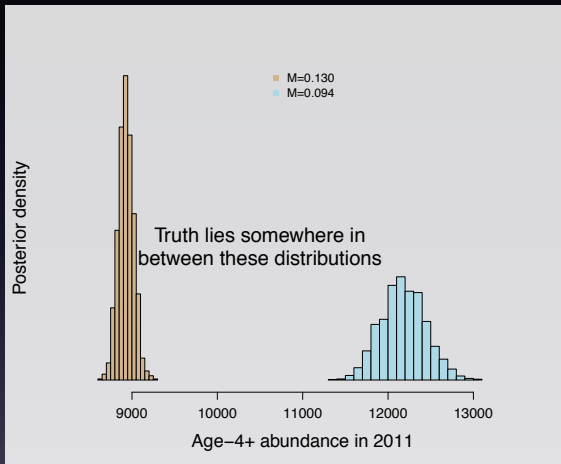


Figure: Marginal posterior density for age-4+ abundance in 2011 with $M=0.13$ (tan) and $M=0.094$ (light blue).

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Strong residual pattern arising age-assignment of newly marked fish (max age=30).

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Strong residual pattern arising age-assignment of newly marked fish (max age=30).

Recapture residuals suggest lower natural mortality rate.

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Summary

Strong residual pattern arising age-assignment of newly marked fish (max age=30).

Recapture residuals suggest lower natural mortality rate.

Assuming the asymptotic natural mortality rate of 0.13:

- Median age-4+ in 2011: 8912 (8736, 9095)–95%CI
- Median age-2 in 2011: 3998 (3814, 4195)–95%CI

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Assuming the asymptotic natural mortality rate of 0.13:

- Median age-4+ in 2011: 8912 (8736, 9095)–95%CI
- Median age-2 in 2011: 3998 (3814, 4195)–95%CI

Freely estimating natural mortality rate ($M = 0.094$):

- Median age-4+ in 2011: 12274 (11773, 12812)–95%CI
- Median age-2 in 2011: 3635 (3463, 3838)–95%CI

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Freely estimating natural mortality rate ($M = 0.094$):

- Median age-4+ in 2011: 12274 (11773, 12812)–95%CI
- Median age-2 in 2011: 3635 (3463, 3838)–95%CI

Uncertainty is grossly under-estimated due to observation error only, and assignment of age from length.

Future Work

Developing a length-based version of ASMR where there is no age-assignment from length.

Key Features:

- Mixed-error model (better uncertainty estimates)
- Growth based on length-transition matrix (no aging info)
- Can incorporate information on individuals < 150 mm.

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Acknowledgments

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