Evaluation of the Statistical Properties of Mark-recapture Estimators of Grand Canyon Humpback Chub Abundance and Trend

David Otis

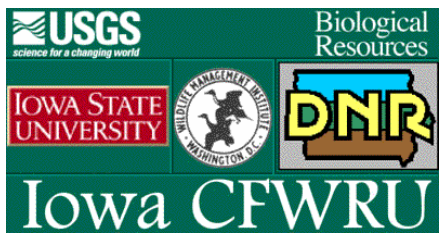
USGS Iowa Cooperative Fish and Wildlife Research Unit

Iowa State University

Acknowledgements

Hadley Wickham, Jenny Loda, Dave Miller (ISU)

Jeff Laake (NMFS)



Background

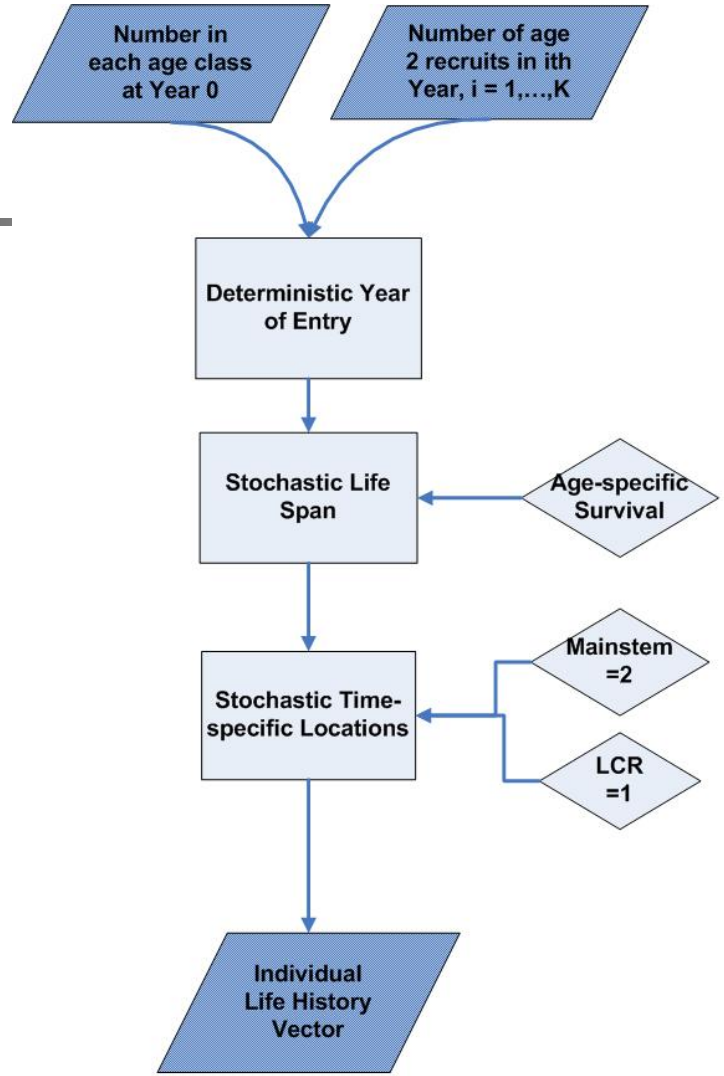
- Capture-recapture (CR) data collected since 1987 under a variety of sampling designs
- Population estimation method depends on
  - Sampling design used to collect the data
  - Statistical model (= assumptions, e.g., closure, demographics)
- Bias and precision of an estimator depend on
  - Validity of the demographic and temporal dynamics assumptions that underlie each design/model
  - Quality and quantity of the data
- Computer simulation is a tool for investigation of comparative performance of different estimators under different sampling and demographic scenarios

Project Objectives

- Use a Monte Carlo simulation model to evaluate the statistical performance of alternative sampling designs and estimators for age-specific population size, recruitment, and trend under different scenarios:
  - Time frame
  - Age-specific survival schedule
  - Movement dynamics
  - Capture effort →probability of capture
- Synthesize results and make recommendations

Simulation Model

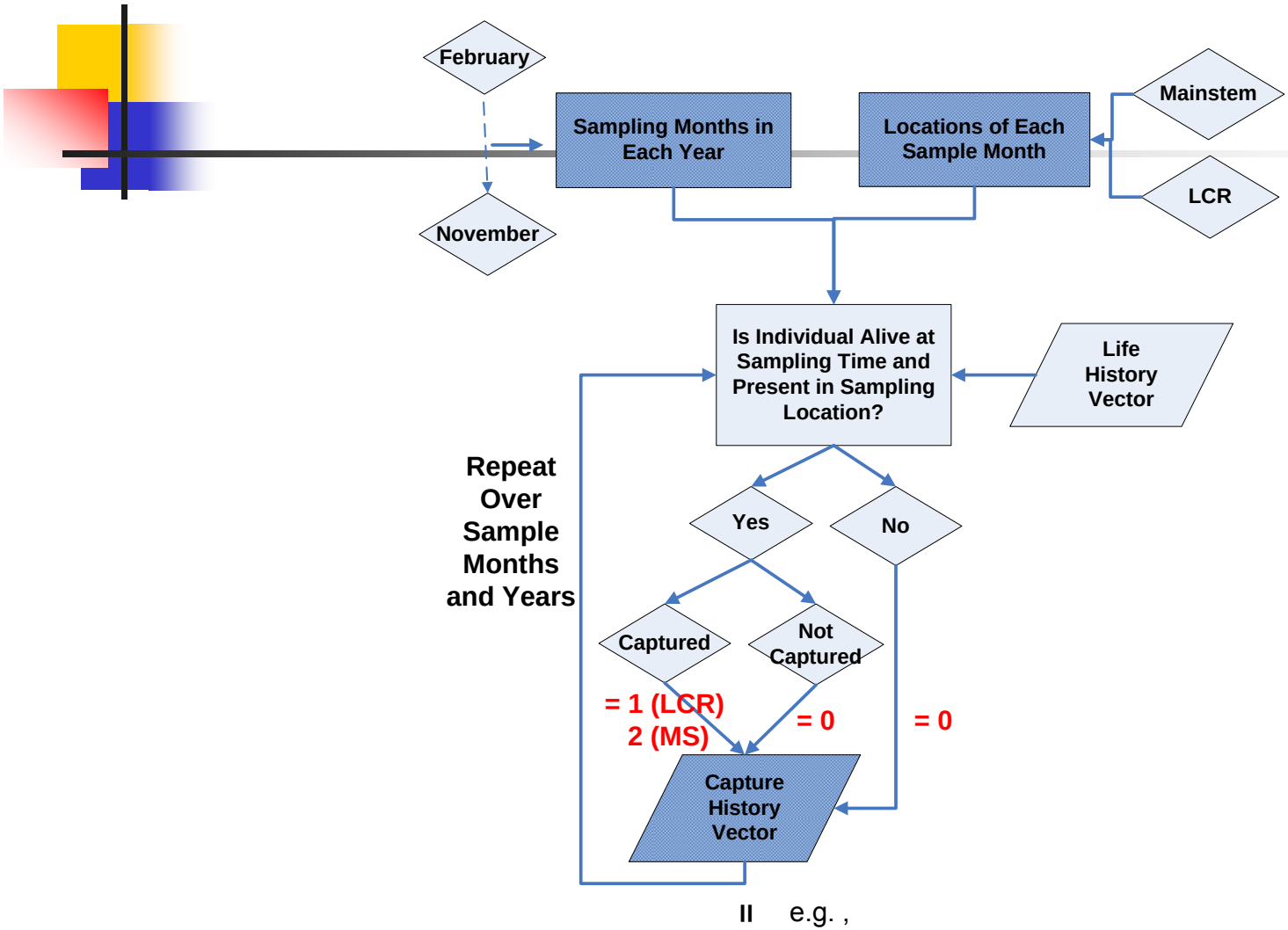
Simulate Life History Vectors for All Individual Fish



e.g. ,

[1 1 2 2 1 1 1 1 0 0 0 …] (12 months x 5 years = 60 digits; 0 = dead)

Simulate Capture History Vectors for All Individual Fish

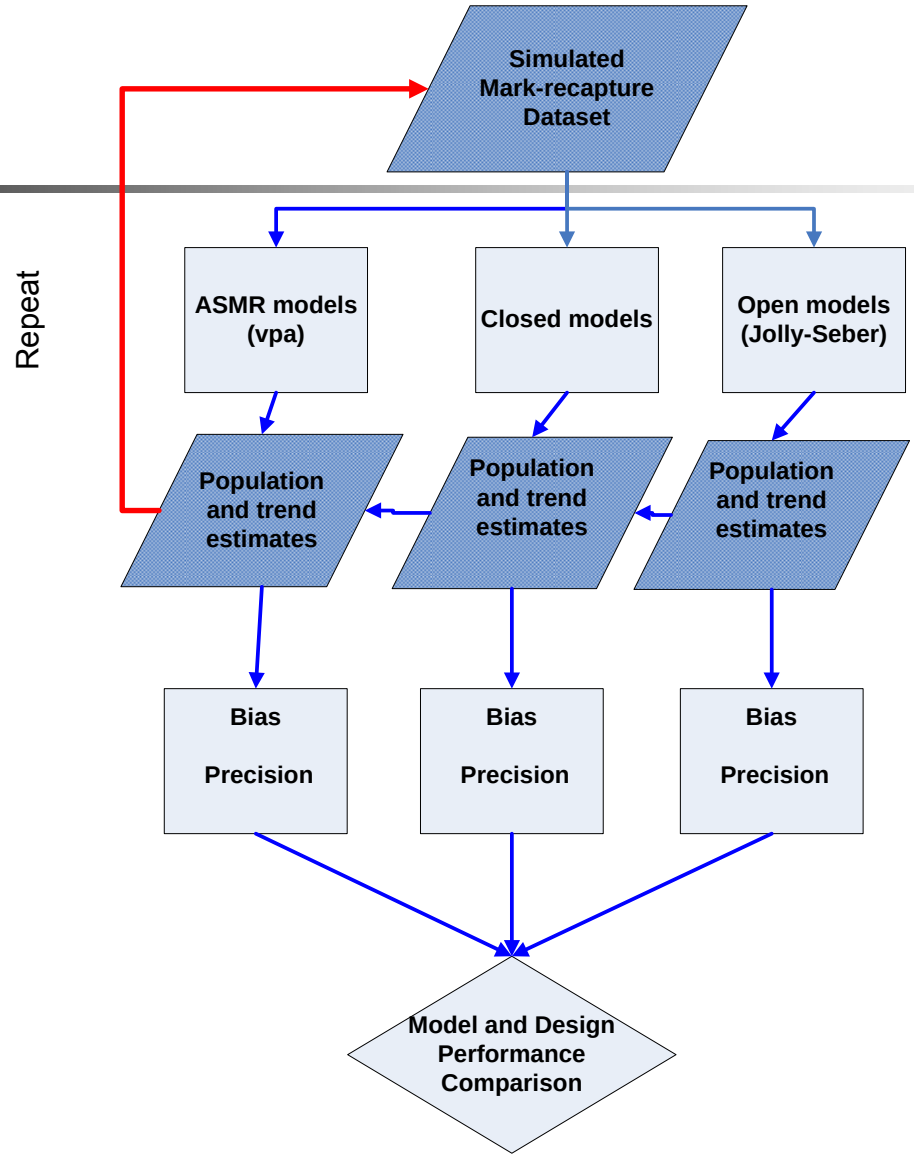


e.g. ,

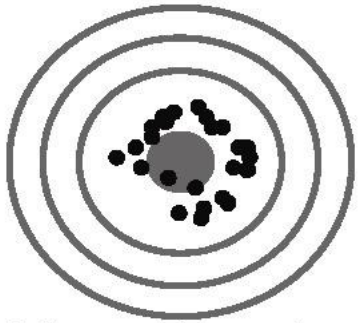
[1 2 0 0 0 2] (Designs 1,3,5)

[1 1 0 1 2 2 0 1] (Designs 2,4)

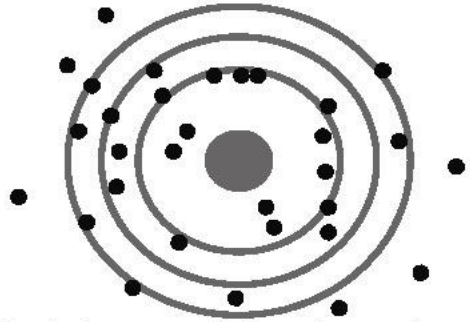
Model and Design Performance



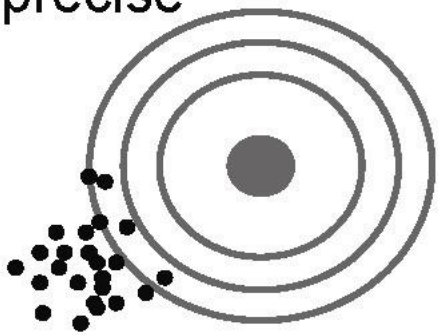
STATISTICAL PROPERTIES OF ESTIMATORS



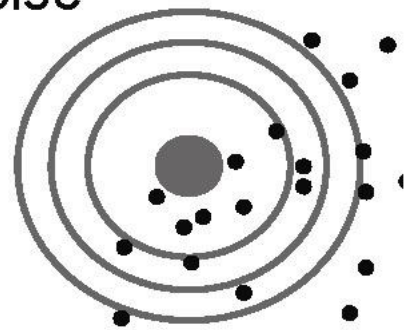
Unbiased and precise



Unbiased but not precise



Biased but precise



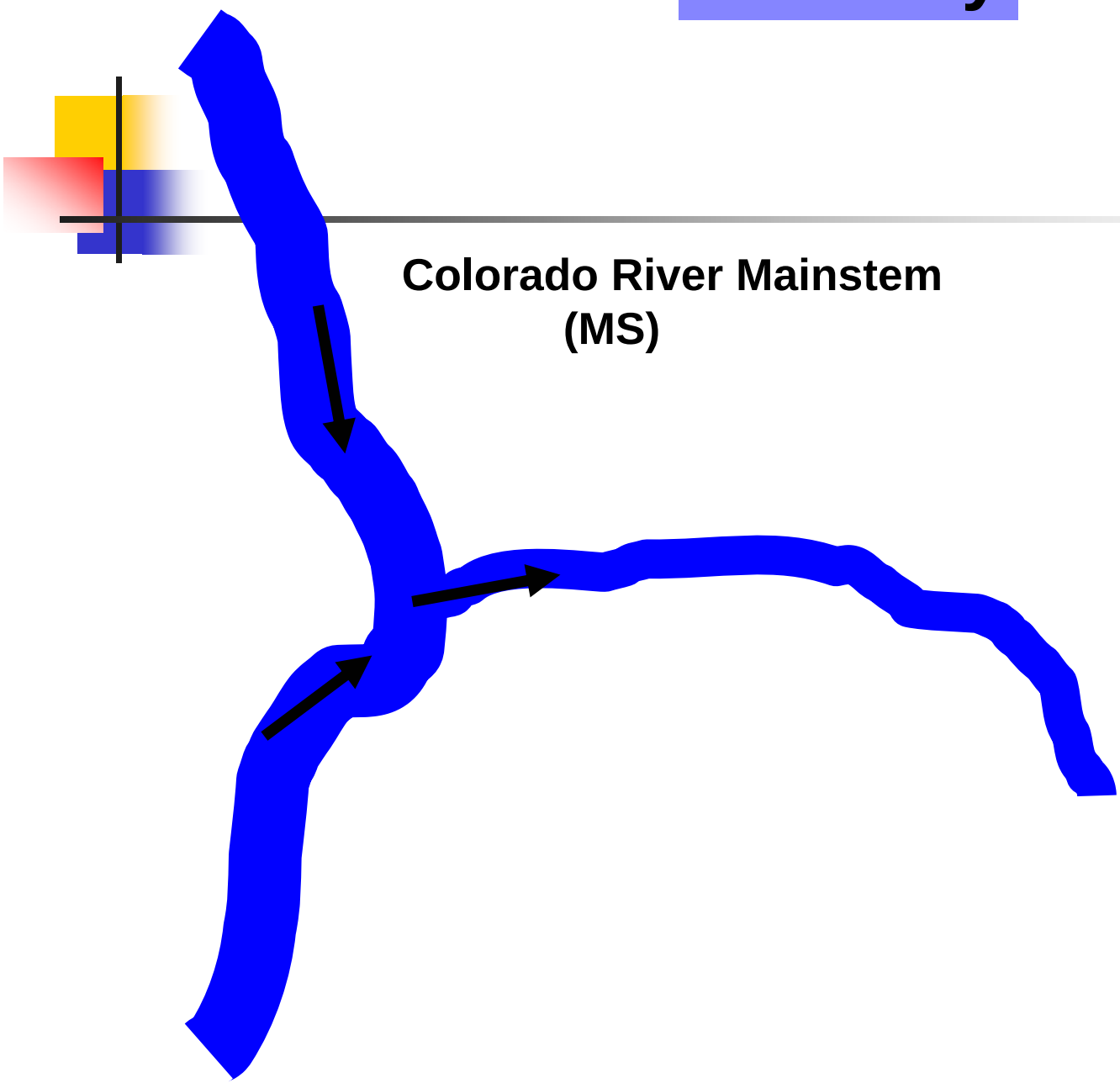
Biased and not precise

Sampling Designs and Estimation Models

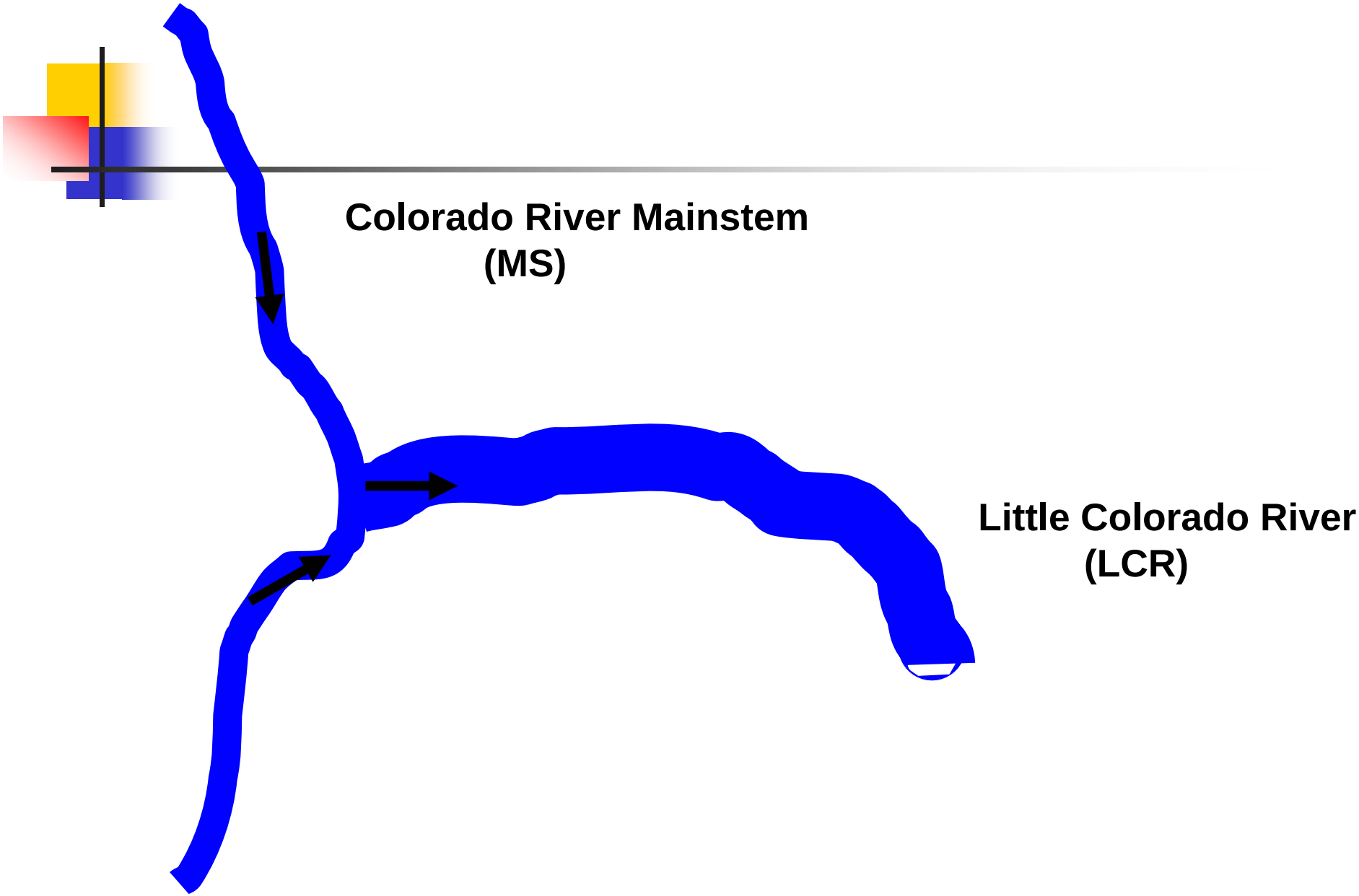
- Designs
  1. Spring concurrent, 3 trips
  2. Spring concurrent, 4 trips
  3. Fall concurrent, 3 trips
  4. Fall concurrent, 4 trips
  5. GCMRC: Spring and fall, LCR, 2 trips each; Summer mainstem, 2 trips
- Estimation models
  - 3 ASMR
  - 3 Closed
  - 1 Jolly-Seber type open

Movement Dynamics

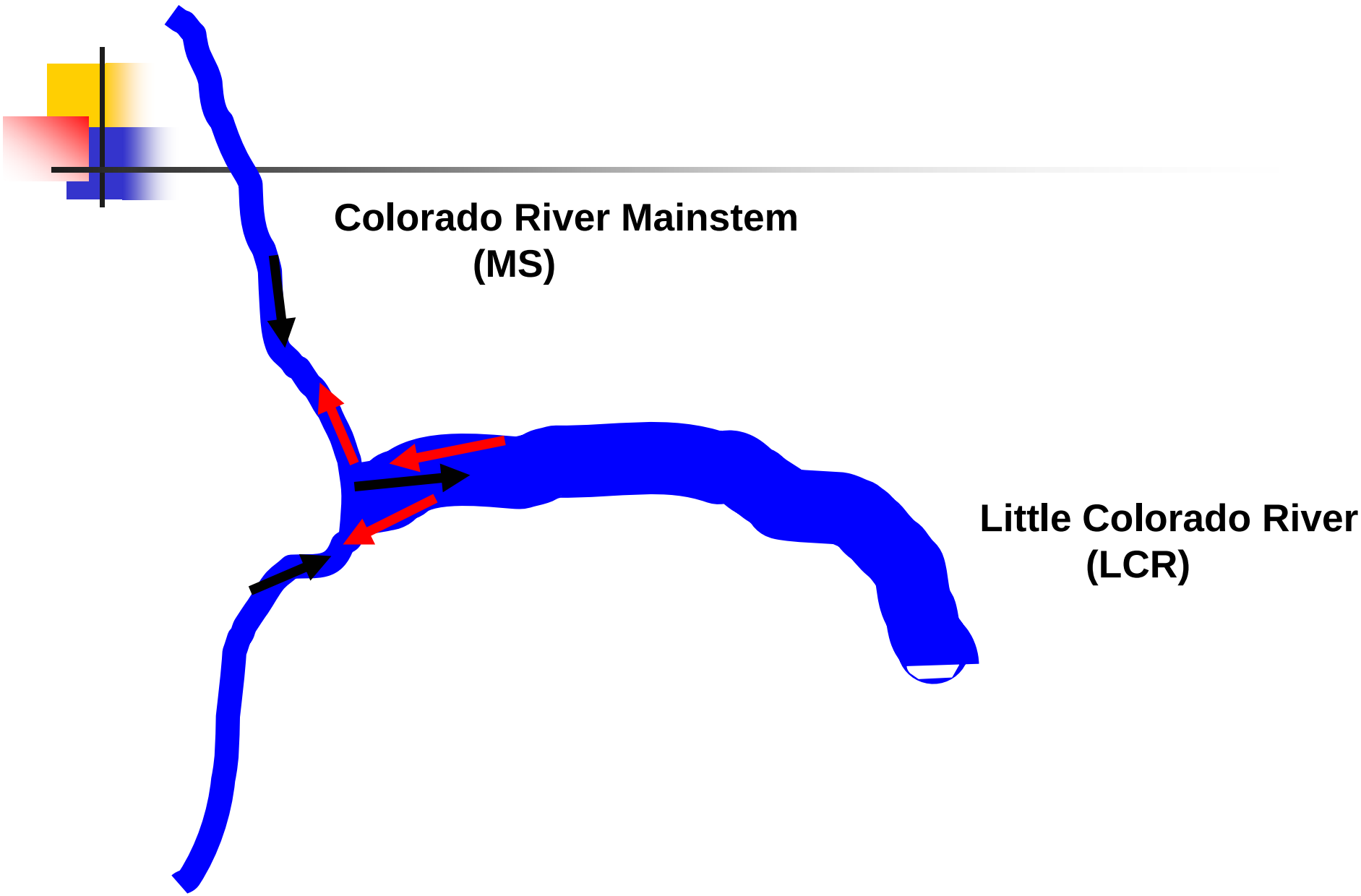
February



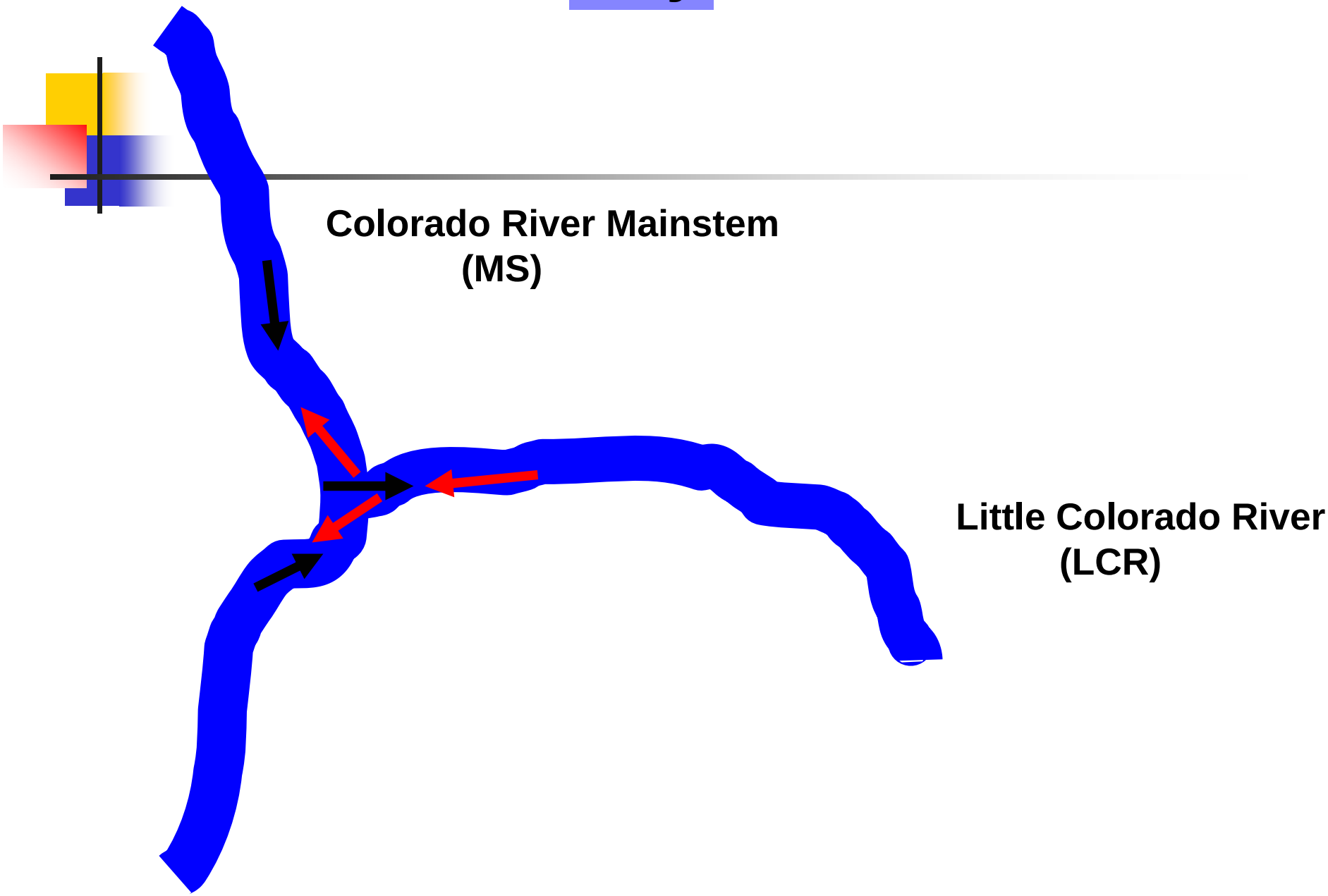
March



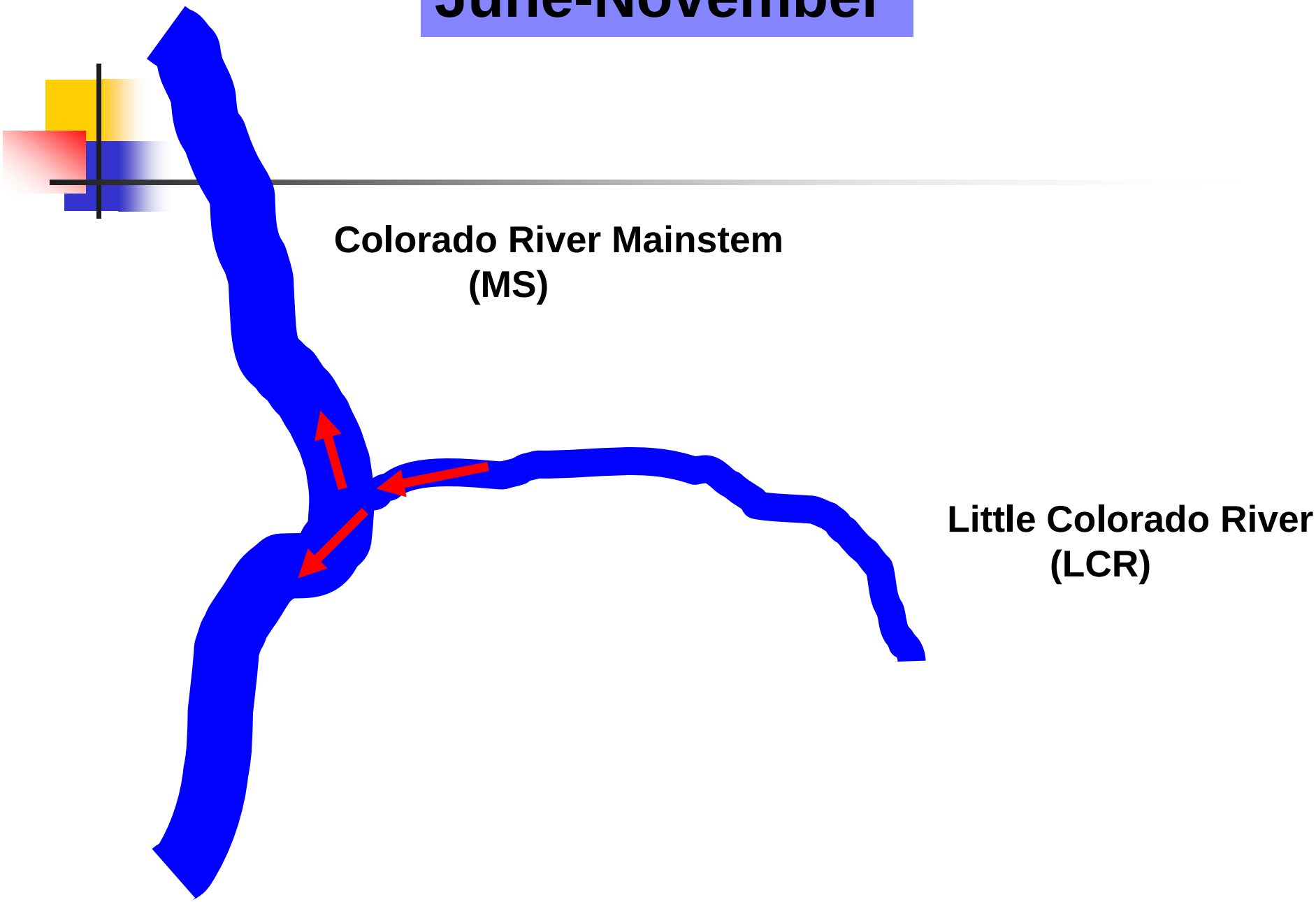
April



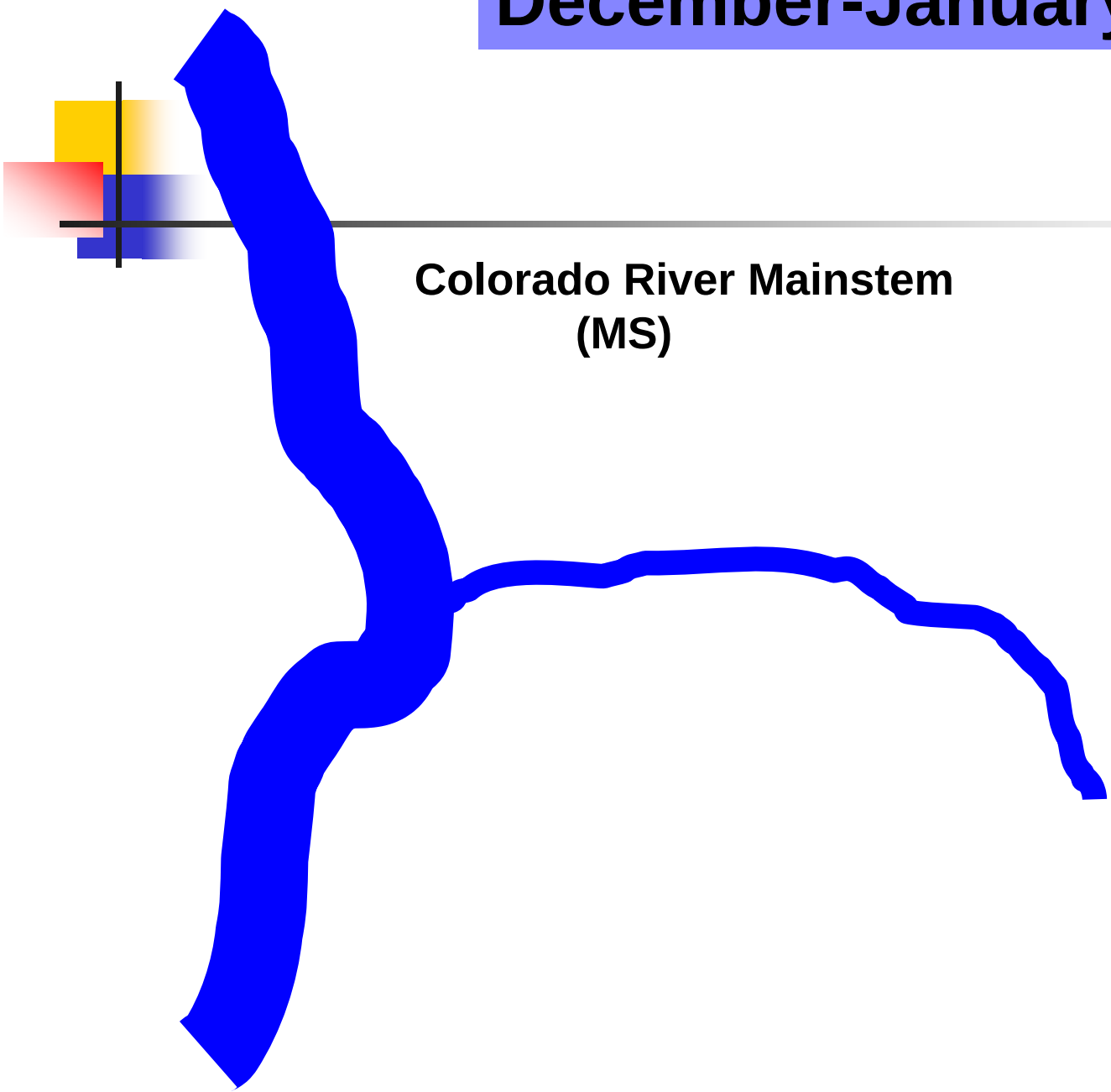
May



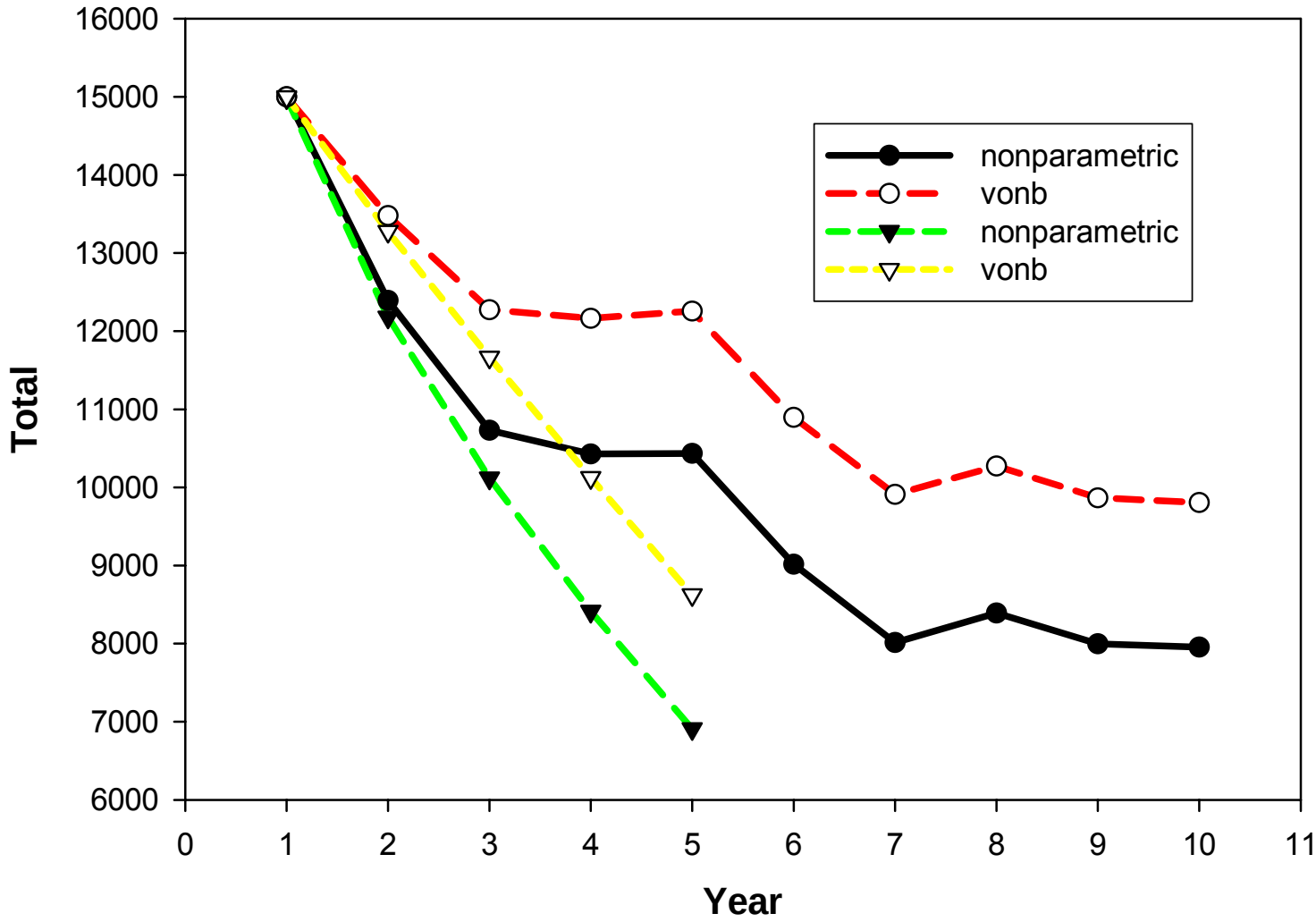
June-November



December-January



True Population Sizes



Results

- Reduction of the set of candidate estimators
- Comparison of estimators
- Comparison of sampling designs
- Miscellaneous
  - Trend estimation
  - Effect of reduced capture probability in LCR
  - Effect of age misclassification

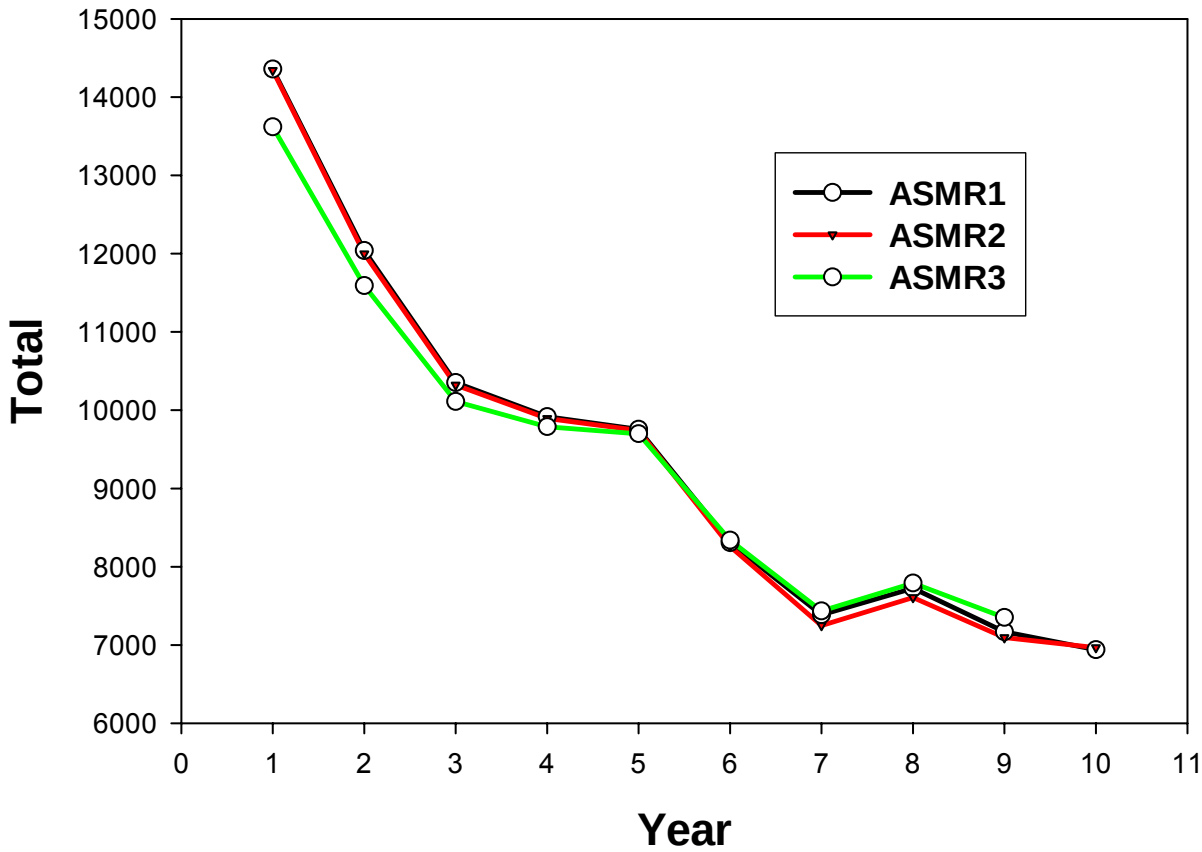
Reduction of the Set of Estimators

Comparison of ASMR Estimators

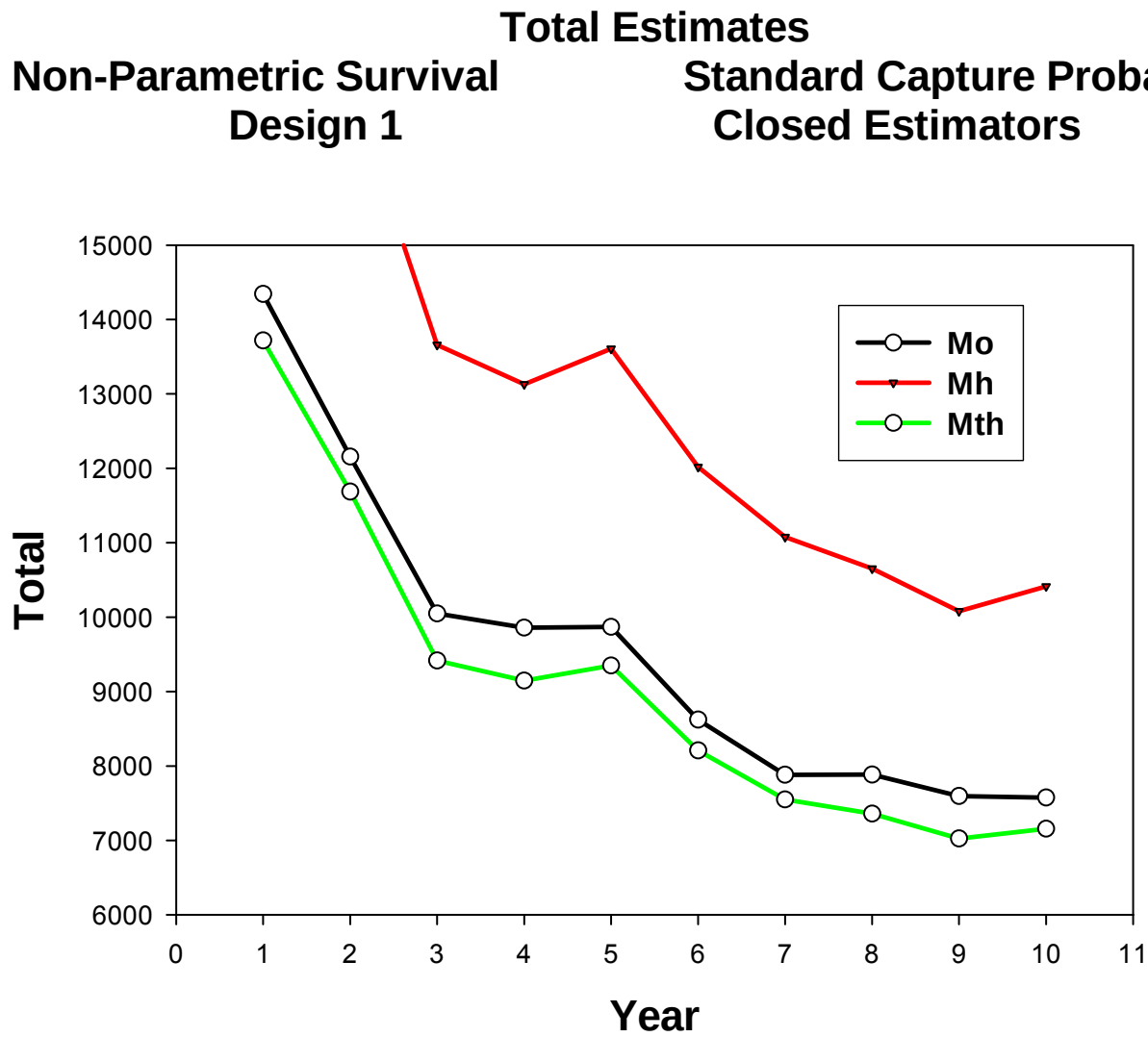
Total Estimates

Non-Parametric Survival Design 1

Standard Capture Probabilities ASMR Estimators



Comparison of Closed Estimators



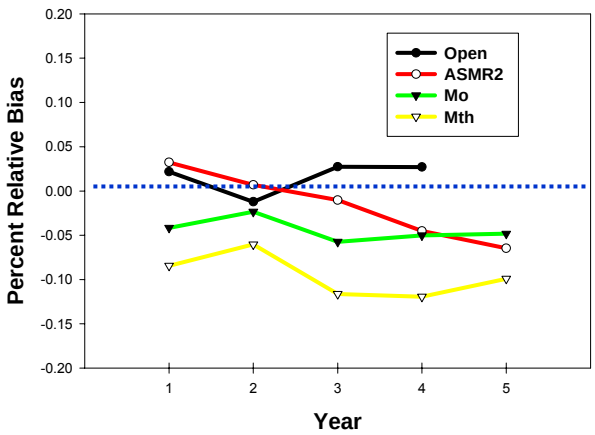
Reduction of the Set of Estimators Conclusions

- 3 ASMR estimators not much different, but ASMR2 generally slightly better, so present only ASMR2
- M_h generally much worse than M_o and $M_{th,}$ so eliminate
- Proceed with ASMR2, Open, M_o and M_{th}

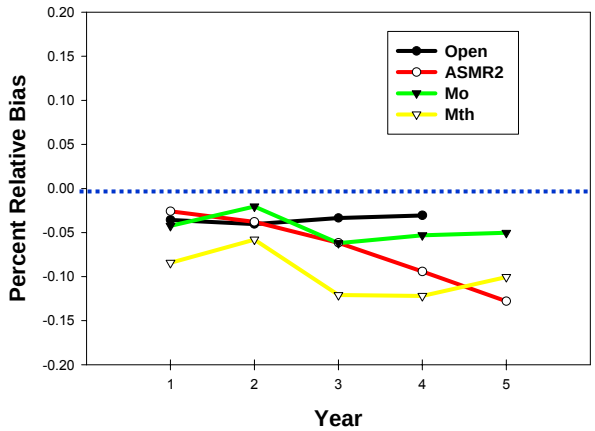
Comparison of Estimators

Percent Relative Bias

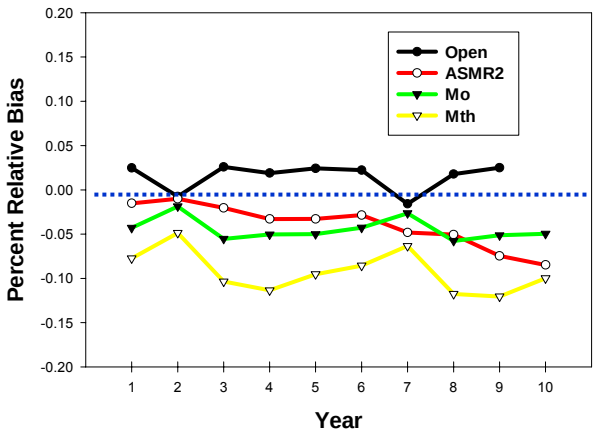
Spring Concurrent Sampling (Feb-Apr) Recruitment Estimates
Nonparametric Survival Standard Capture Probability



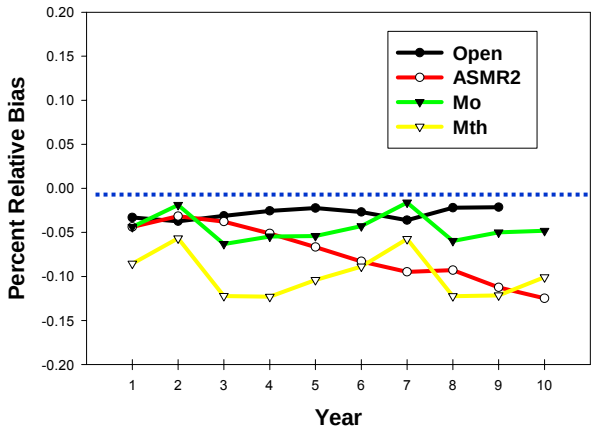
Spring Concurrent Sampling (Feb-Apr) Total Estimates
Nonparametric Survival Standard Capture Probability



Spring Concurrent Sampling (Feb-Apr) Recruitment Estimates
Nonparametric Survival Standard Capture Probability

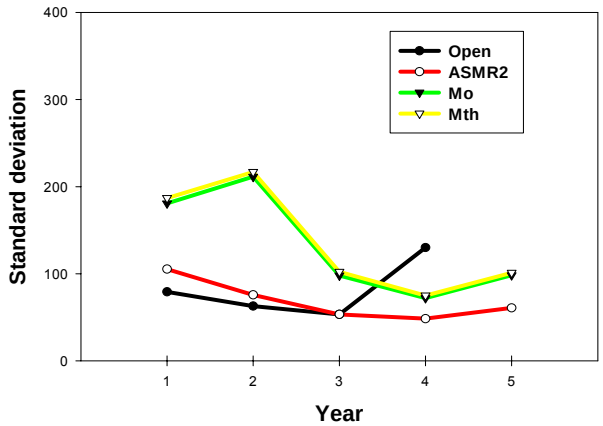


Spring Concurrent Sampling (Feb-Apr) Total Estimates
Nonparametric Survival Standard Capture Probability

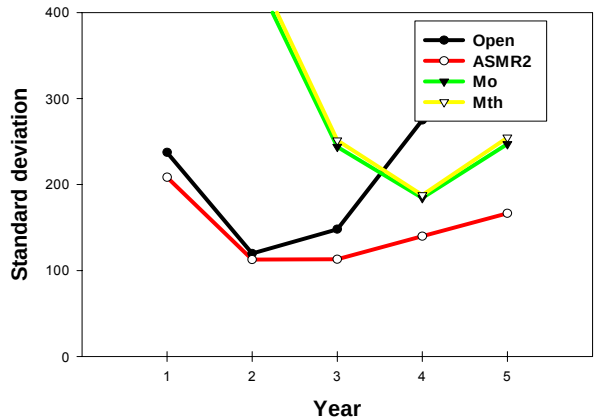


Precision

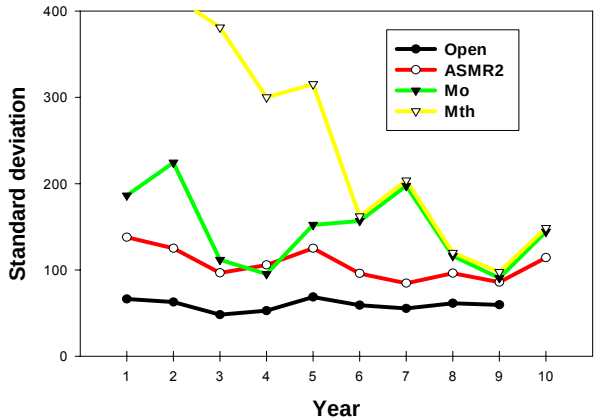
Spring Concurrent Sampling (Feb-Apr) Recruitment Estimates
Nonparametric Survival Standard Capture Probability



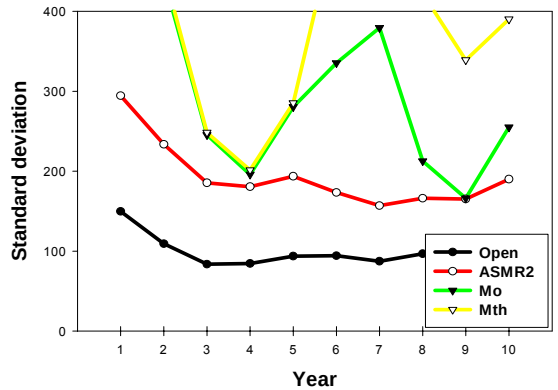
Spring Concurrent Sampling (Feb-Apr) Total Estimates
Nonparametric Survival Standard Capture Probability



Spring Concurrent Sampling (Feb-Apr) Recruitment Estimates
Nonparametric Survival Standard Capture Probability



Spring Concurrent Sampling (Feb-Apr) Total Estimates
Nonparametric Survival Standard Capture Probability

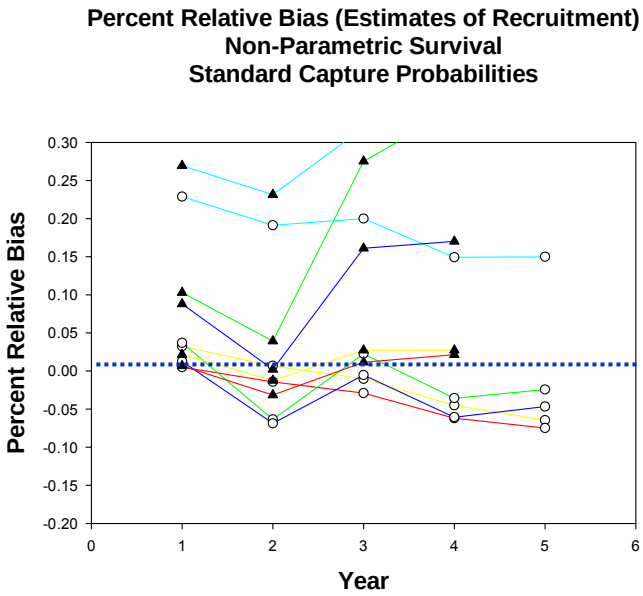


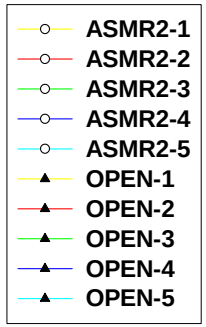
Comparison of Estimators
Conclusions

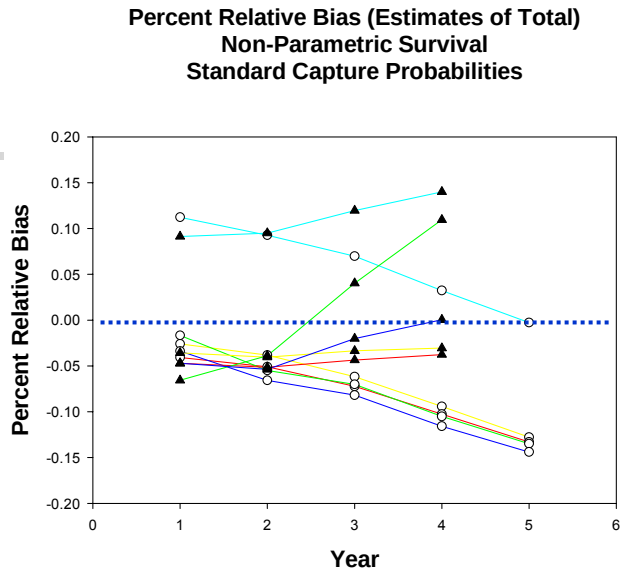
- 2 closed models are poor
- Both ASMR and Open have PRB < 10%, but Open is less biased in Design 1
- ASMR more precise for Y = 5, and Open more precise for Y = 10 in Design 1
- ASMR less biased in Design 3, especially for recruits, and performs better with von B survival schedule

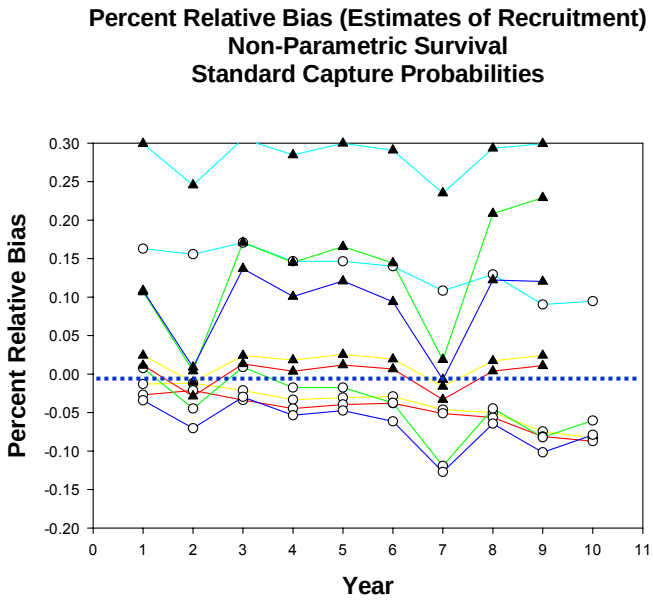
Comparison of Designs

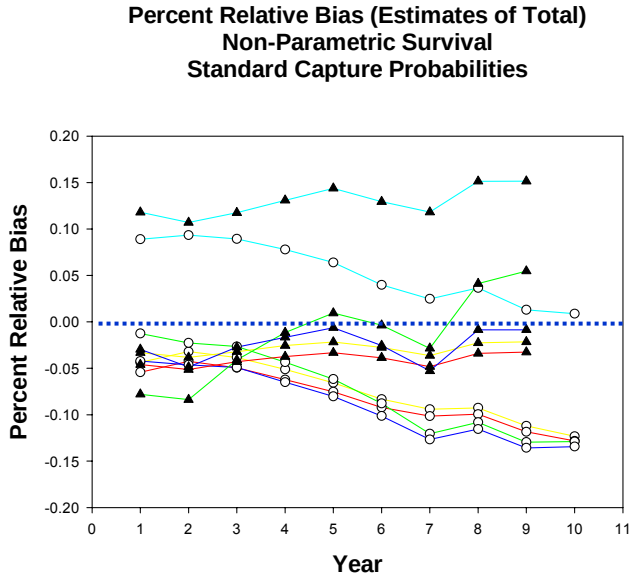
Percent Relative Bias



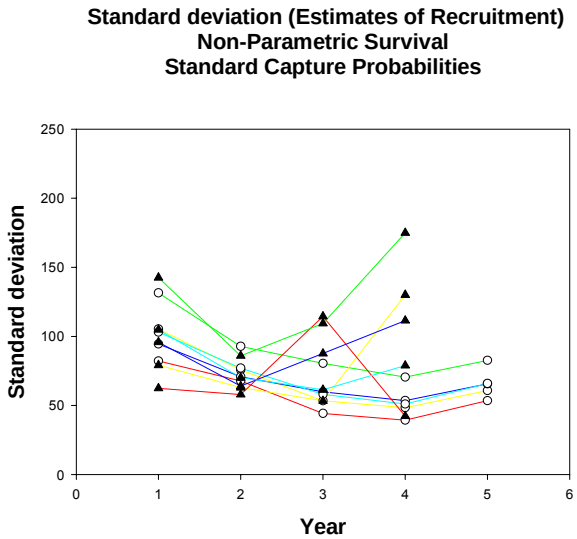


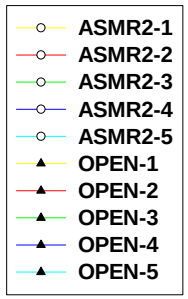


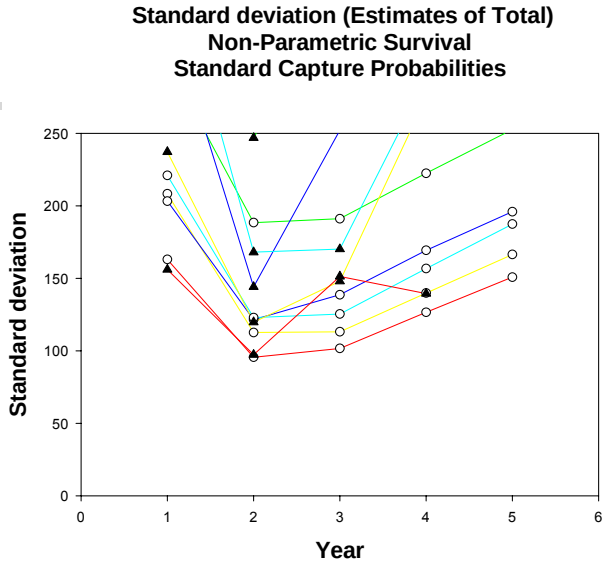


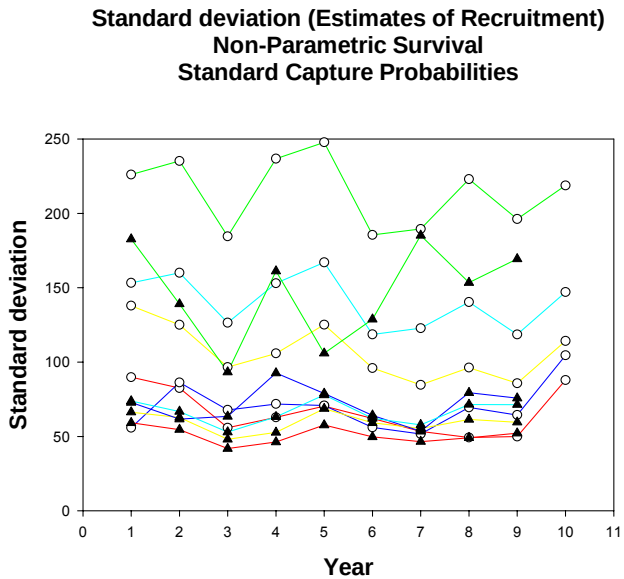


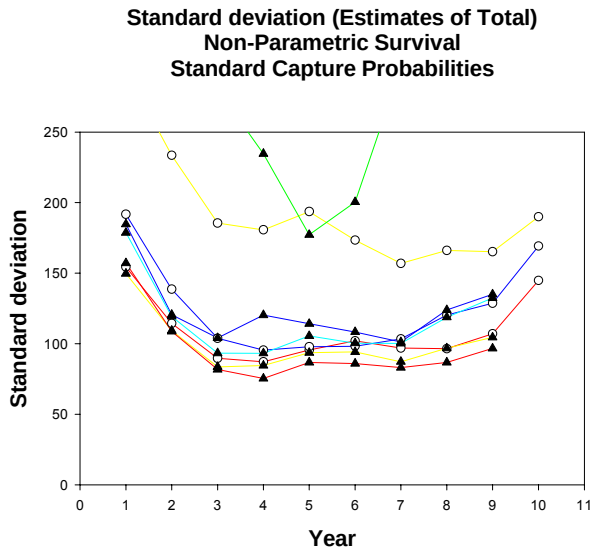
Precision


Standard deviation (Estimates of Recruitment)
Non-Parametric Survival
Standard Capture Probabilities
Standard deviation
Year


ASMR2-1
ASMR2-2
ASMR2-3
ASMR2-4
ASMR2-5
OPEN-1
OPEN-2
OPEN-3
OPEN-4
OPEN-5


Standard deviation (Estimates of Total)
Non-Parametric Survival
Standard Capture Probabilities
Standard deviation
Year


Standard deviation (Estimates of Recruitment)
Non-Parametric Survival
Standard Capture Probabilities
Standard deviation
Year


Standard deviation (Estimates of Total)
Non-Parametric Survival
Standard Capture Probabilities
Standard deviation
Year

Comparison of Designs
Conclusions

- Four trips produce marginal increase in precision relative to 3 trips, but no change in bias
- Bias generally less than 10% for all Designs except Design 5, which produces larger bias
- Precision is very good for all Designs except Design 3
- No difference in relative performance of Designs with respect to survival assumptions

Miscellaneous

Estimation of Trend

- Estimates of log-linear trend in both recruitment and total population size have minimal bias and high precision (± 1-2%) for both ASMR and Open models

Effect of Decrease in Capture Probability in the LCR

(Based on a Single Simulation)

- Minimal effect on PRB
- Causes relatively large decrease in precision, especially for Open model, but precision still generally good

Effect of Age Misclassification (Based on Nonparametric Survival and Y = 5)

- Misclassified age at first capture

Scenario 1	Scenario 2
P[correct] = .6	P[correct] = .5
P[± 1 ageclass] = .3	P[+ 1 ageclass] = .25
P{ ± 2 ageclass] = .1	P{ + 2 ageclass] = .25

- No important effect on bias or precision

Summary Statistical Conclusions

- Spring concurrent sampling with 3 trips is the best design
- Both ASMR and an Open Jolly-Seber type estimator produce good results, except for significant bias with GCMRC sampling design
- Good performance of estimators due to large capture probabilities
- No large, consistent superiority in performance of ASMR versus Open model
- Open model has other advantages
  - Fewer restrictive assumptions about capture probabilities and survival structure and hence probably more robust to violation of assumptions
  - Can utilize formal model selection theory
  - Straightforward variance estimation