Abundance Trends and Status of the Little Colorado River Population of Humpback Chub: An Update Considering data 1989-2006

Presentation to the Glen Canyon Dam Technical Workgroup

By

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Report Objectives

- Update 2002 HBC stock assessment (Coggins et al. 2006) with most recent information
  - Catch-rate Indices (LCR Inflow and Lower LCR)
  - Summarize Spring LCR Closed Population Estimates
  - Update Age-Structured Mark-Recapture (ASMR) model with data through 2006
    - Utilize various model selection tools to arbitrate among ASMR 1-3
    - Estimate age-length relationship from tagging data
    - Incorporate uncertainty in assignment of age.

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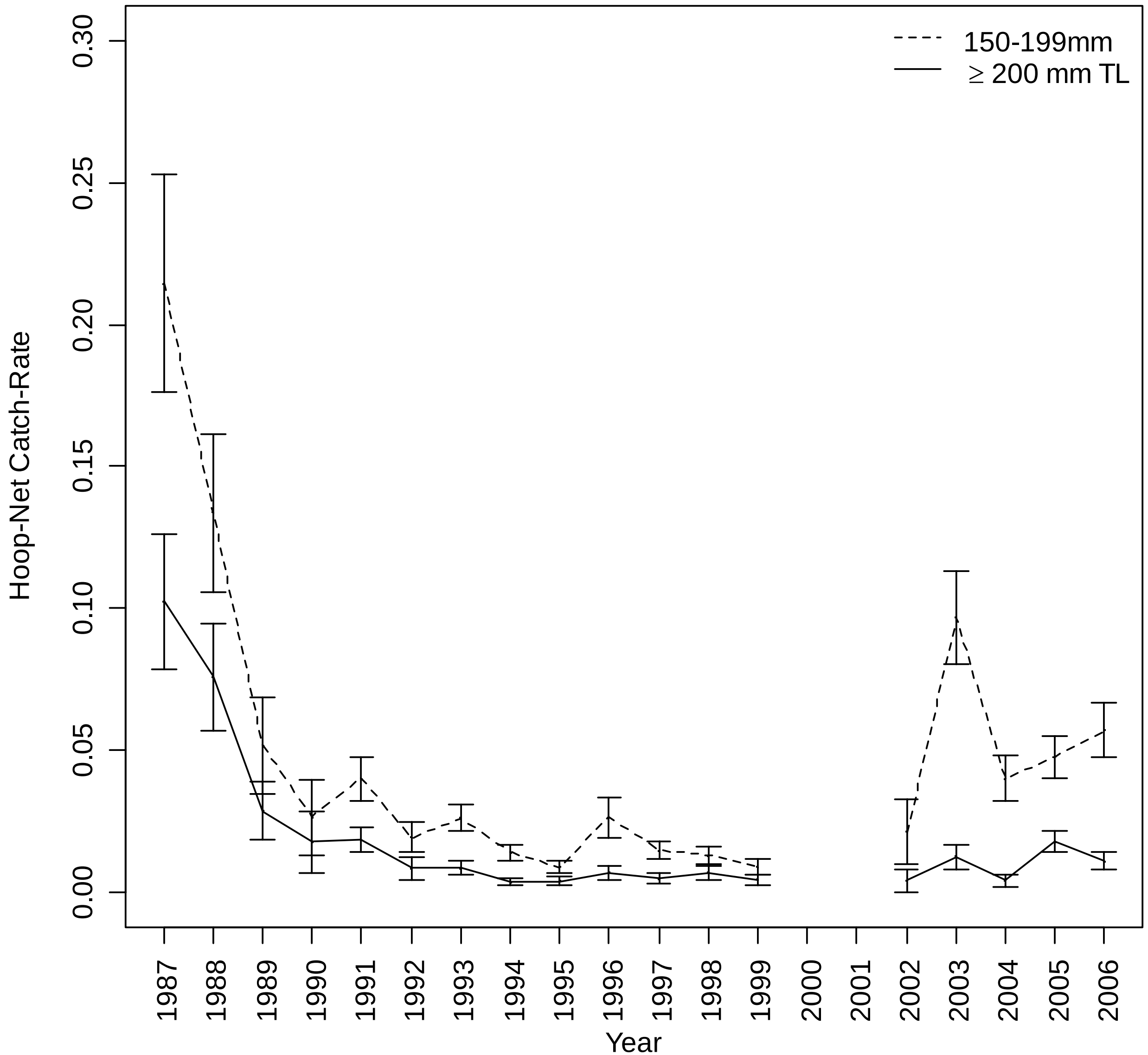
HBC Catch-Rate Indices

HBC Hoop-net Catch-rate in lower 1,200 m of the LCR

- Spring Sampling
- 30+ days
- Hoop-nets in standardized locations
- Error Bars are 95% CI



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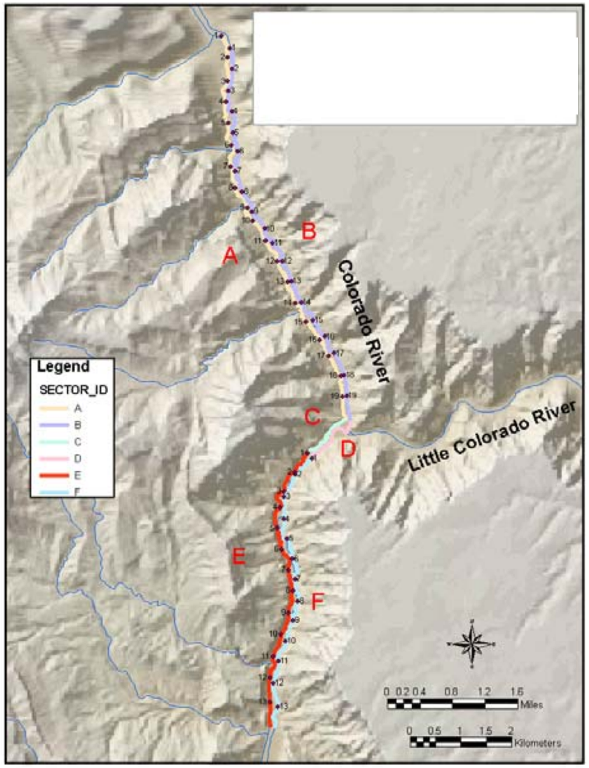
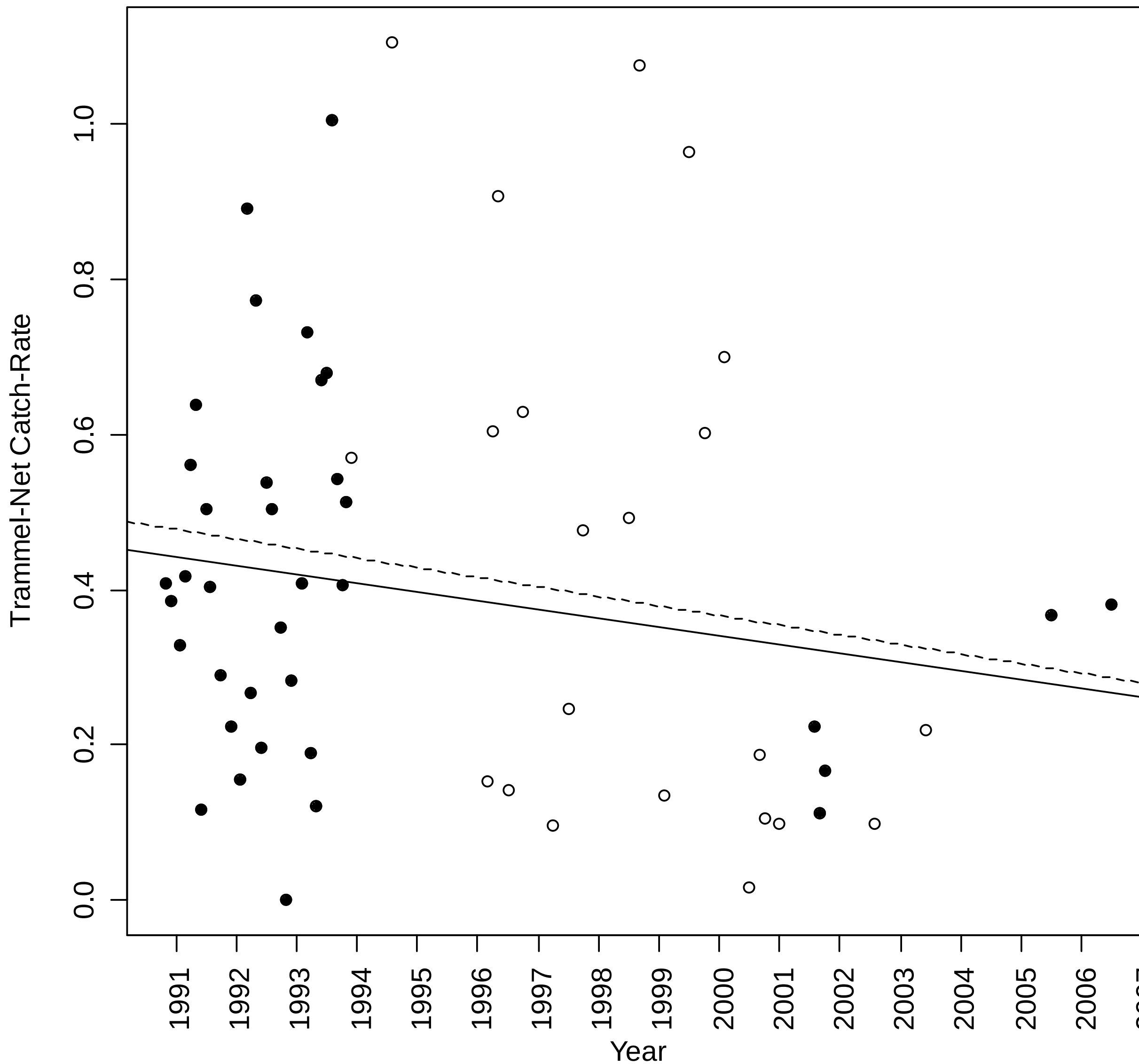
HBC Trammel-net Catch-rate in LCR Inflow Reach



- Monthly Catch-rate (fish/hour/100m)
- Solid dots are representative sampling
- Open dots are limited sampling



Spring LCR HBC Abundance Estimates

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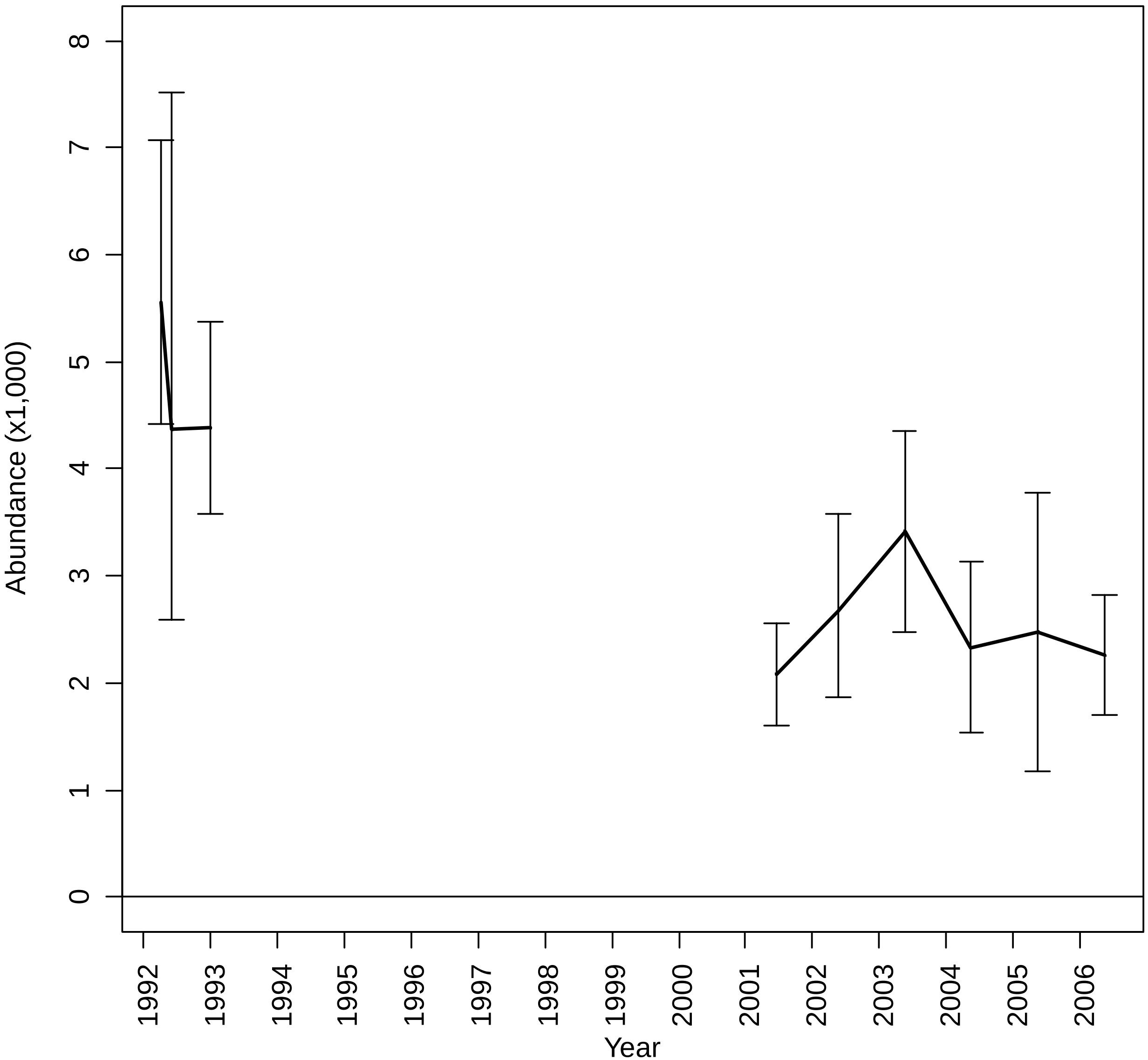
Spring LCR HBC Abundance Estimates

- 2-Event Lincoln-Petersen closed population mark-recapture experiments
- Abundance of HBC >= 150 mm Total Length
- Error Bars are 95% CI



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ASMR Open Population Estimates

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Background – ASMR Model Structure

- Coggins, L.G., Jr., W.E. Pine, III, C.J. Walters, S.J.D. Martell. 2006b. Age-structured mark-recapture analysis: a virtual-population-analysis-based model for analyzing age-structured capture-recapture data. North American Journal of Fisheries Management. 26:201-205.

- ASSUMPTIONS
  - ASMR assumes a length/age dependent mortality schedule.

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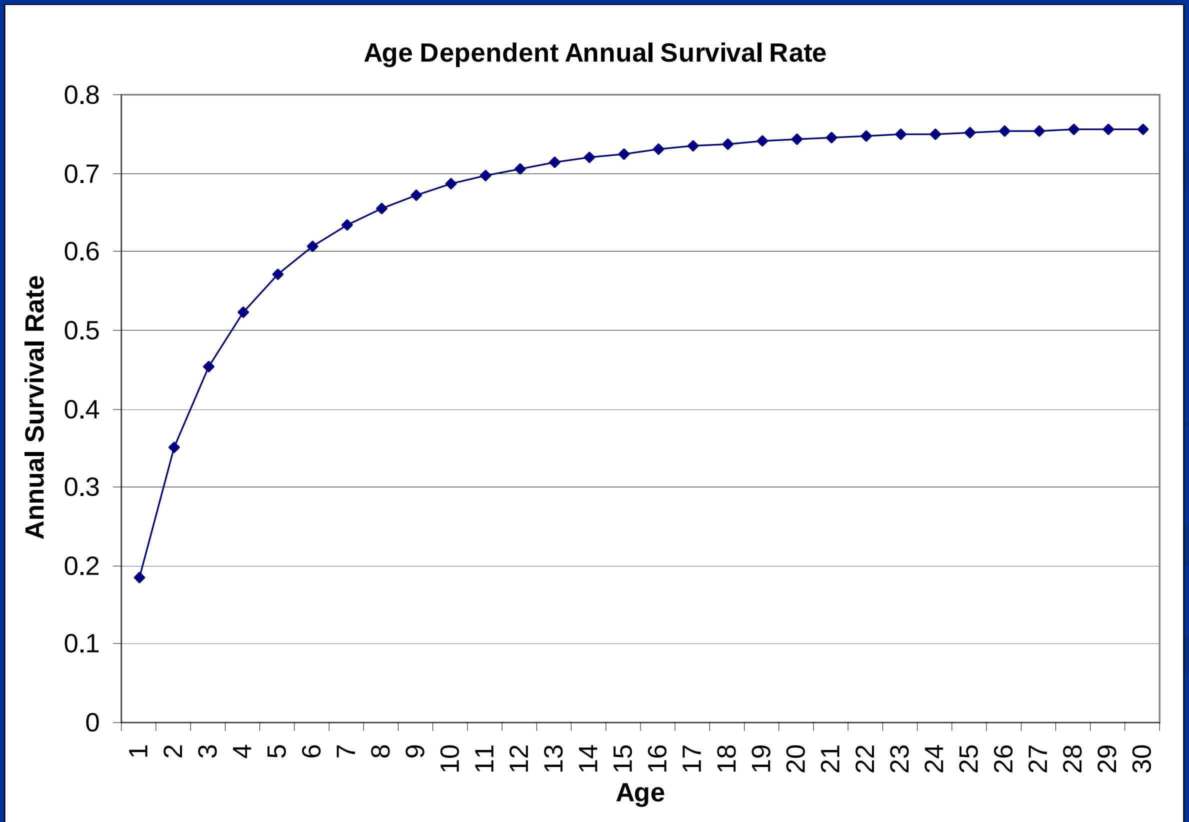
Background – ASMR Model Structure

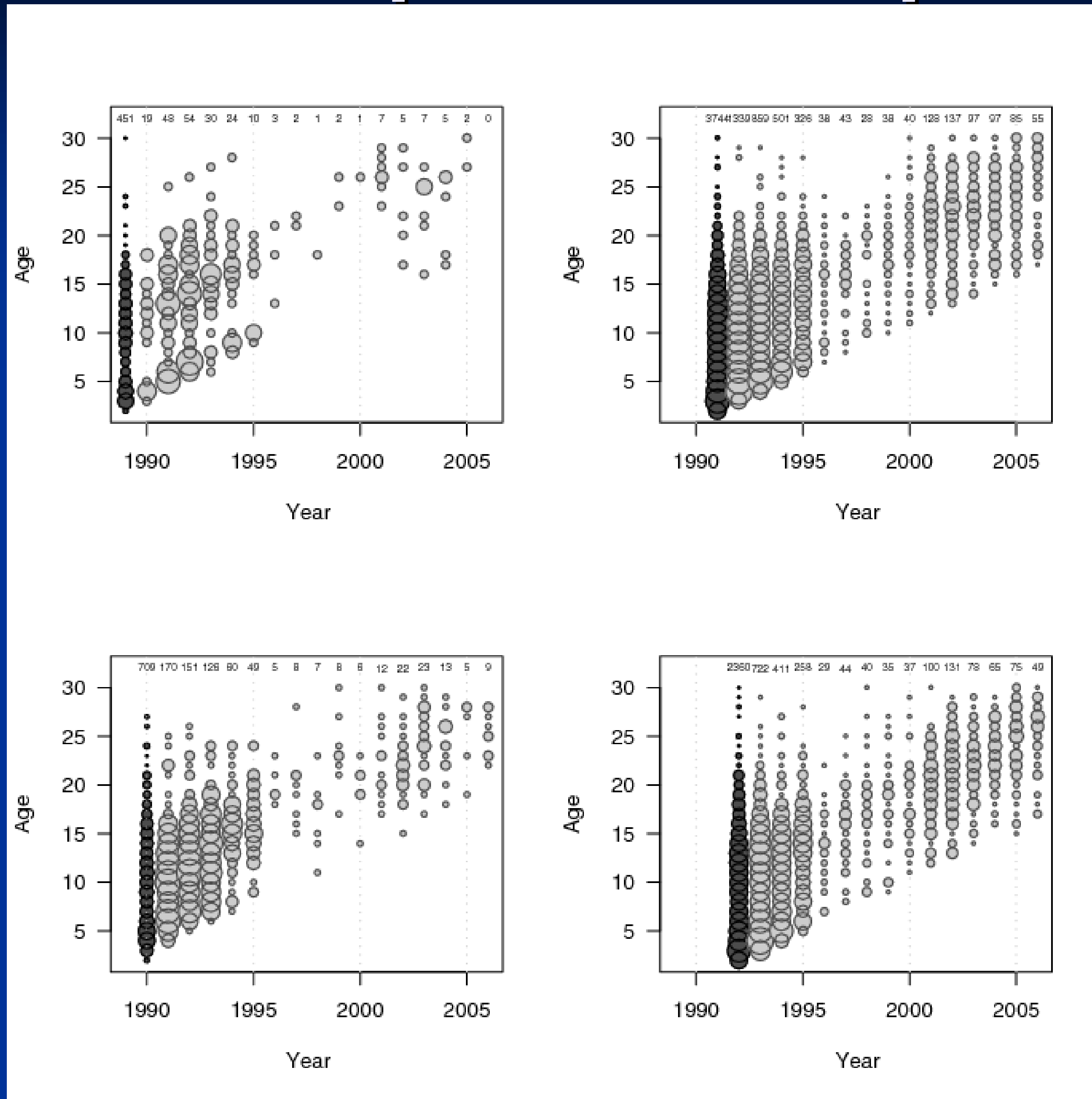
- Lorenzen (2000) type Mortality Schedule
  - Mortality rate proportional to 1/length using von Bertalanffy growth parameter k
    - Estimate Mortality of oldest fish
    - Von Bertalanffy k and Madult used to calculate mortality rate of younger fish



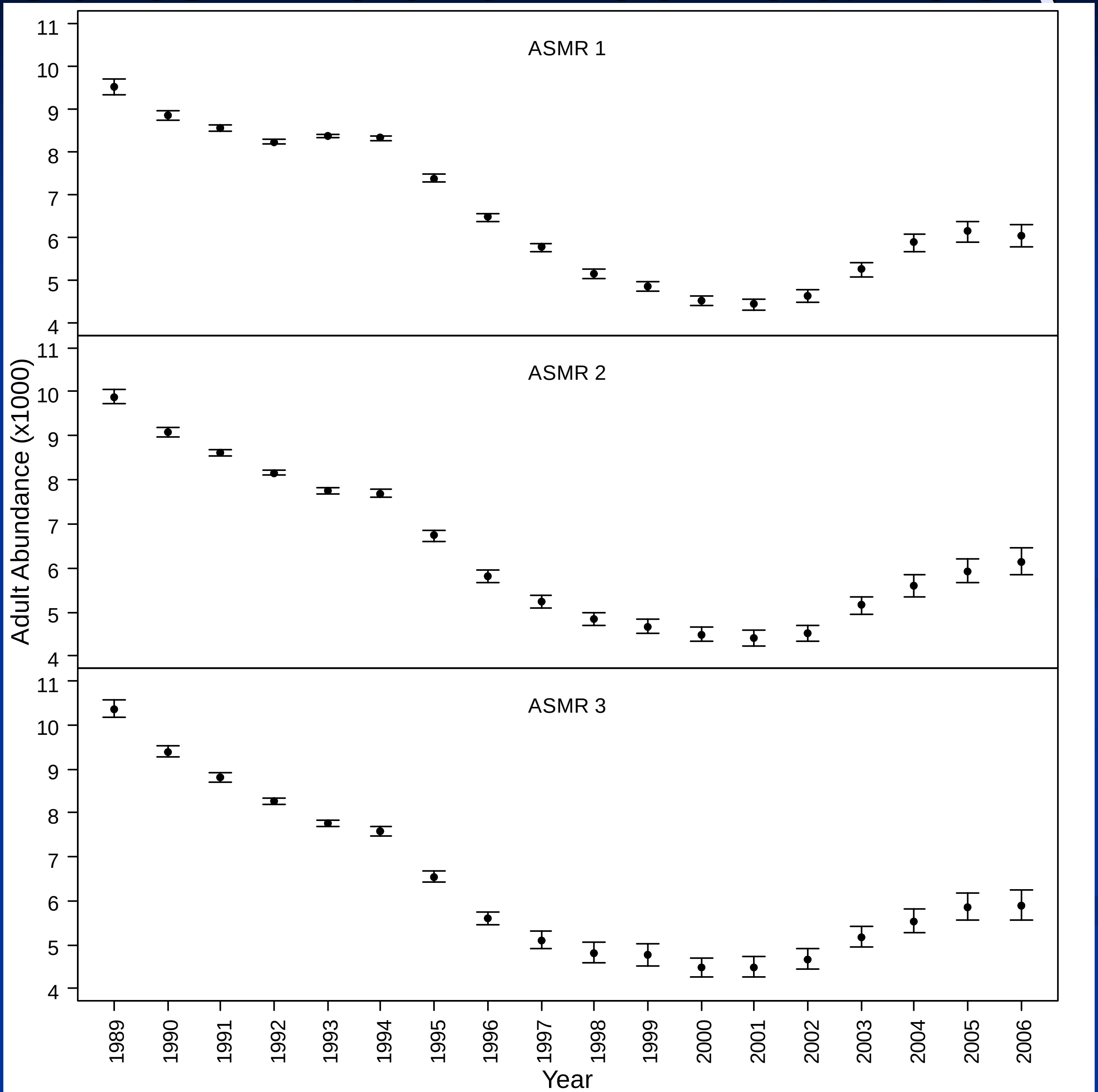
Background – ASMR Model Structure

- ASSUMPTIONS
  - Assumes size (age) dependent mortality rate
  - Three different formulations of ASMR
    - ASMR 1 and ASMR 2 assume that vulnerability to capture is asymptotic with age.
    - ASMR 3 uses conditional maximum likelihood estimators to estimate each time and age specific capture probability

Results-Simple Data Inspection



Results- Adult Abundance (4+)



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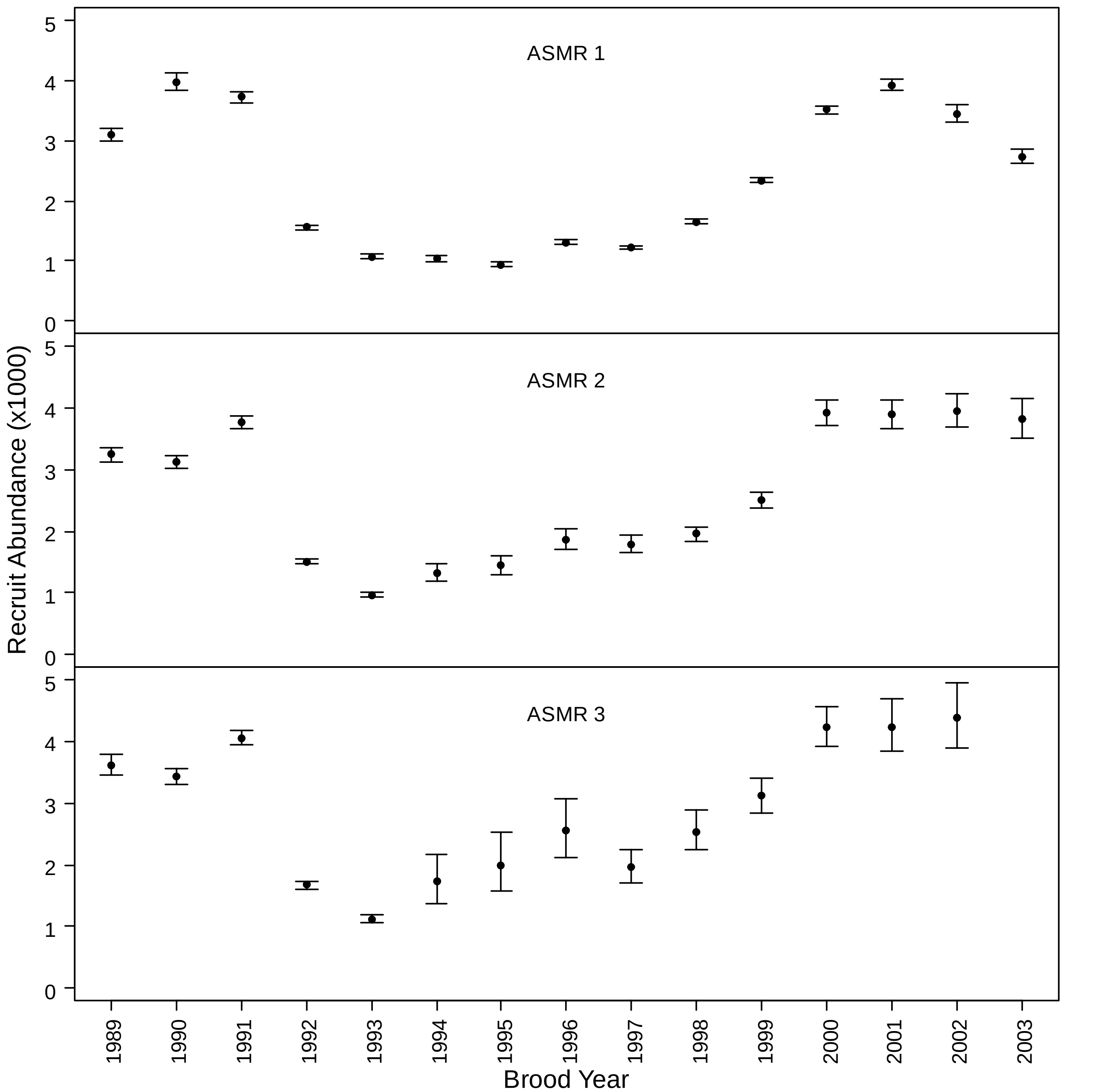
Results- Recruit Abundance



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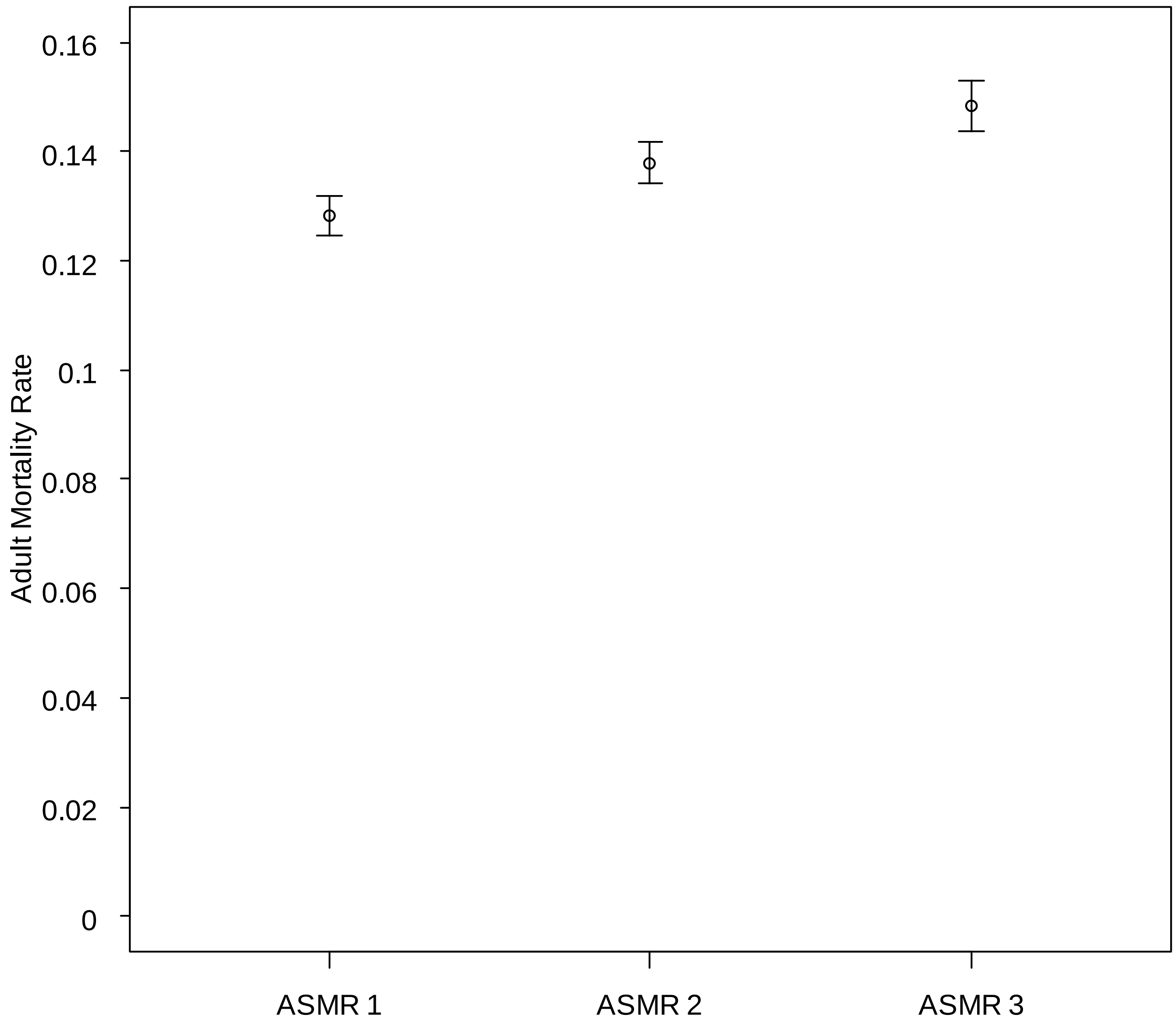
Results- Adult Mortality



Results- Which one is “Right”?

- Who Cares… they all say the same thing about adult abundance!
- Maybe we should care… slightly different hypotheses about recruitment.

- How to Arbitrate among models?
  - Pearson Residual Patterns
    - How well does the model fit (predict) the data?
  - AIC scores
    - Kullback-Leibler distance

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$$r_{a,t} = \frac{o_{a,t} - p_{a,t}}{\sqrt{\frac{p_{a,t}(1 - p_{a,t})}{n_t}}}$$

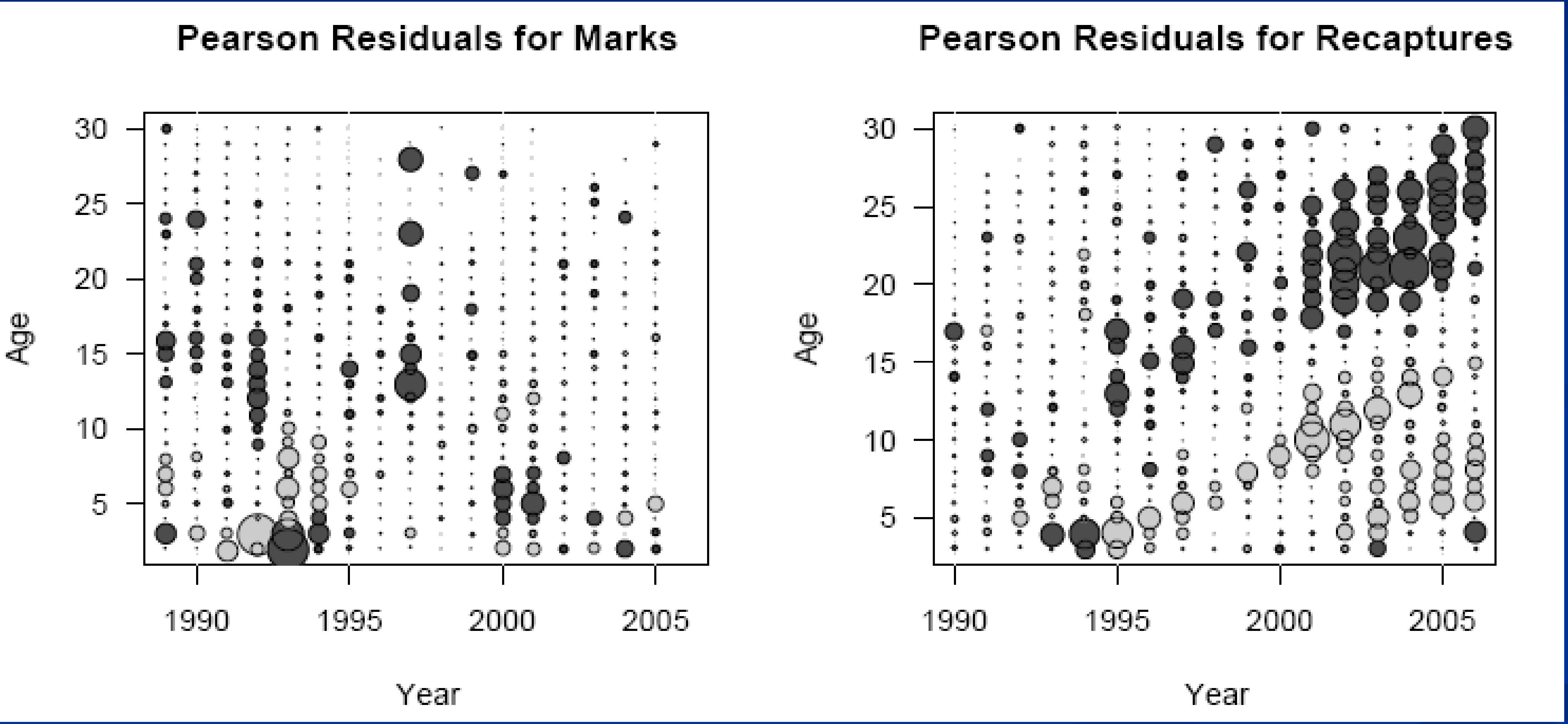
Results- Which one is "Right"?

- Pearson Residuals

$$r_{a,t} = \frac{o_{a,t} - p_{a,t}}{\sqrt{\frac{p_{a,t}(1 - p_{a,t})}{n_t}}}$$

Results- Which one is “Right”?

ASMR-1

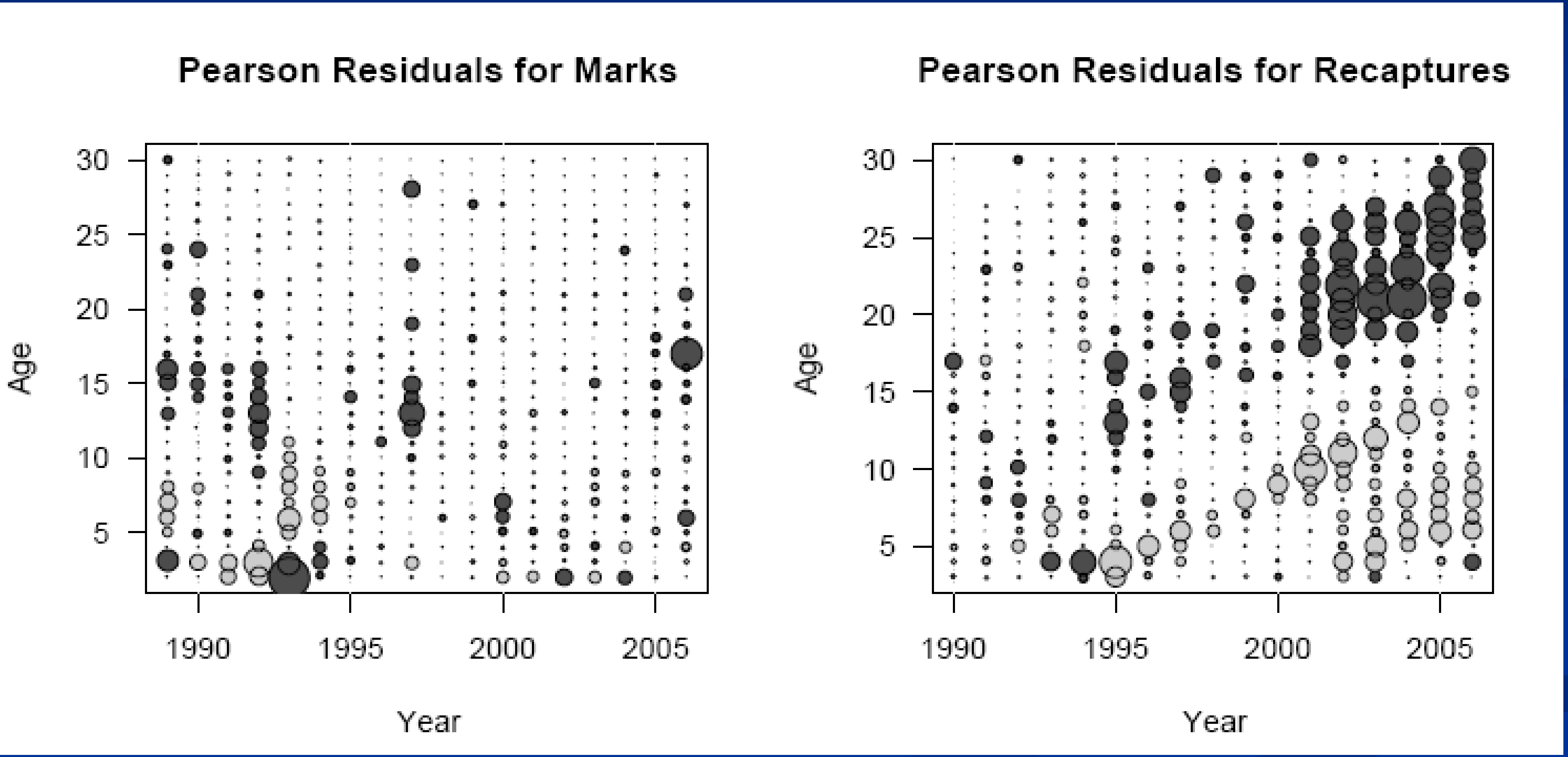


Black=More fish observed than predicted

Grey=Fewer fish observed than predicted

Results- Which one is "Right"?

ASMR-2

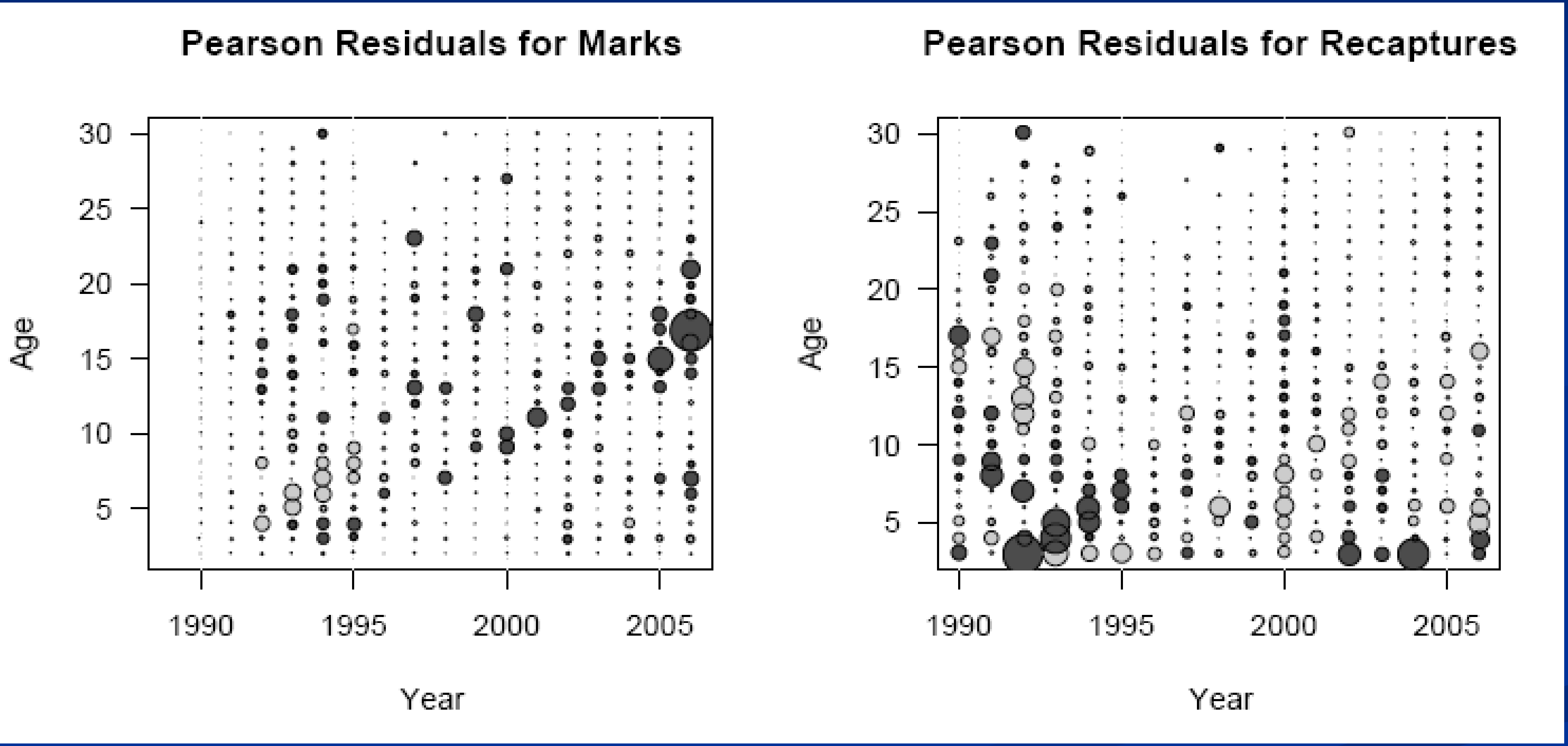


Black=More fish observed than predicted

Grey=Fewer fish observed than predicted

Results- Which one is "Right"?

ASMR-3



Black=More fish observed than predicted

Grey=Fewer fish observed than predicted

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Results- Which one is "Right"?

Model	AIC	# Parameters	Rank	ΔAIC
ASMR1	-196278	18	3	2577
ASMR2	-197183	30	2	1672
ASMR3	-198856	895	1	0

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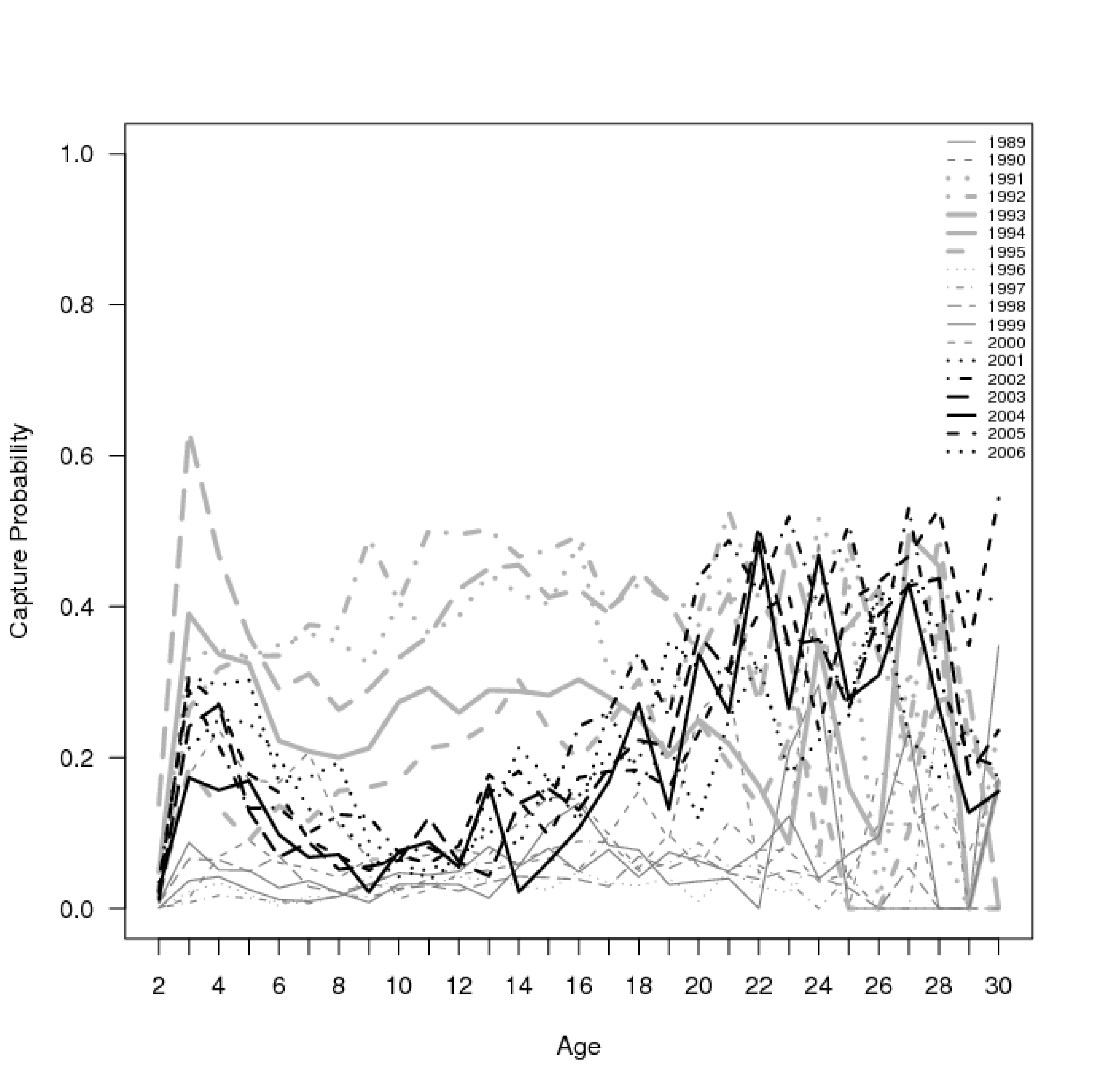
Results- Why is ASMR3 “Right”?



Is there anything wrong with this assessment?

- Estimates are extremely precise… maybe too good.
- HBC review panel (Kitchell et al. 2003) recommended evaluating the effect of ageing error on analysis.

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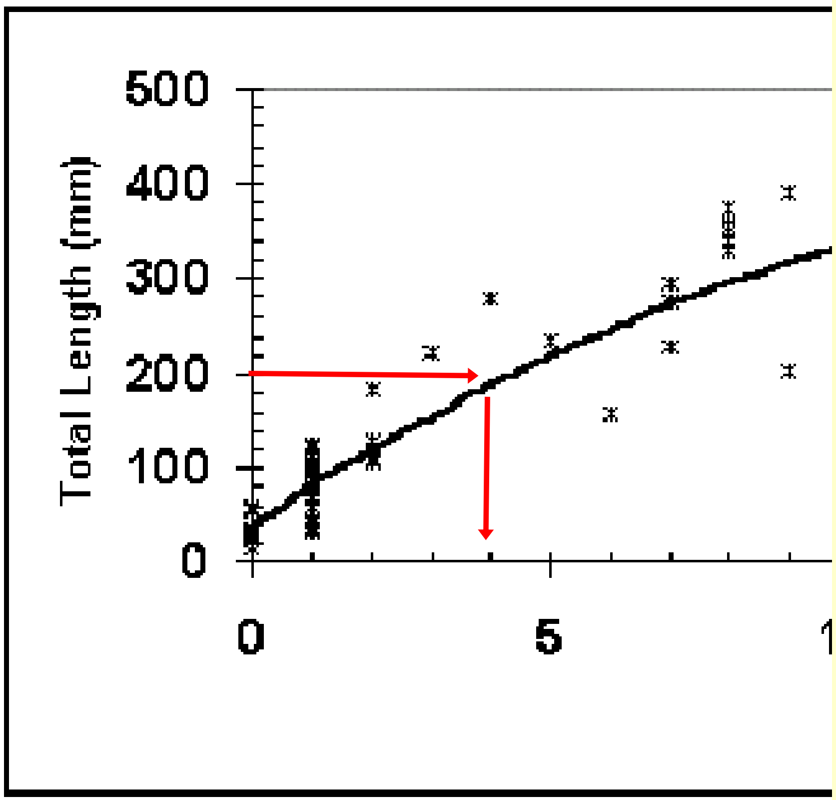
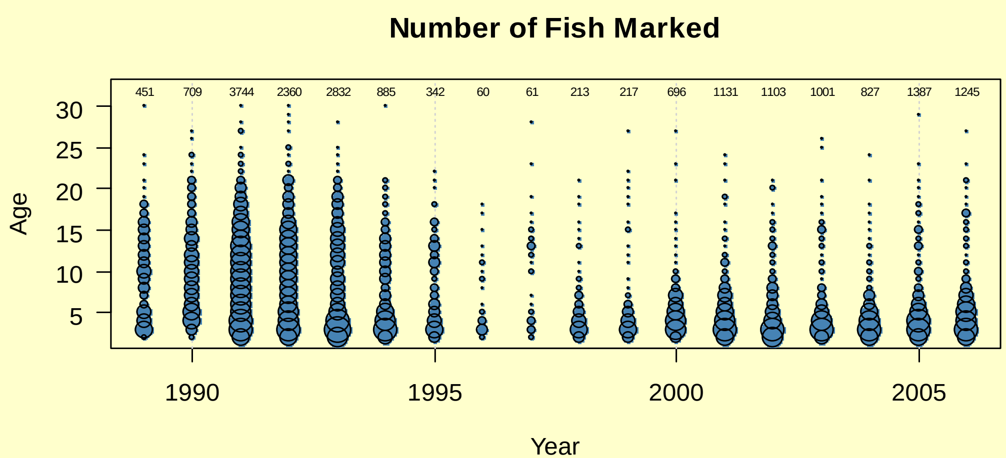
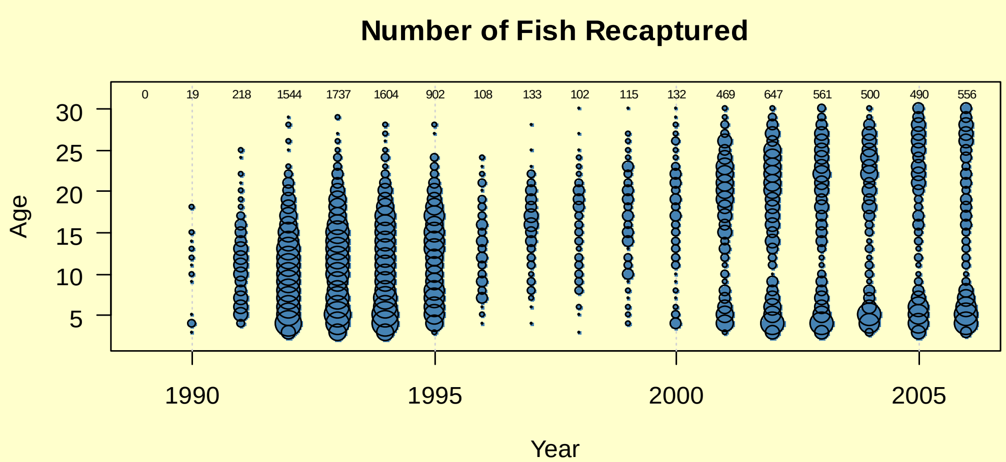
How do you Age chub?

- THE OLD WAY







The Problems

- Better describe humpback chub growth. Why?
  - Based on very limited dataset
  - May not accurately portray growth
    - Particularly growth changes associated with ontogenetic habitat shifts
- Incorporate uncertainty in age assignments into parameter estimates from ASMR. Why?
  - Current assessments may overstate confidence in monitoring results by not honestly incorporating uncertainty from the ageing process.

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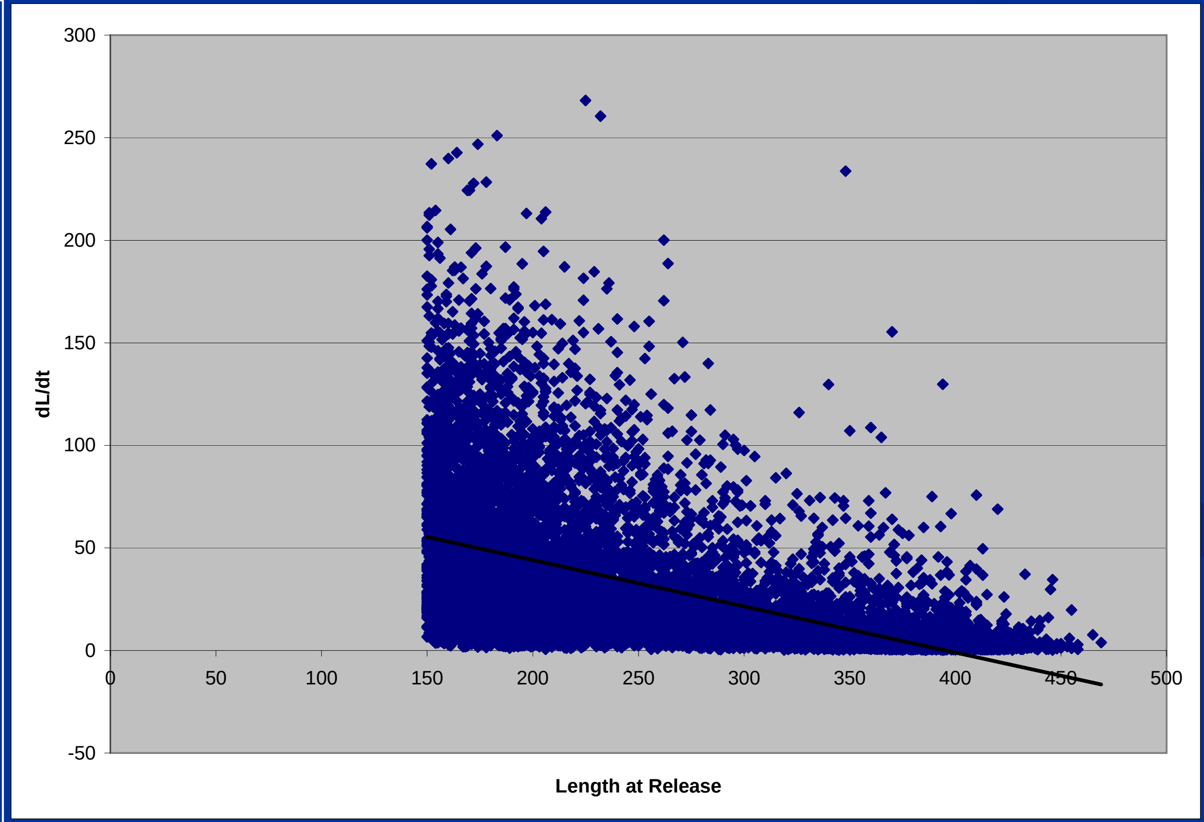
Problem 1 – Better Growth Curve

- Use Mark-Recapture Methods to Estimate Fish Growth Curves (Fabens 1965, Wang 1998, Laslett 2002)

- General Idea:

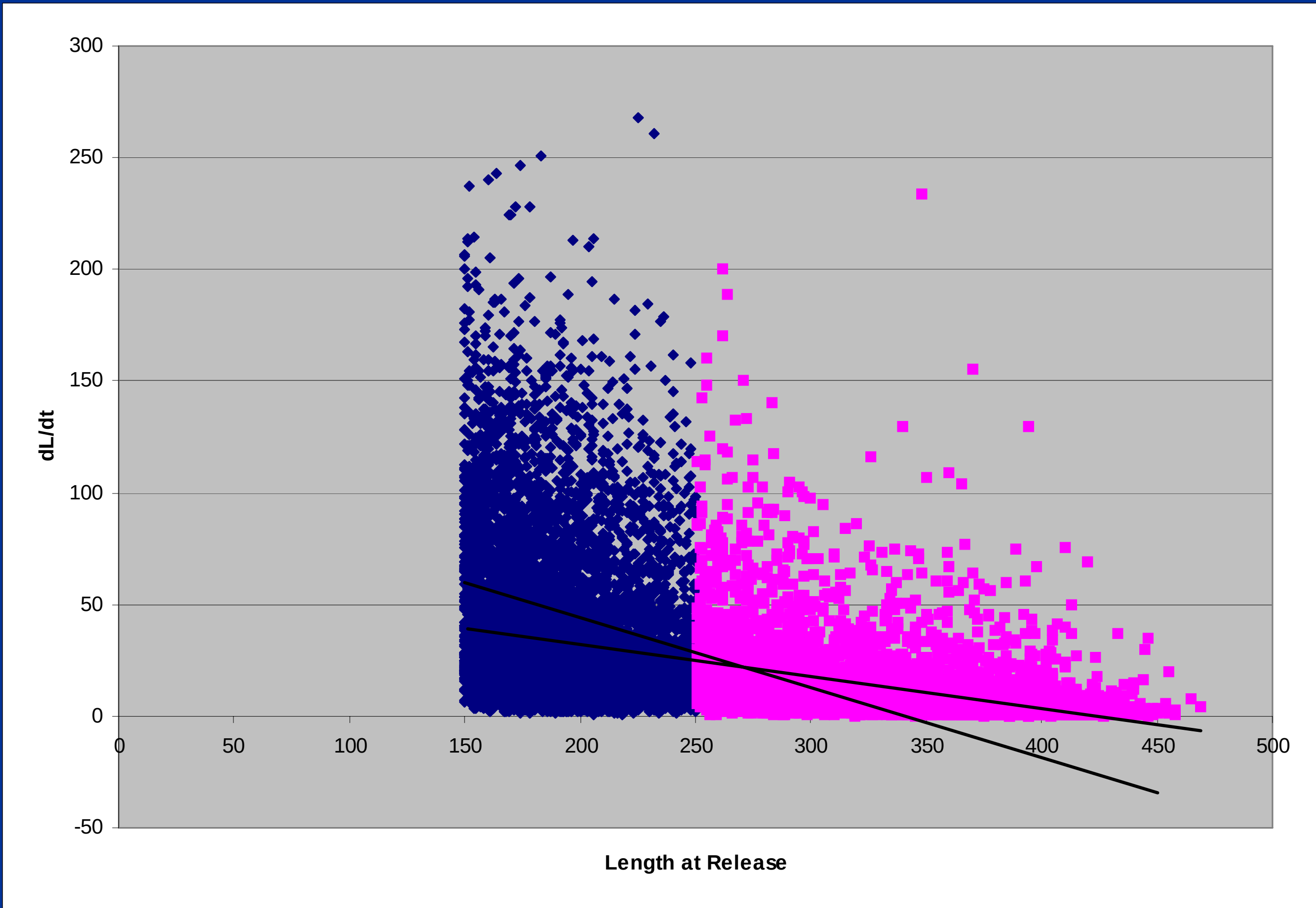
- Fit a standard von Bertalanffy growth model to predict growth rate as a function of length.



Problem 1 – Better Growth Curve

- Problem 1.a What if growth is not well represented by a standard von Bertalanffy growth curve?
  - Use a different growth curve.

- Can either fit growth rates of small fish well or growth rates of large fish well.



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Problem 1 – Better Growth Curve I

- Generalized Von Bertalanffy Model
  - Essington et al. 2001
    - Rate of Weight Change

$$\frac{dW}{dt} = HW^{d} - kW^{n}$$

- Anabolic Processes
- Catabolic Processes

- Specify allometric relationship

$$W = aL^{b}$$

- Analogous relationship for length
- Temperature independent growth model (TIGM)

$$\frac{dL}{dt} = \alpha L^{\delta} - \kappa L^{\eta}$$

Problem 1 – Better Growth Curve II

- Generalized Von Bertalanffy with Temperature Dependence
  - Walters and Essington (*In Prep.*)

$$\frac{dL}{dt} = \alpha L^{\delta} f_c(T) - \kappa L^{\eta} f_m(T)$$

$$f_c(T) = Q_c^{\frac{(T-10)}{10}}$$

$$f_m(T) = Q_m^{\frac{(T-10)}{10}}$$

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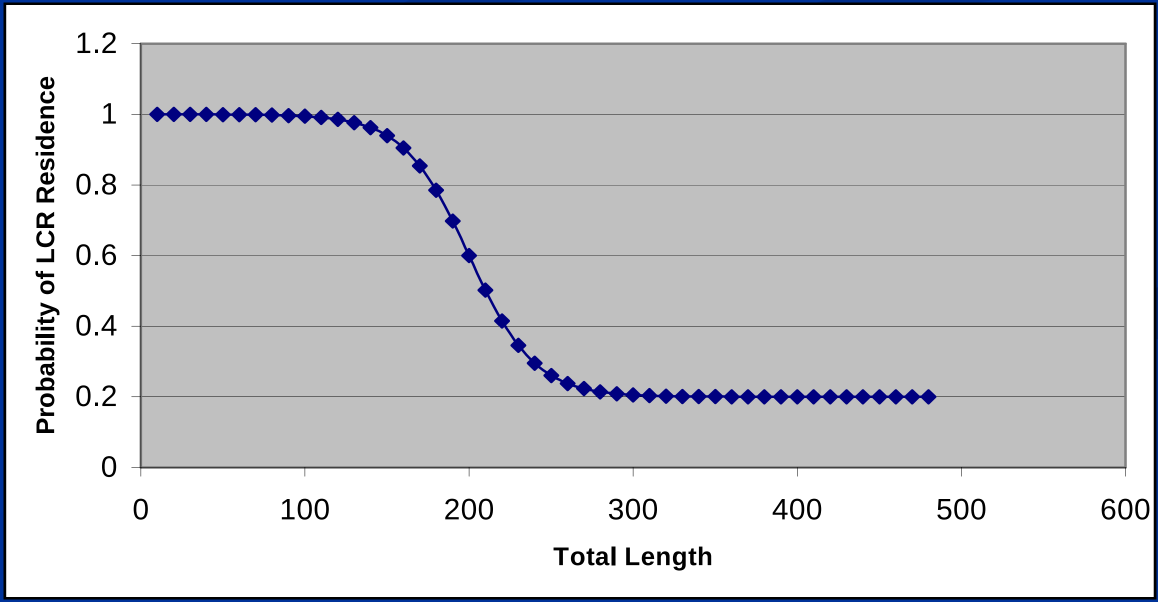
Problem 1 – Better Growth Curve II

- How do you get the Temperature? $f_m(T) = Q_m^{\frac{(T-10)}{10}}$

- The temperature that a fish experiences depends on whether or not it is in the LCR or the Mainstem and what the temperatures are in each of those habitats.

$$PLCR = 1 - \frac{0.8}{1 + e^{-\frac{(L - L_t)}{20}}}$$



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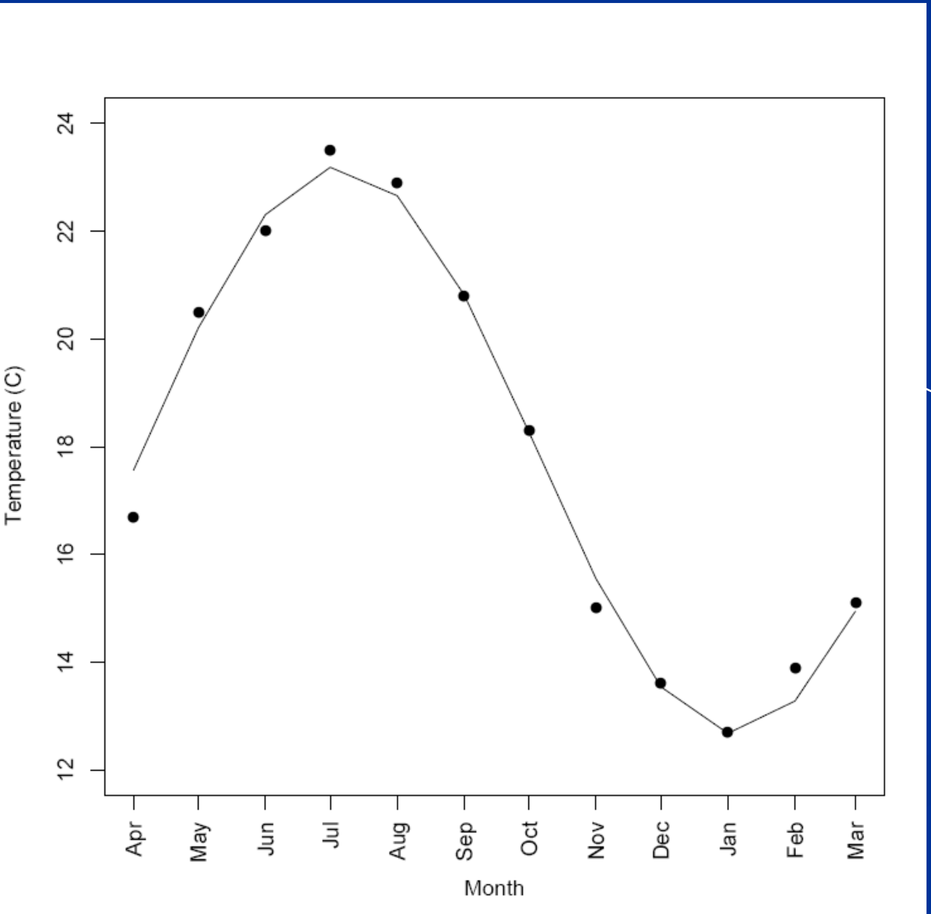
Problem 1 – Better Growth Curve II

- The temperature that a fish experiences depends on whether or not it is in the LCR or the Mainstem and what the temperatures are in each of those habitats.

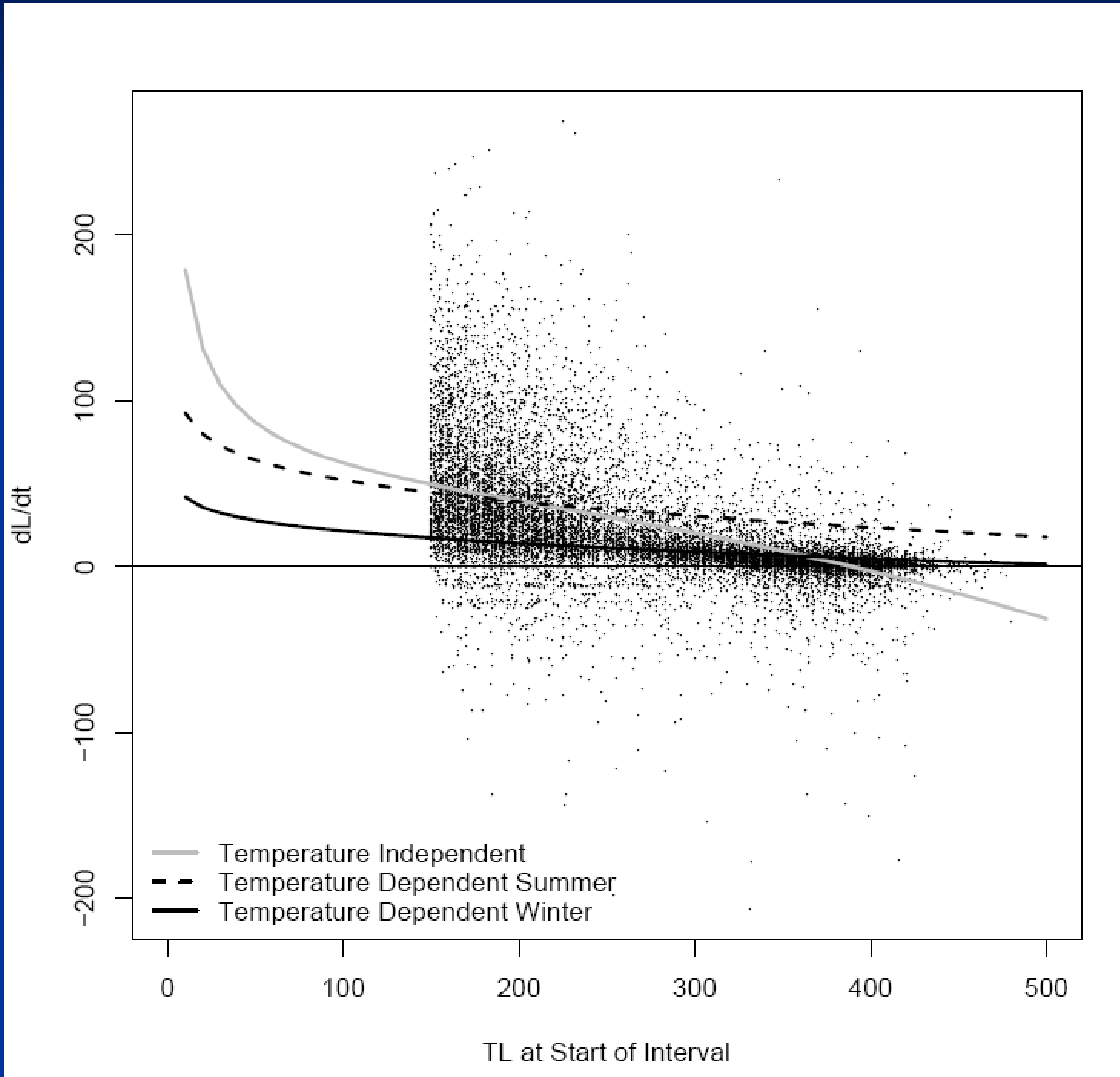


10º C

$$T(t) = (PLCR)T_{LCR}(t) + (1 - PLCR)T_{MS}(t)$$

Growth Curves Fit

- Temperature independent growth curve is a compromise between the winter and summer temperature dependent curves



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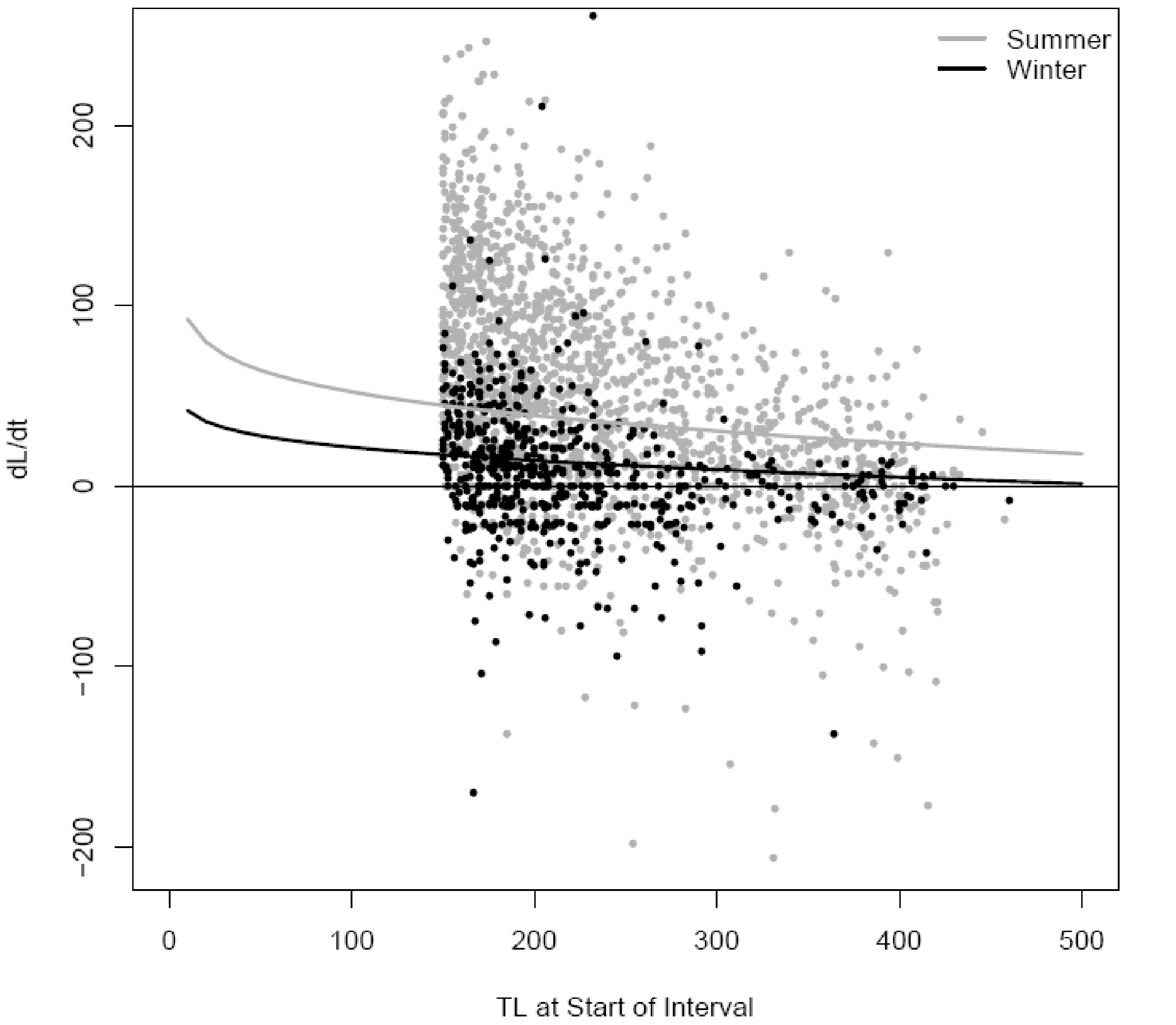
Growth Curves Fit

- Growth rate appears to be oscillating up and down with temperature



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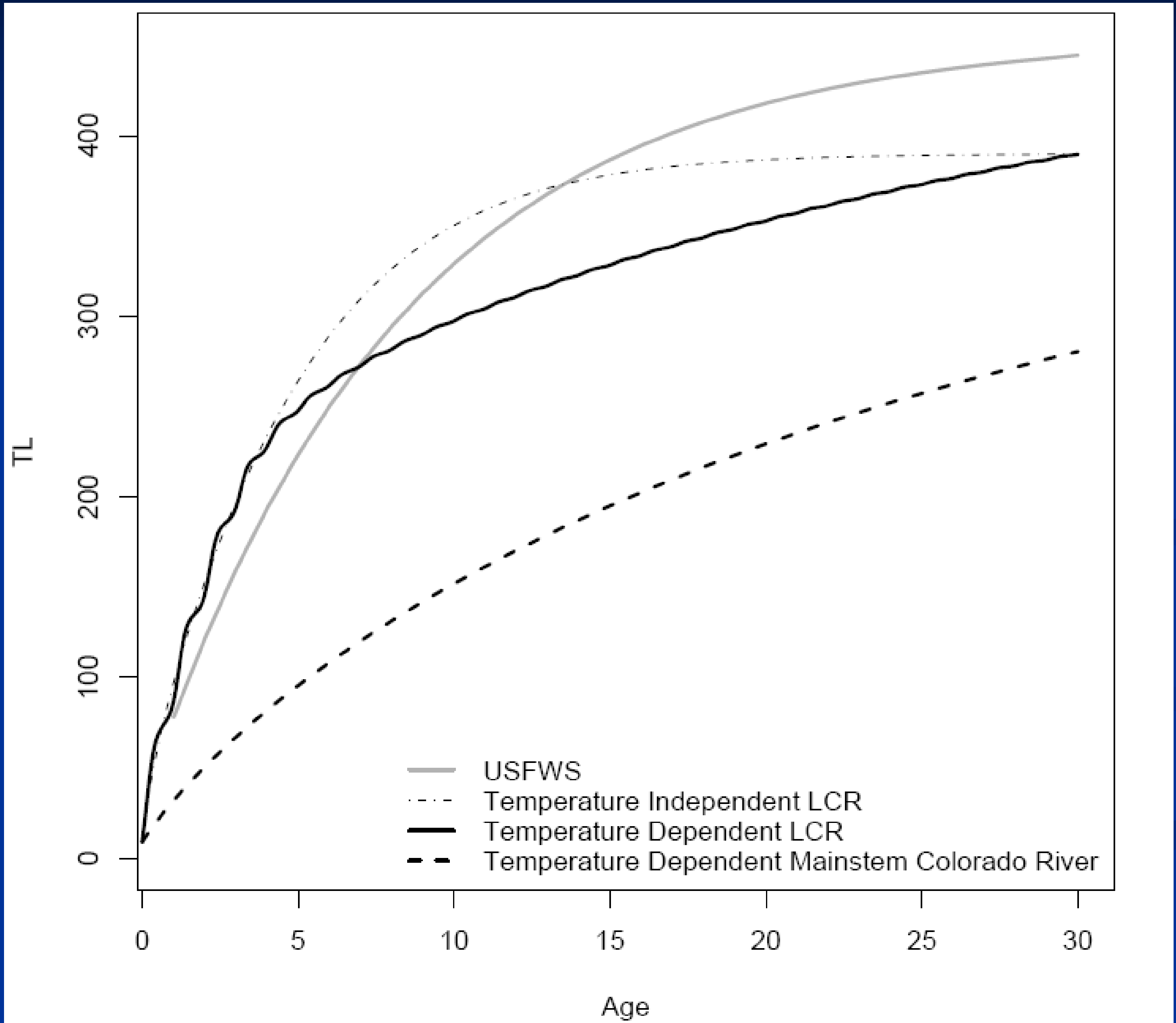
Age-Length Relationship



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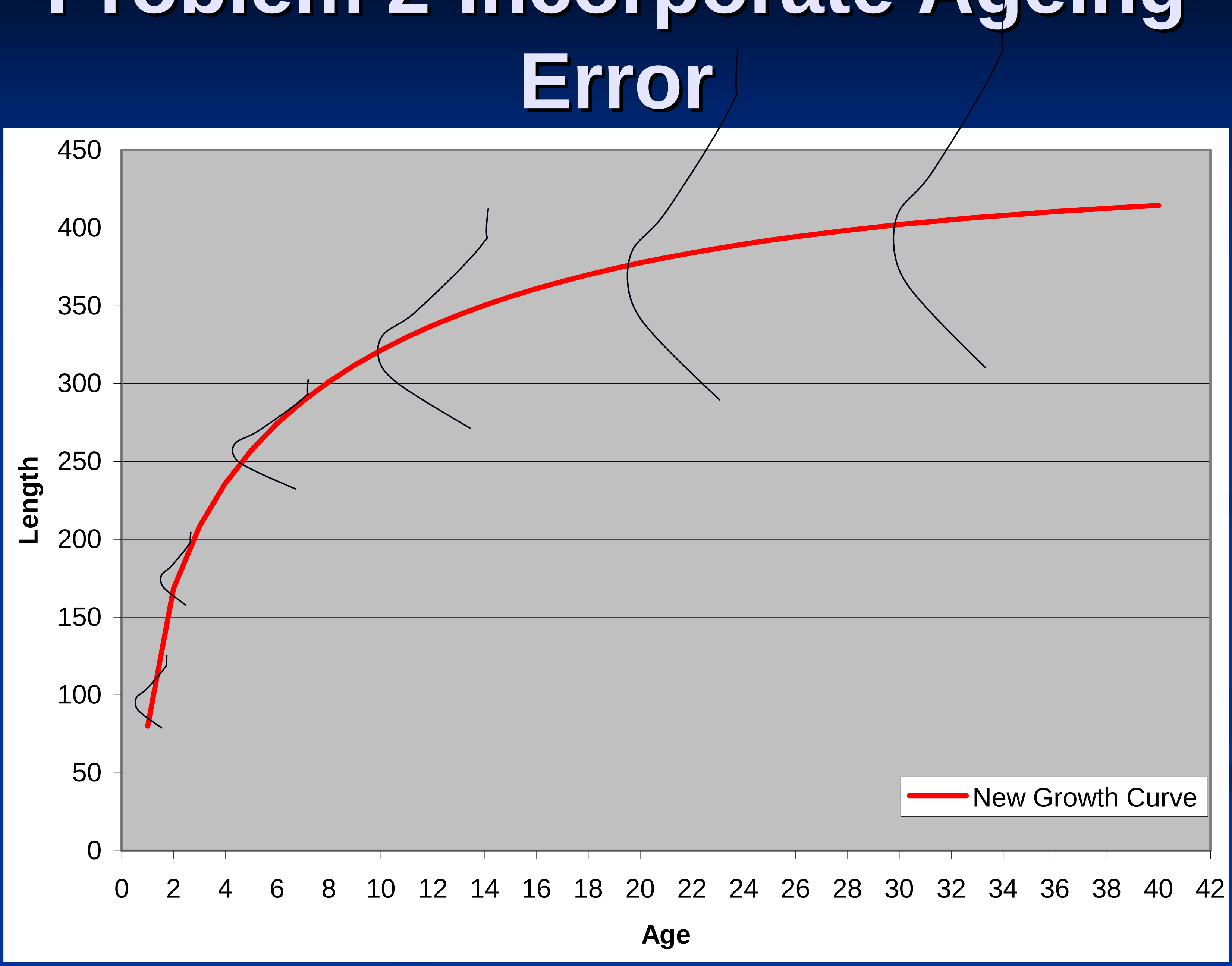
Which one is "Right"?

- AIC score clearly indicates that the temperature dependent growth model is superior.

Model	H	d	m	n	L_∞	σ^2_L	Q_c	L_t	Log Likelihood	AIC	# Params.	Rank	?AIC
TIGM	163	0.52	.0007	1.15	391	961	--	--	-66,823	133,658	6	2	38,493
TDGM	21.0	.61	0.46	.89	434	2000	4.59	236	-47,574	95,165	8	1	0

Problem 2-Incorporate Ageing Error



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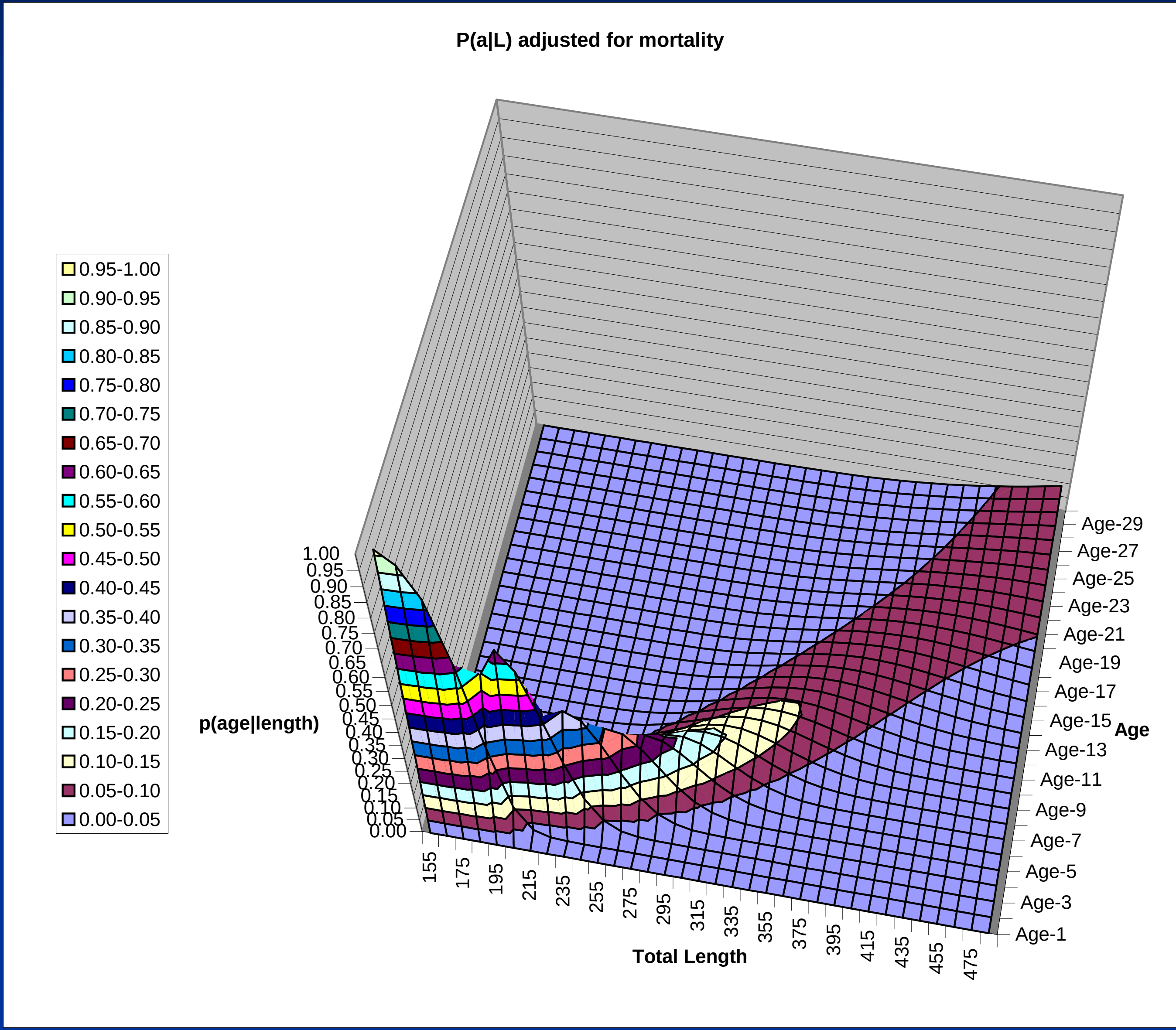
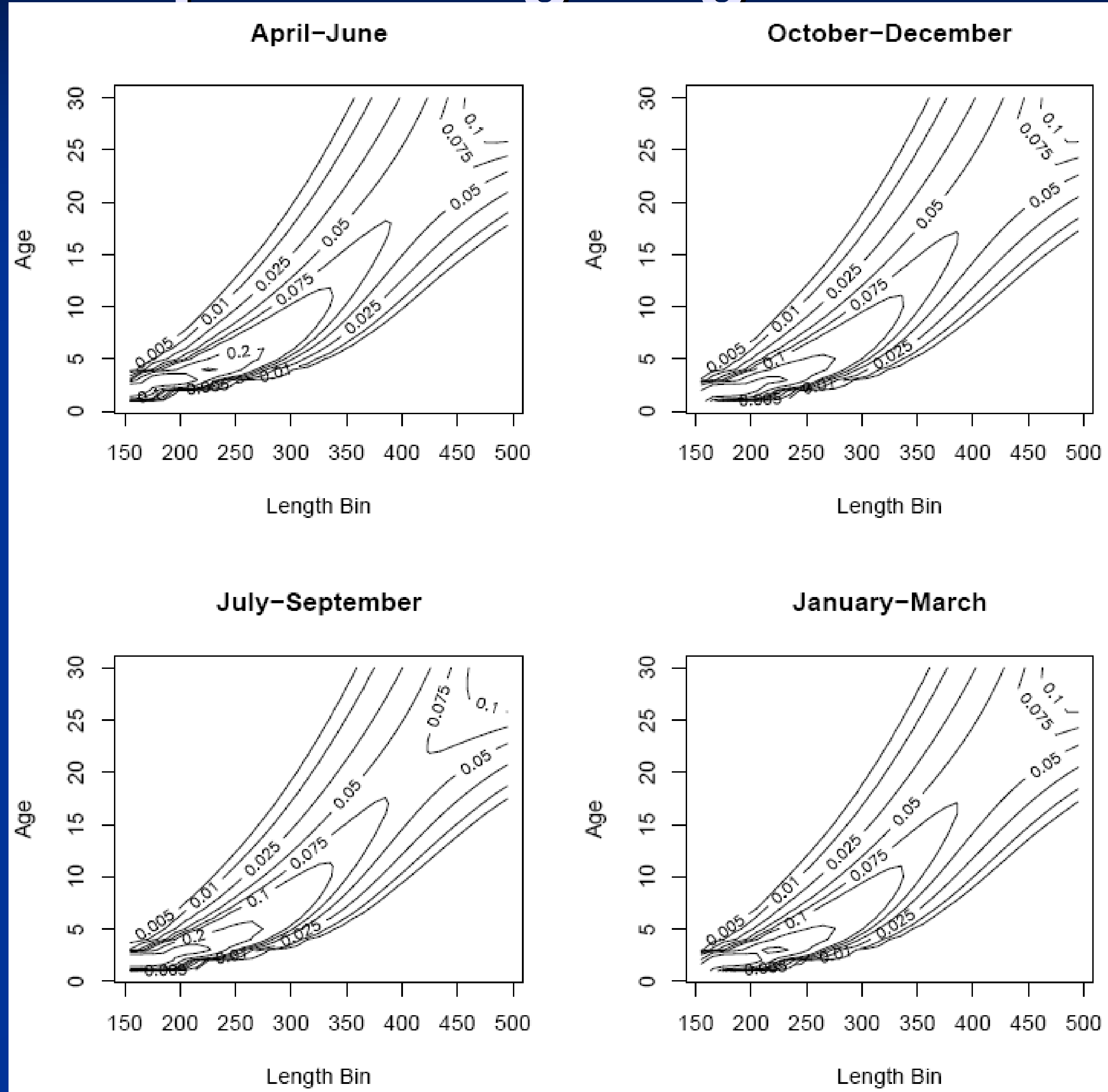
Problem 2-Incorporate Ageing Error

- Generally following ideas by Taylor et al. 2005



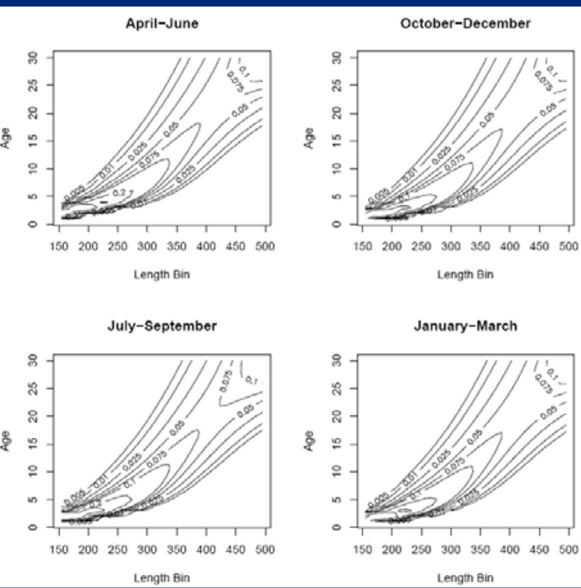
Problem 2-Incorporate Ageing Error

- Generate seasonal age|length probability surfaces to assign age based on month of year fish was captured.

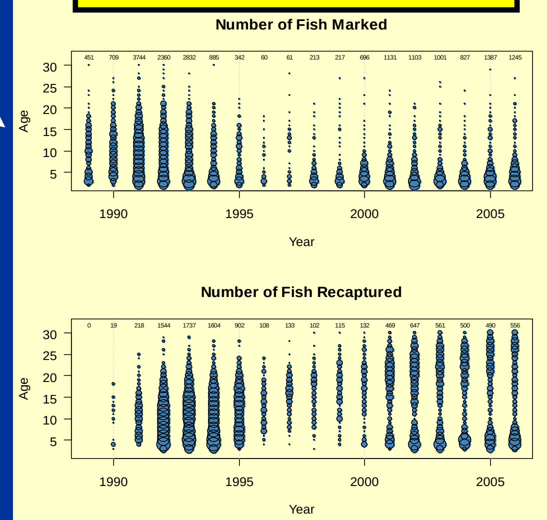


Problem 2-Incorporate Ageing Error

- Flow chart of Monte Carlo simulation…1000 times



AGE-Structured
Mark-Recapture
Data



ASMR

Model

Estimates of:
Abundance,
Recruitment,
Mortality

- Length of each marked and unmarked fish

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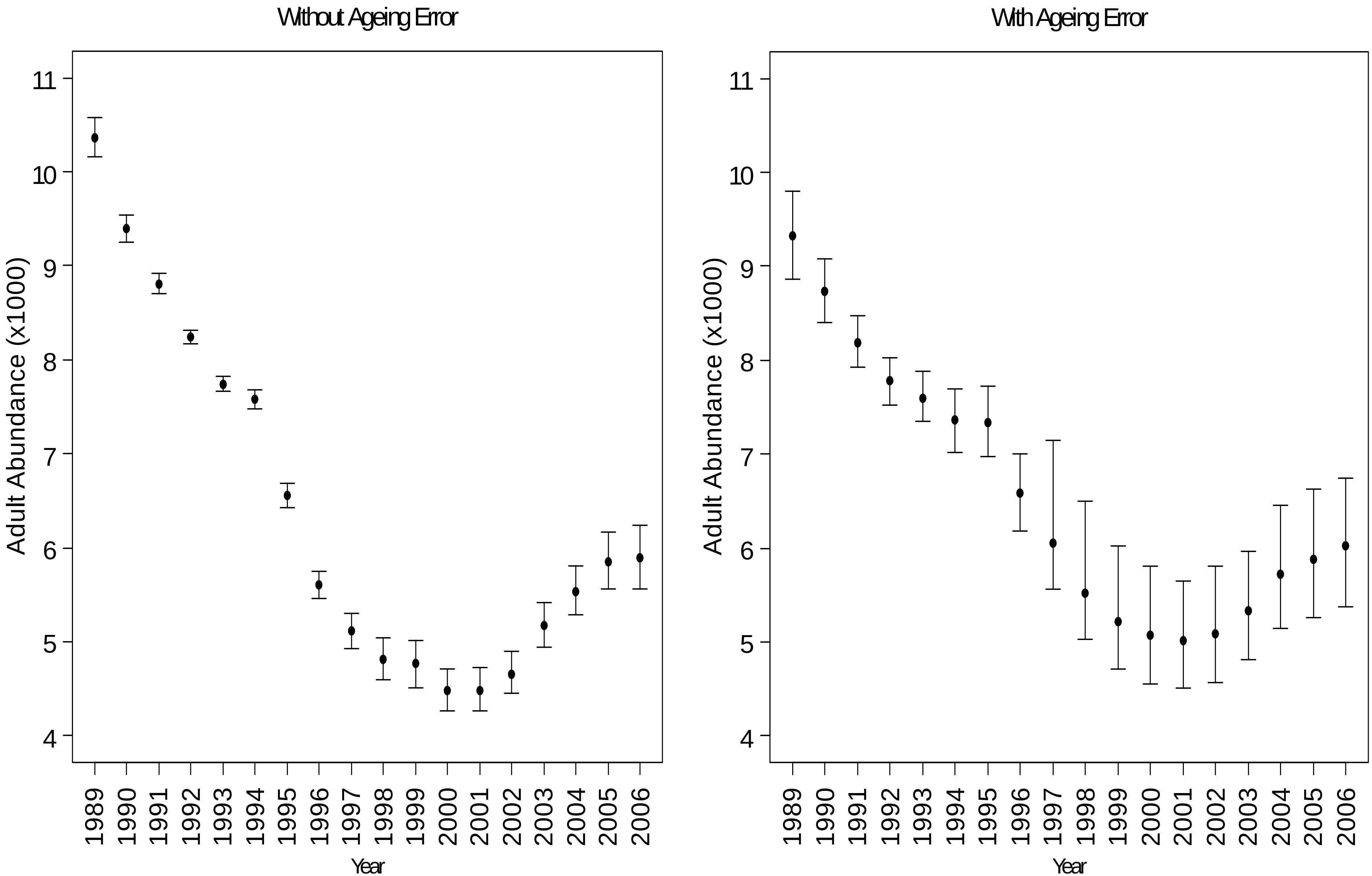
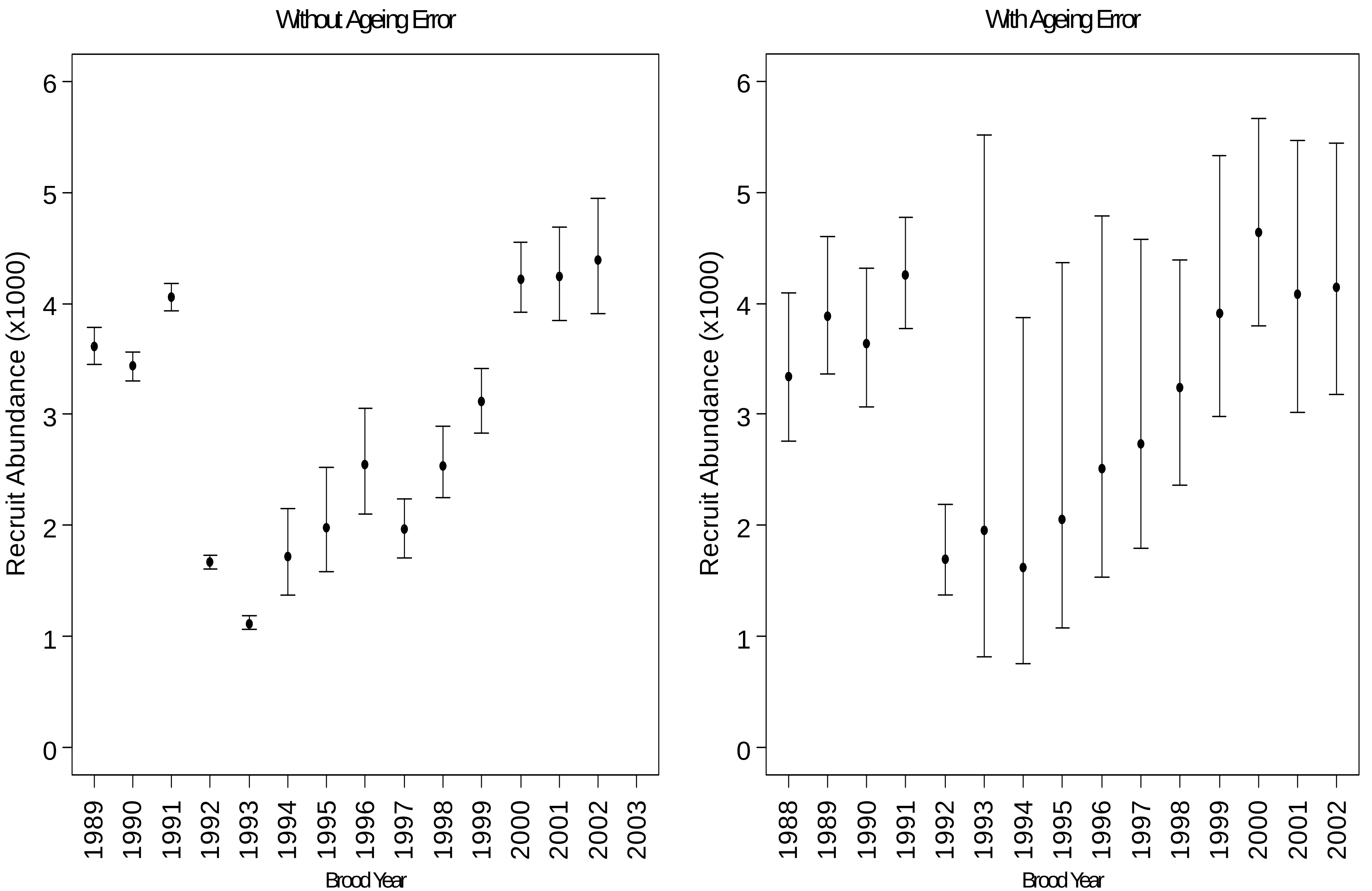
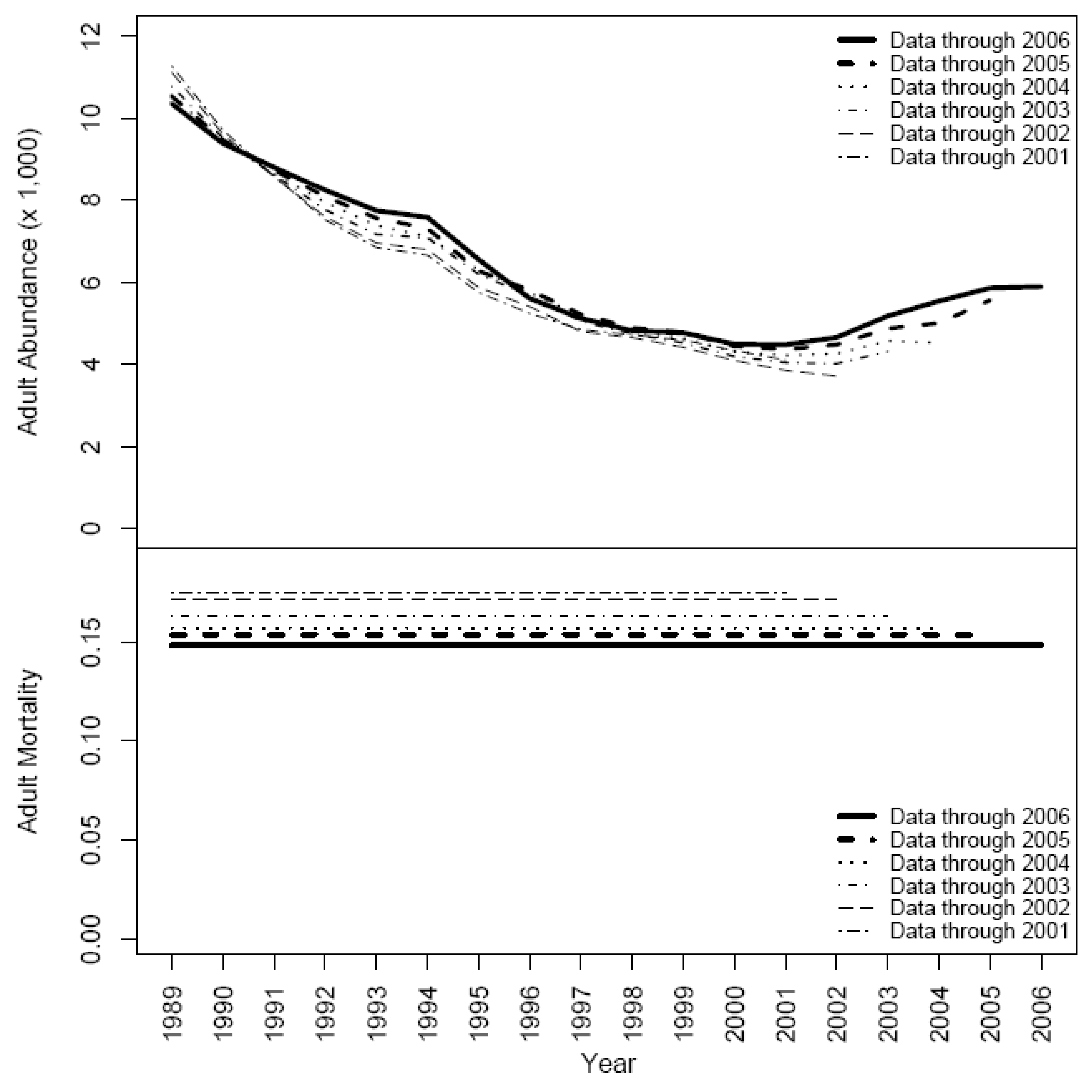
Results- Adult Abundance without/with Ageing Error



Results- Recruit Abundance without/with Ageing Error



Results- Retrospective Analysis



Conclusions

- Model selection tools clearly indicate ASMR3 is most consistent with the data.
  - Why big changes in age-specific vulnerability over time?
    - Less trammel-netting in the mainstem?
    - More reliance on small hoop-nets in the LCR?
    - Limited temporal coverage?
- ASMR3 adult (4+) abundance estimates considering ageing error:
  - 2006 - 6,017 (95% CI 5,369–6,747)
  - 1989 - 9,322 (95% CI 8,867–9,799)
  - ~ 20-25% increase in point estimates since 2001
  - Most likely associated with increased recruitment beginning no later than 1999 and possibly as early as 1996

Conclusions

- ASMR Results do not track well with catch-rate indices or Spring LCR mark-recapture
  - For catch-rate data, not too surprising considering reliability of catch-rate metrics.
  - A bit disconcerting for Spring LCR abundance estimates, but not too surprising considering imprecision to detect a 25% increase.
  - Preliminary Spring 2007 LCR abundance estimate looks to be much larger than 2006 ~2x (van Haverbeke, pers. comm.)
    - Provides support for ASMR, but questions reliability of closed population estimates in the LCR.

Conclusions

- Considering ageing error doesn't seem to add excessive bias, but does decrease precision
  - Need to have big changes in recruitment to detect with ASMR.
  - Argues for experimental treatments that have high probability to impart large changes in recruitment.
- Big changes (decreases in effort) in sampling program are not advised as it is problematic for data interpretation.
  - Witness long lasting effects of decreases in sampling effort ~1996-1999.

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