Effect of flow-dependent change in habitat on YOY steelhead populations in a Lake Michigan tributary: results of a multi-modeling approach

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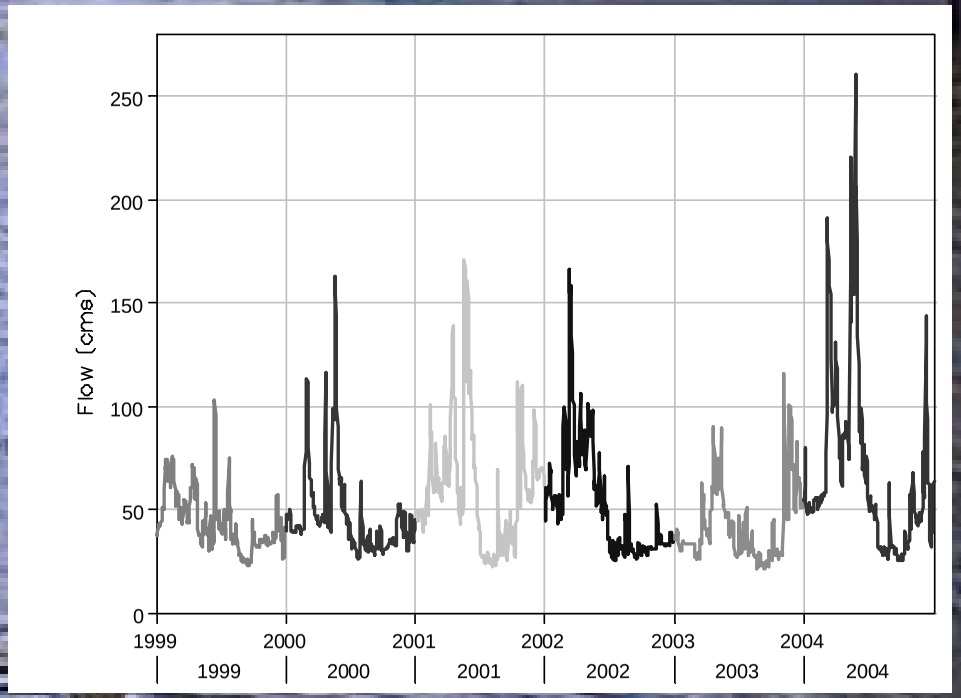
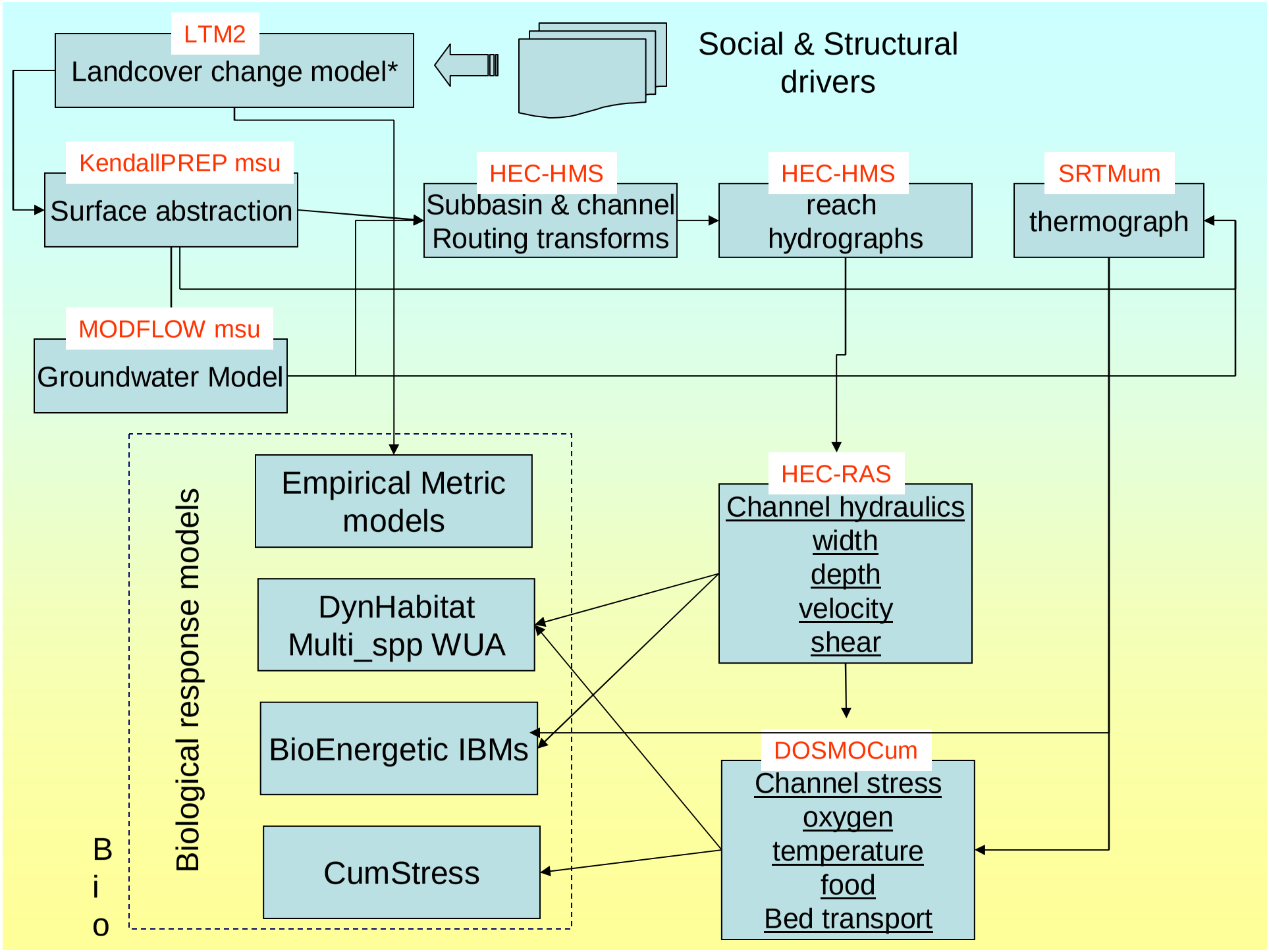
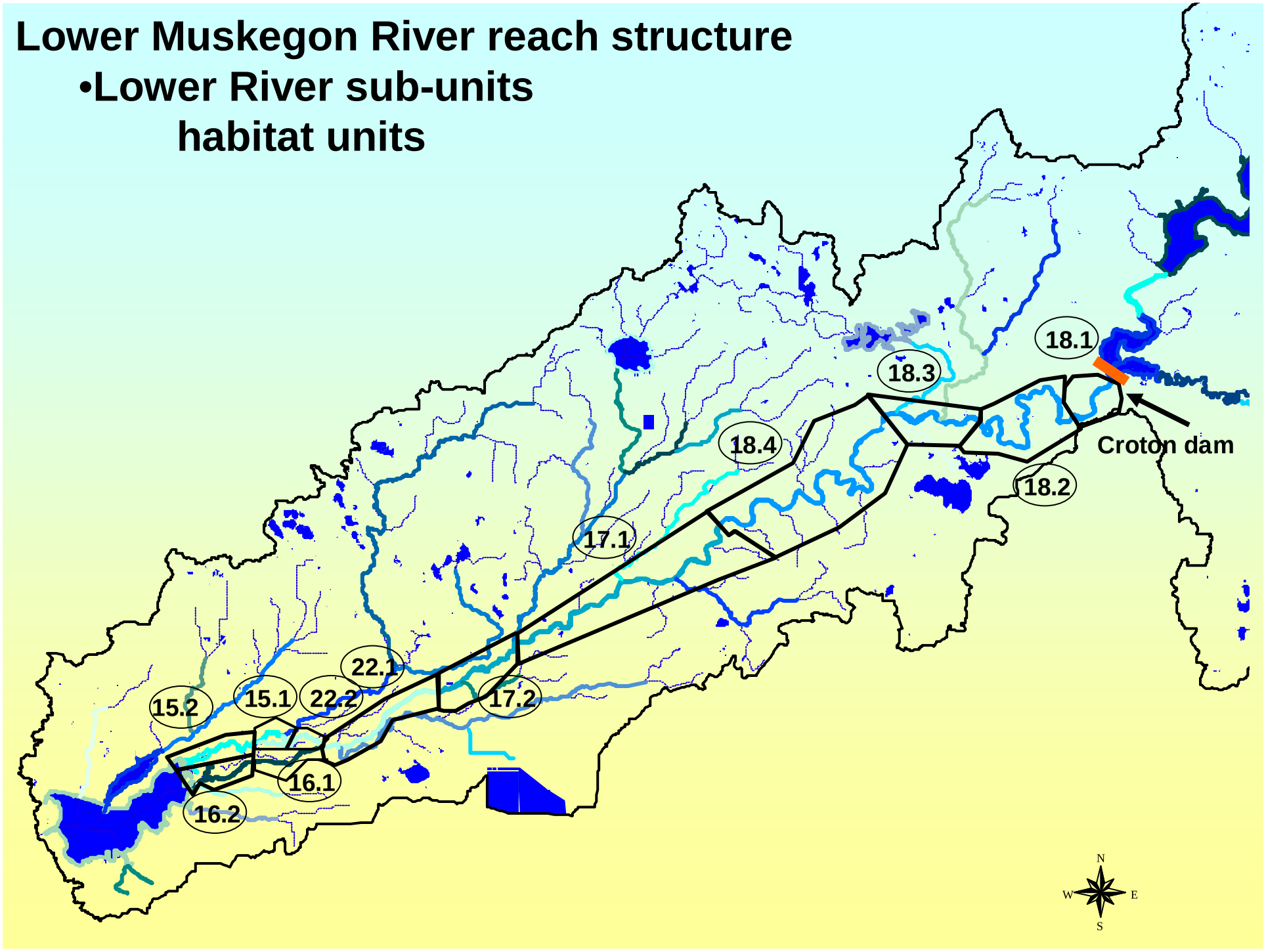
How do natural and other variations in hydrology affect habitat and fish recruitment ?



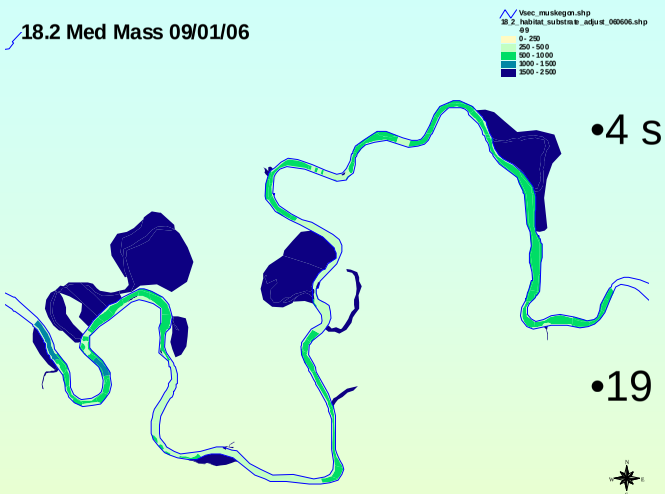

LTM2
Landcover change model*
Social & Structural drivers
KendallPREP msu
Surface abstraction
HEC-HMS
Subbasin & channel Routing transforms
HEC-HMS
reach hydrographs
SRTMum
thermograph
MODFLOW msu
Groundwater Model
Biological response models
Empirical Metric models
DynHabitat Multi_spp WUA
BioEnergetic IBMs
CumStress
HEC-RAS
Channel hydraulics
width
depth
velocity
shear
DOSMOCum
Channel stress
oxygen
temperature
food
Bed transport
Bio

Lower Muskegon River reach structure

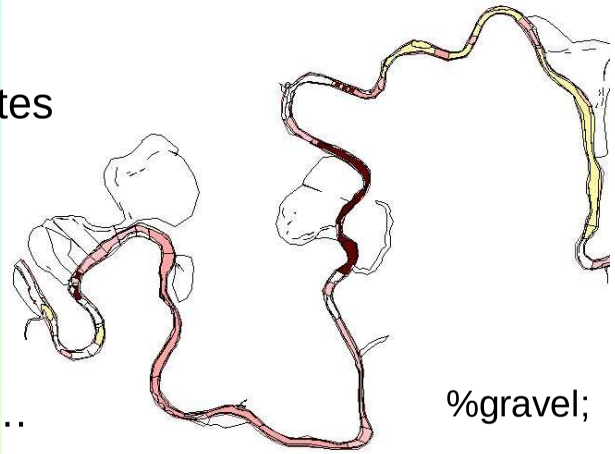
- Lower River sub-units
  - habitat units



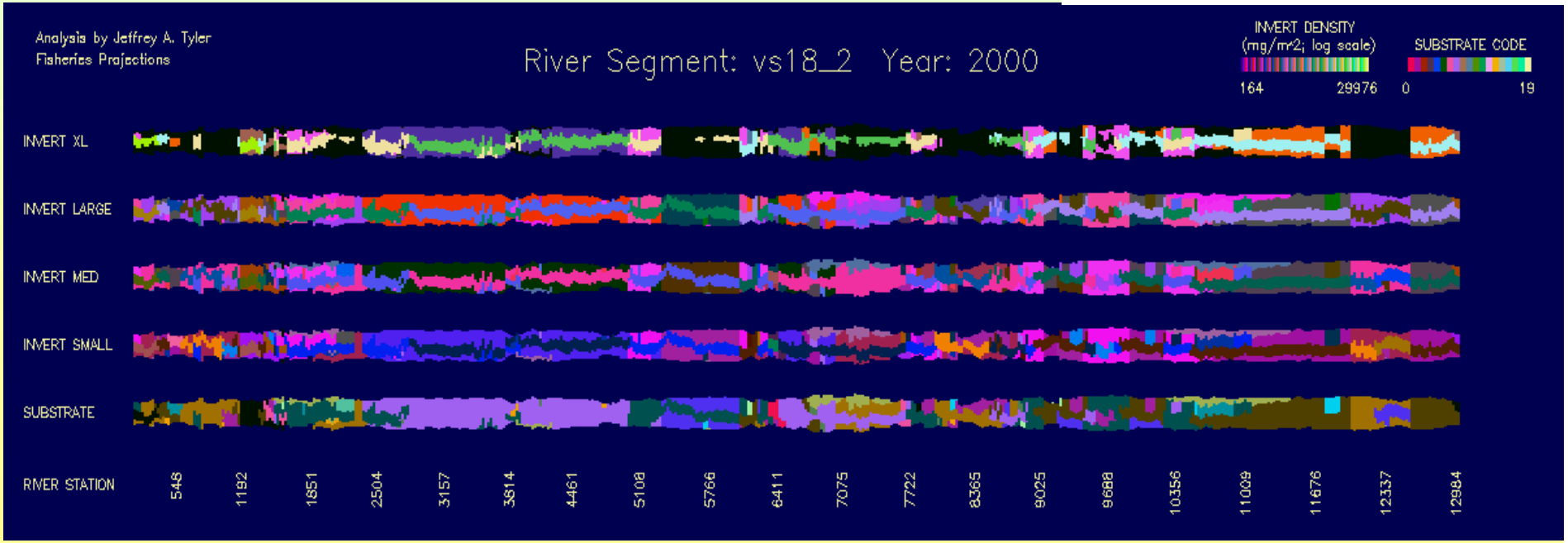
Spatially Heterogeneous Food and Substrate in Muskegon River Segment 18.2



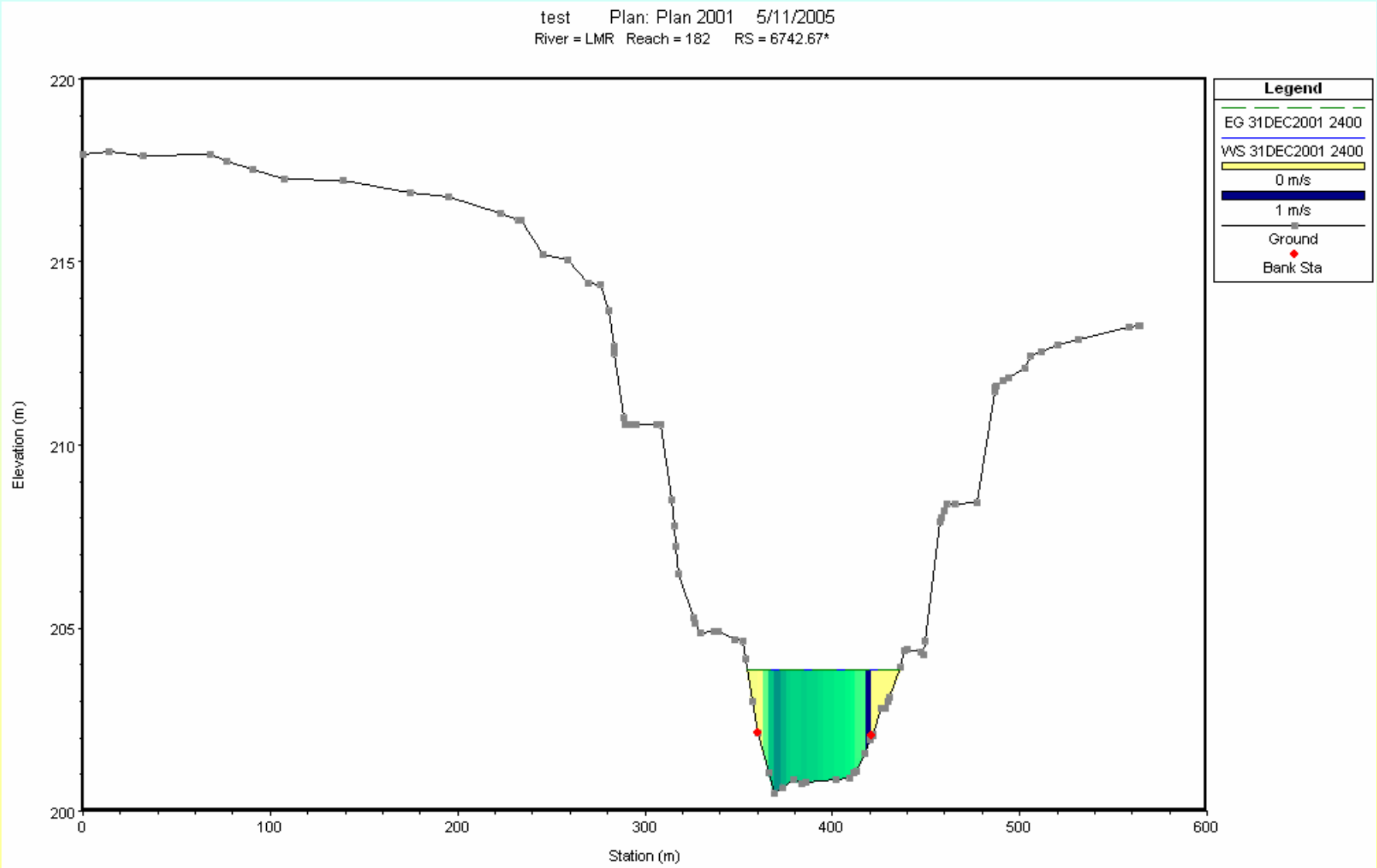
- 4 size classes of benthic invertebrates
- 19 classes of substrate
  - gravel, cobble, sand, silt, clay…



%gravel;



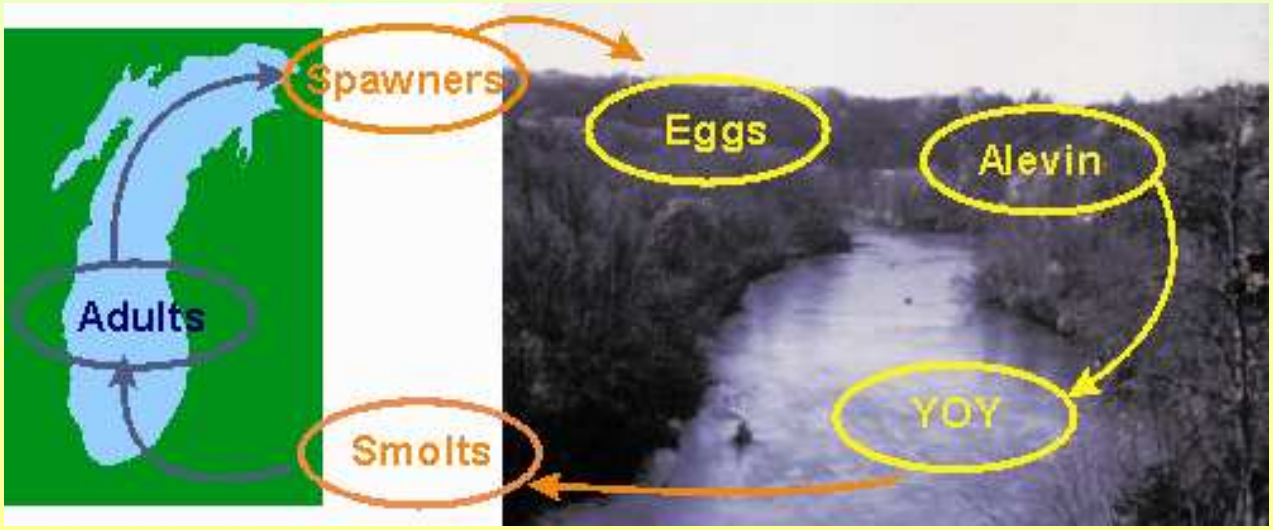
HEC-RAS Model Output
Daily simulations of depth, velocity, cells



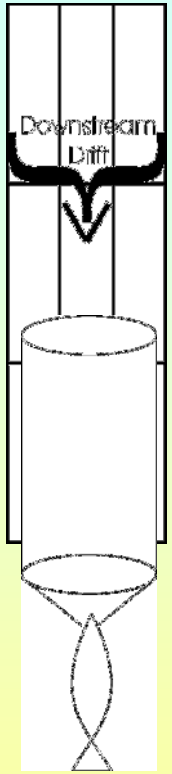
Steelhead Individual-Based Model (IBM)

- HEC-RAS/GEO-RAS provide the environment.

- IBM encompasses spawning (~day 80) to growing season (day 300).
  - Spawning: 700 mm Females. Suitable habitat based on WUA from substrate, depth and velocity. Eggs/redd based on length.
  - Eggs and alevin modeled as redd-cohorts. Development based on temperature, mortality from predation, temperature, scour.
  - YOY modeled as individuals.

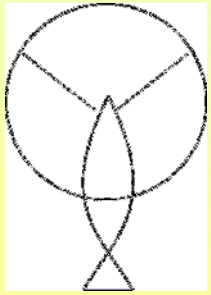


Steelhead IBM:
YOY foraging and prey sources



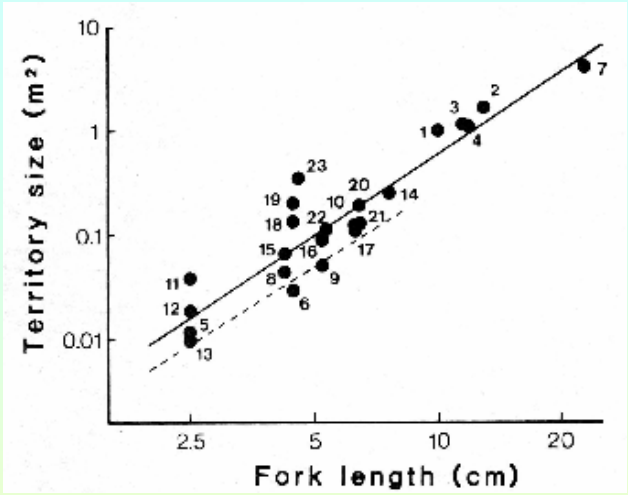
- Drift Foraging
  - All YOY forage on drifting invertebrates.
  - Water velocity determines capture rate.
  - Drifting invertebrates come from the upstream cells assuming an instantaneous drift rate of 0.5%.
  - Density of drifting invertebrates from upstream is averaged among the 3 upstream cells.

- Benthic Foraging
  - Large YOY maintain foraging stations and feed on benthic invertebrates. Capture probability = 10%.
  - Stations assigned to fish based on weight.
  - Feeding territory size increases with length.

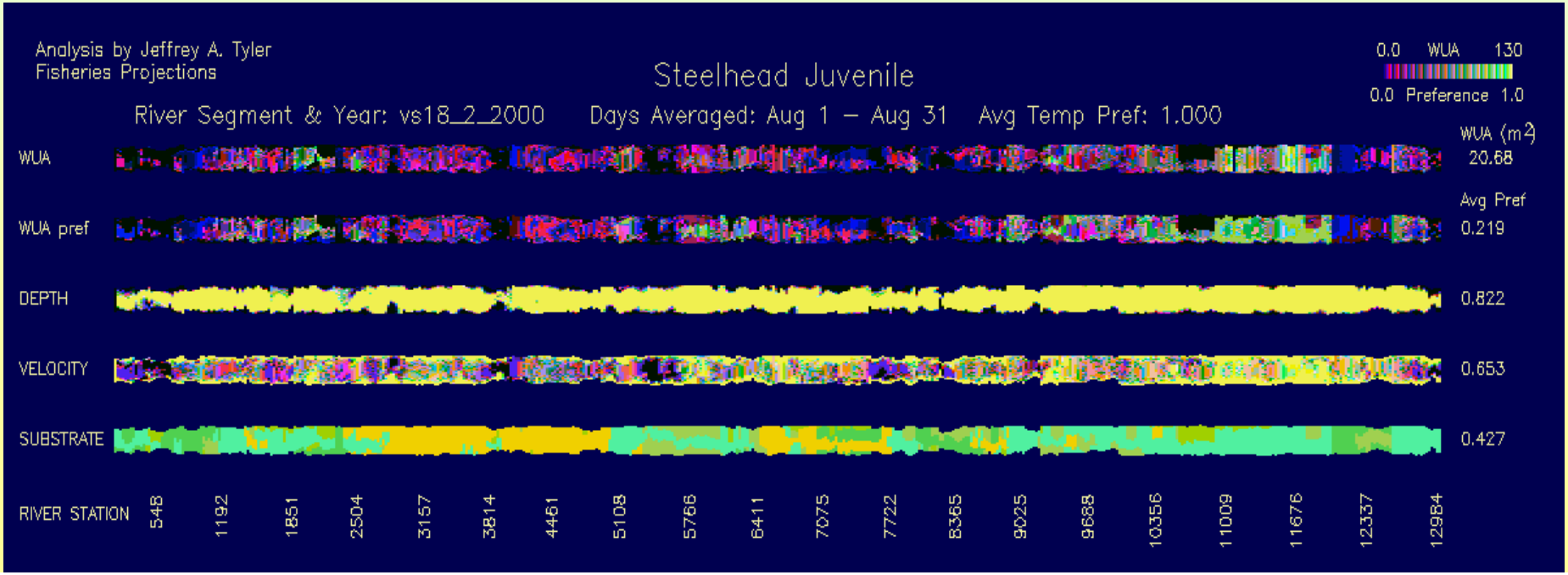


Steelhead IBM: YOY Stations

- Station number depends on the length of the fish in the cell using the relationship from Grant & Kramer (1990).

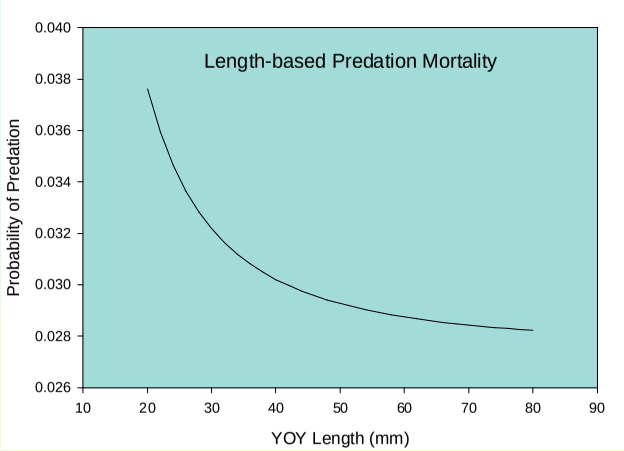


- Station number modified by cell WUA.



Steelhead IBM: YOY mortality

- Predation
  - mortality decreases with parr length.



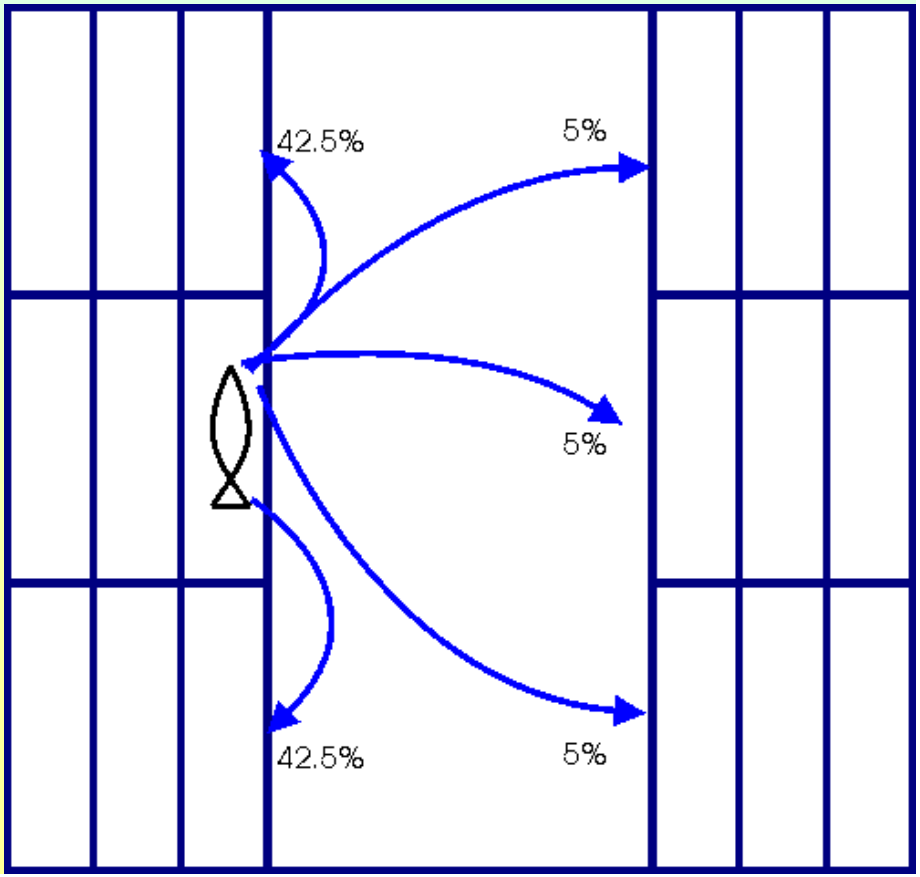
- Starvation
  - occurs when parr weight falls below 50% of expected parr length.

- Temperature
  - mortality increases with temperature (T) (Hokanson et al 1977)

Steelhead IBM: YOY movement

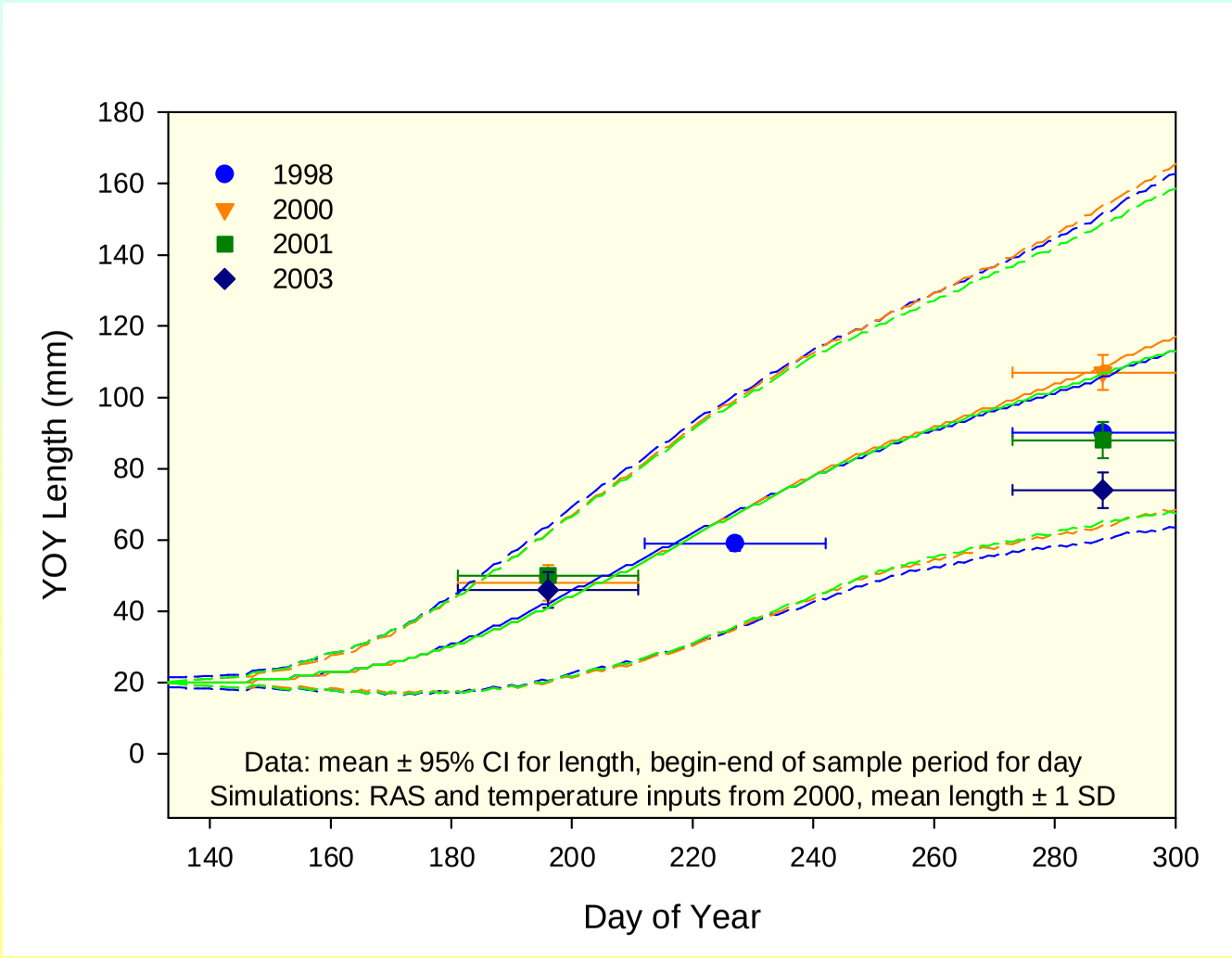
- Follows a combined Marginal Value Theorem-Minimize Mortality/Growth rule.

- Five options on where to move.
- Movement and station assignment operate at different spatial scales.



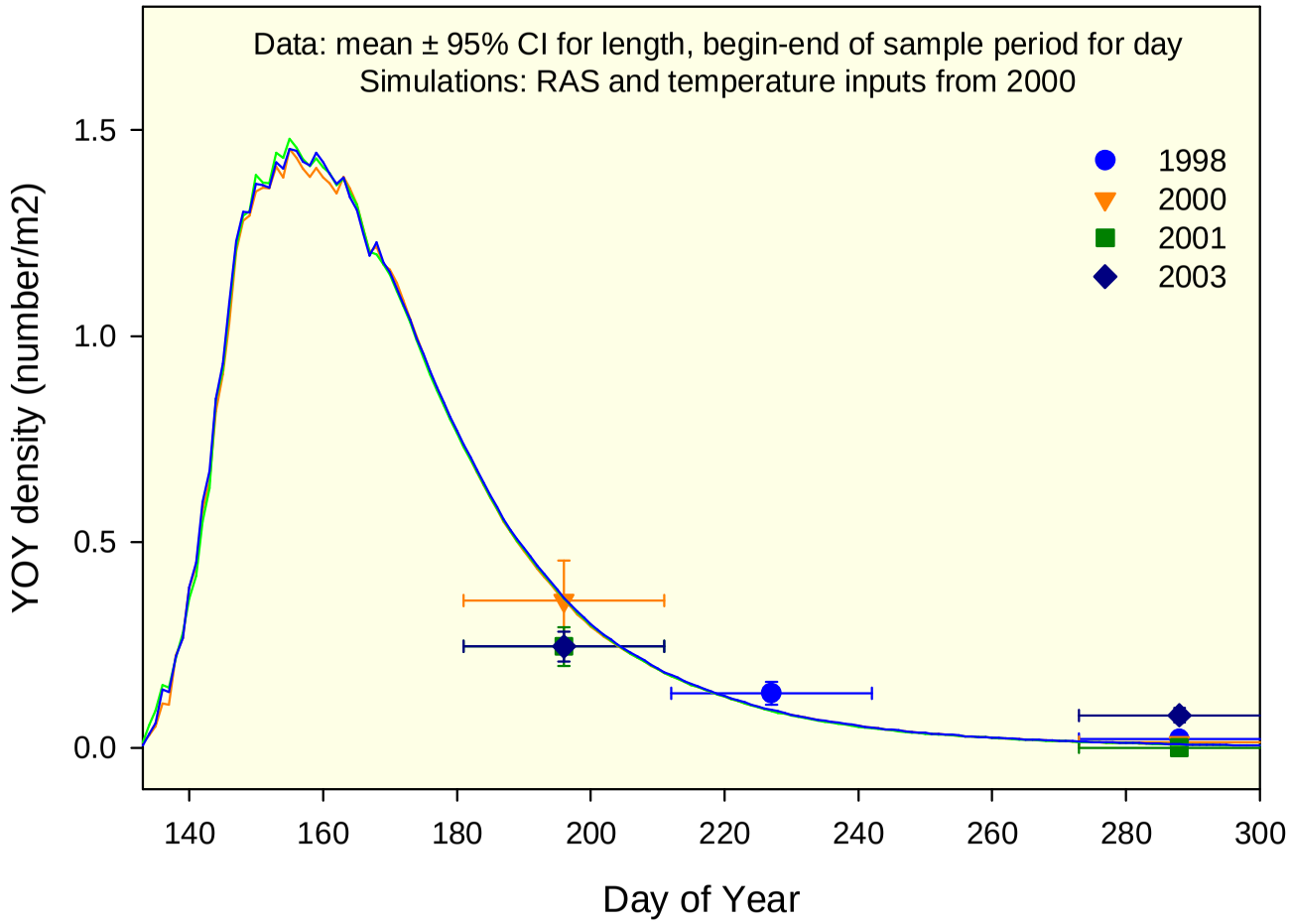
Steelhead IBM:
Model Calibration: Growth

- Simulation run with HEC-RAS flow and temperature inputs from 2000

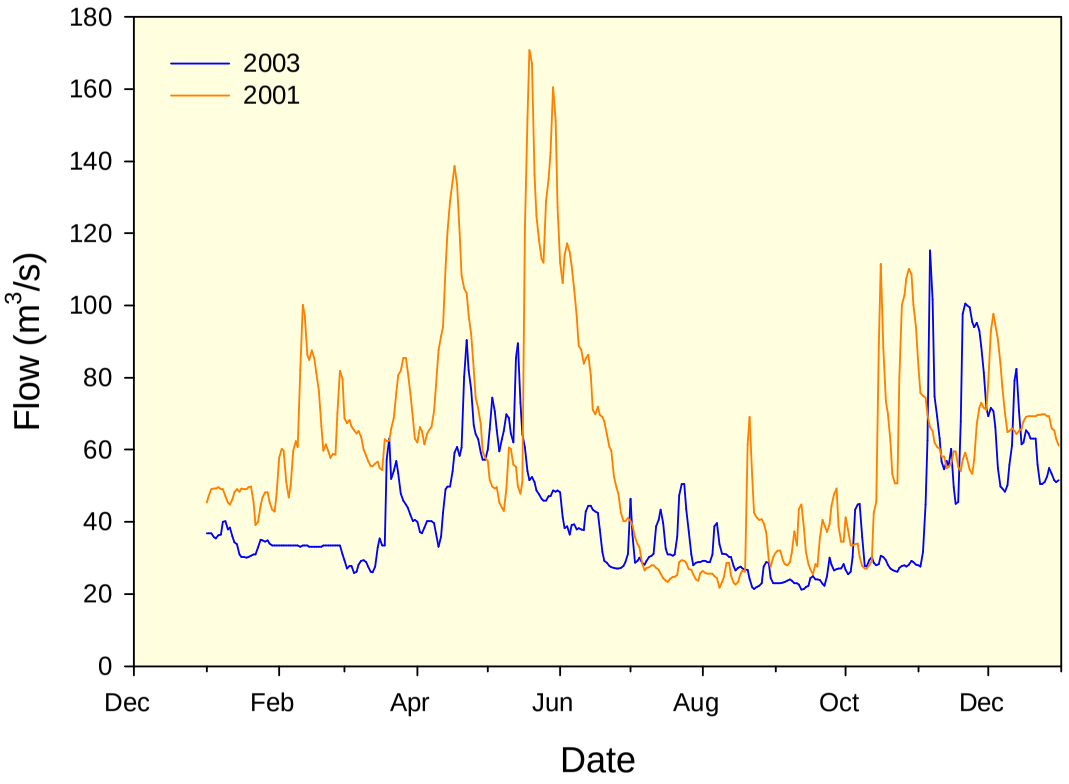


Steelhead IBM:
Model Calibration: YOY Density

- Simulation run with HEC-RAS flow and temperature inputs from 2000

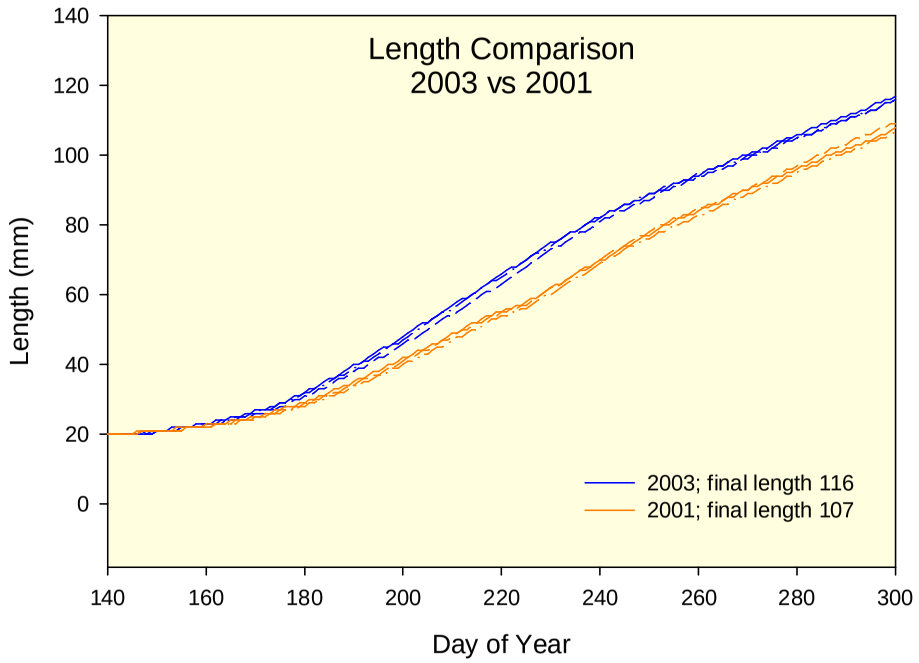


How do natural changes in hydrology affect steelhead recruitment?

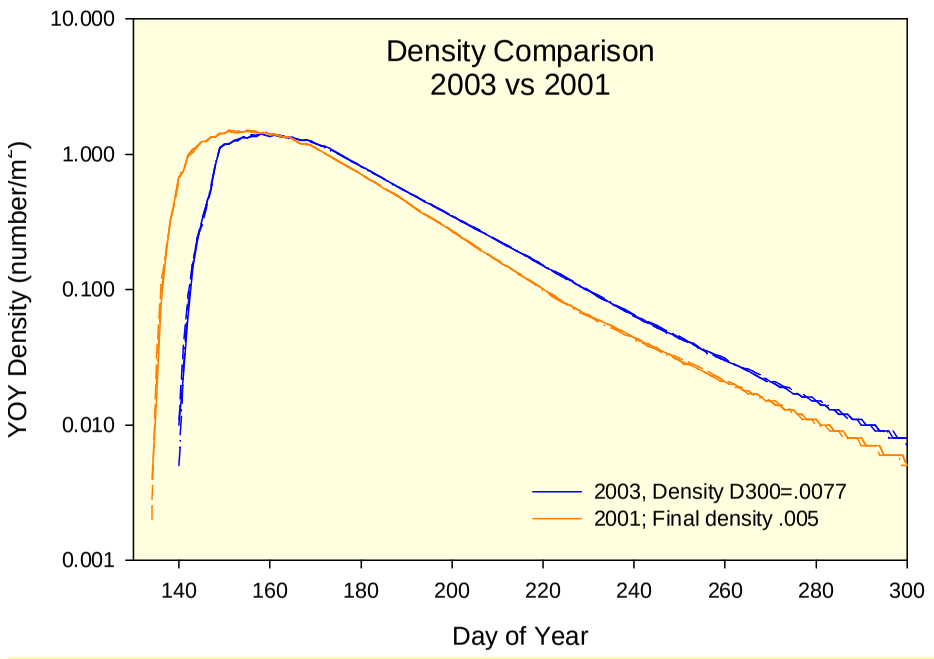


- 2003 a low flow year.
- 2001 a high flow year.
- RAS outputs generated for each year.
- YOY steelhead recruitment compared.
  - Population number
  - Average length

Steelhead IBM:
Effect of Hydrology on YOY Length and Density

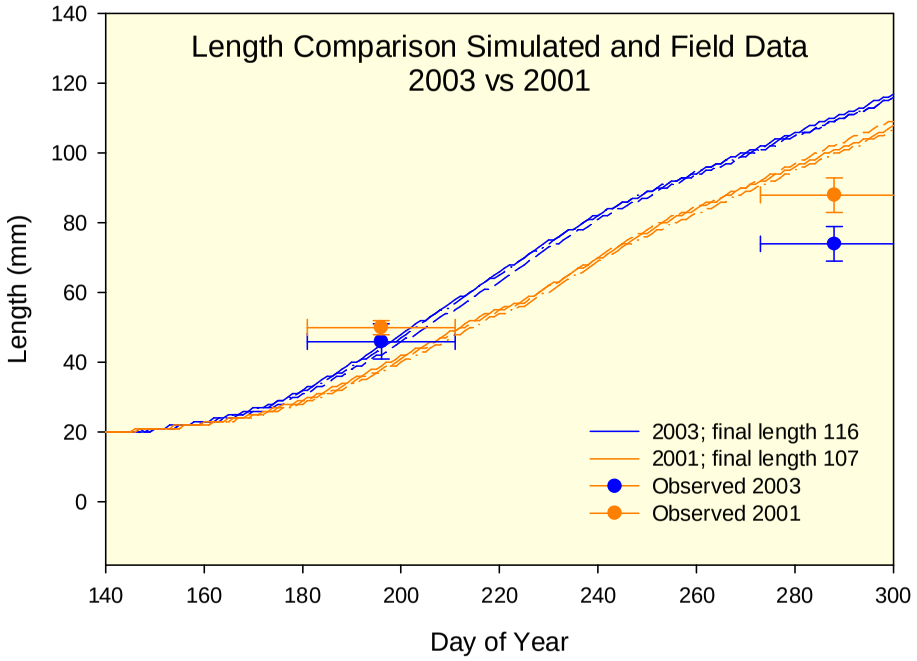


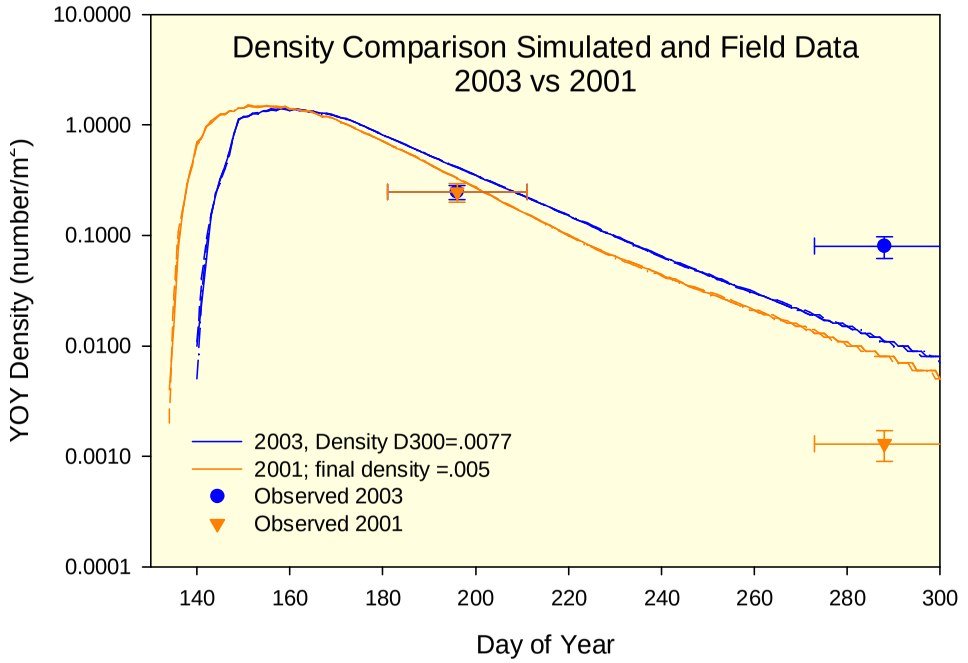
YOY length 11% lower in 2001 than in 2003



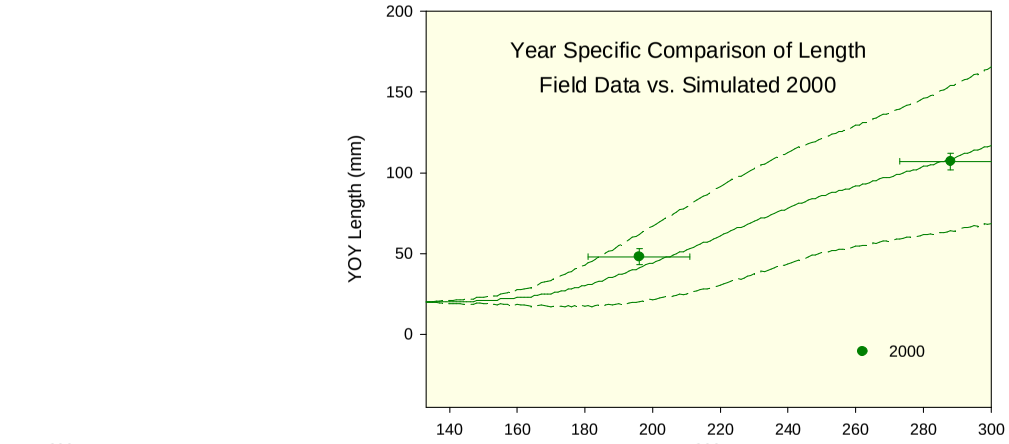
YOY density 28% lower in 2001 than in 2003

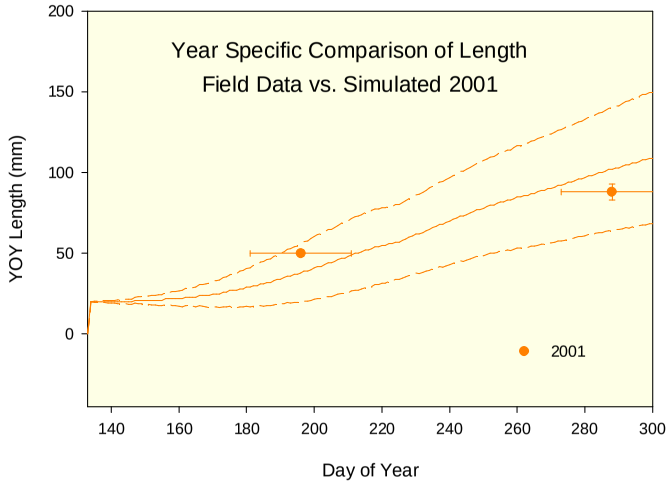
Steelhead IBM:
Effect of Hydrology on YOY length and density
Simulation vs. Field Data

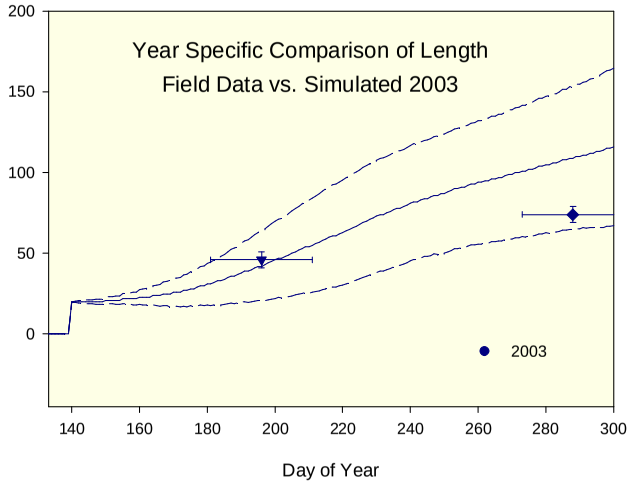




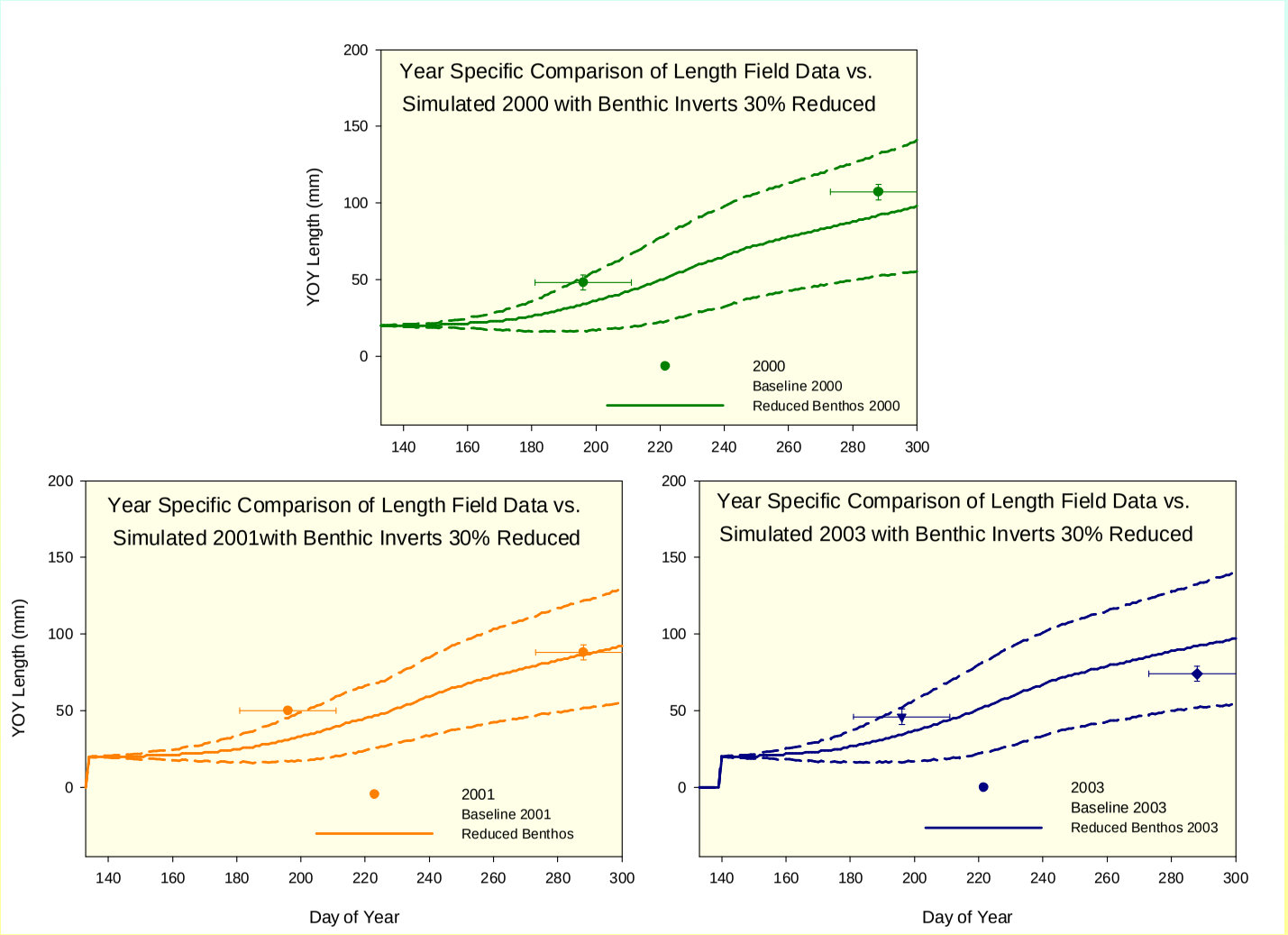
Steelhead IBM:
Year Specific Length Comparisons
Flow and temperature inputs from specific years



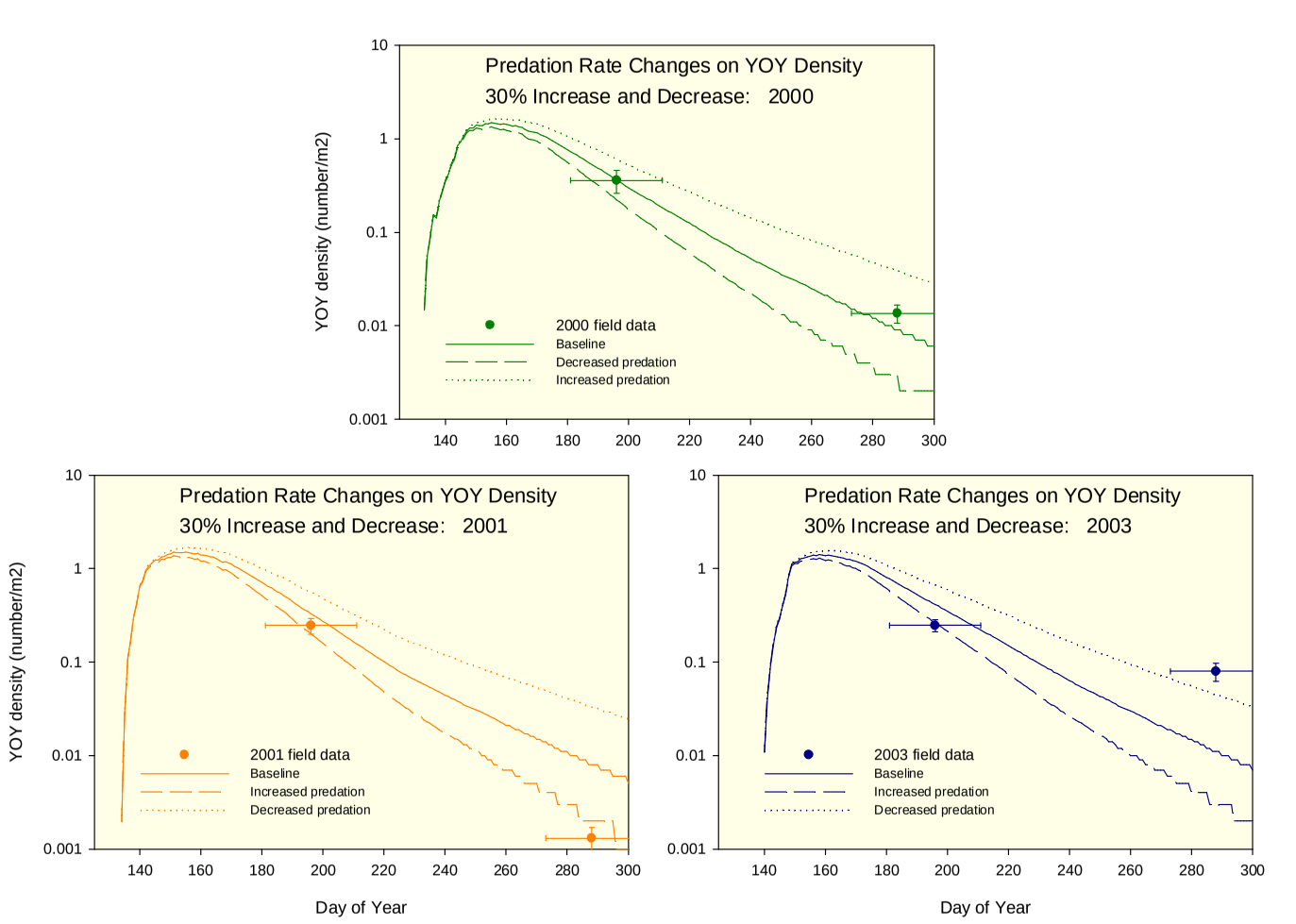




Steelhead IBM:
Year Specific Length Comparisons
with 30% Reduction in Benthic Invertebrates



Steelhead IBM:
Year Specific Density Comparisons
with 30% Increase and Decrease in Predation



Conculsions & Next Steps

- Natural variation in hydrology alone can affect survivorship and growth of YOY steelhead; 2003 vs 2001 simulations.
  - 28% decrease in the number of YOY steelhead produced.
  - 11% decrease in YOY length.
- Flow cannot explain all of the observed variation in the data.
- Variation in predation and food density can put bounds on length and density projections from the model.
- Add omitted functional links in the model.
  - Flow effects on benthos
  - Flow effects on predation
- Run long term simulations to examine effects on fish of:
  - Climate change
  - Land use change