Modeling Ogeechee River Shortnose Sturgeon

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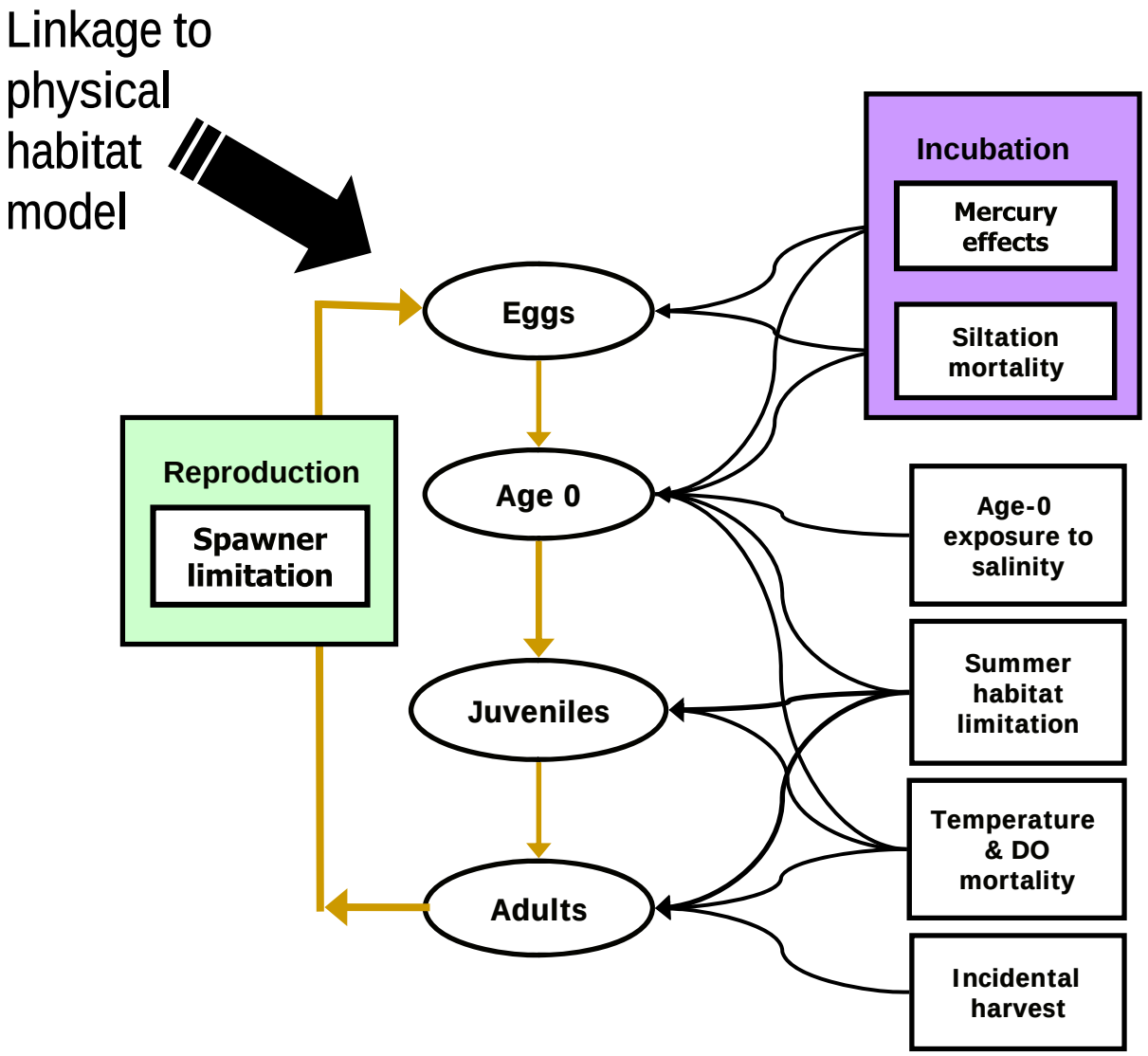
Population viability analysis (PVA)

Individual-based, spatially explicit model



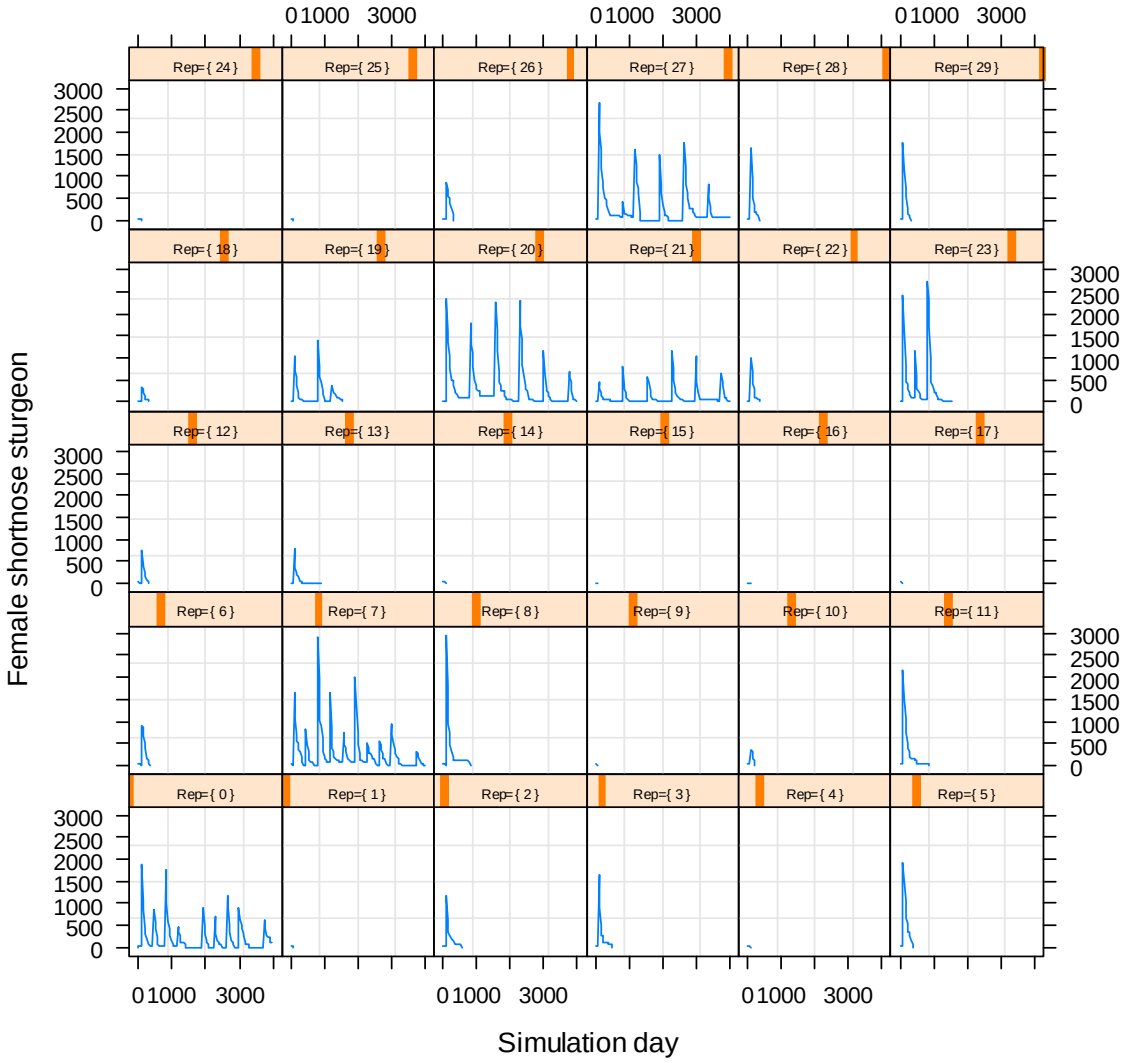
- **Physical habitat (river water quality) influences sturgeon activities**
  - **Feeding**
  - **Growth**
  - **Movement**
  - **Survival**
  - **Reproduction**
- **Different life stages are sensitive to different habitat factors.**
- **Allee effects**

Research questions

- Is the Ogeechee population limited by spawner numbers?
  - Given adequate habitat, what is minimum viable population size?
- Is the Ogeechee River population limited by habitat?
  - Summer water quality
  - Rice canals and salinity
- Is mercury a credible threat to reproduction?
- Is incidental harvest mortality as by-catch in the commercial shad fishery limiting the population?

PVA extinction thresholds

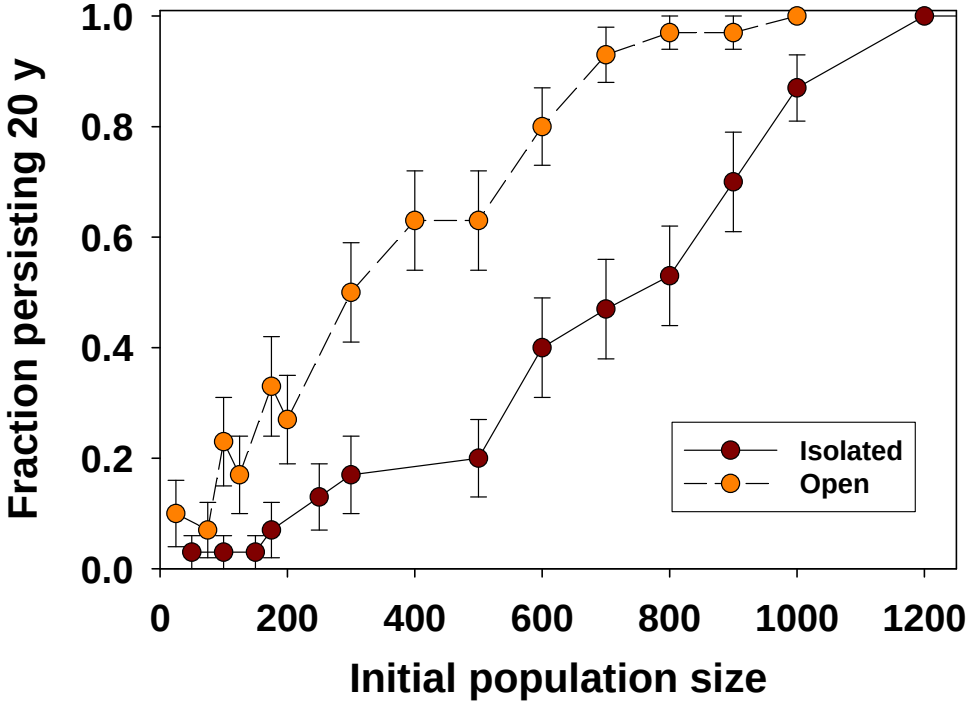
- **30 replicate populations starting with N(0) = 75.**
- **Annual recruitment**
- **Record fraction that persisted 20 y) and the distribution of time to extirpation**
- **Historical period, not future**
- **Future simulations would require trends in temperature and sea-level rise**



N(0)=75

MVP given suitable habitat?

Preliminary results



- All habitat-related sources of mortality are “turned-off” in the PVA
- Fraction persisting increases with initial size.

Research questions

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- Is the Ogeechee River population limited by habitat?
  - Summer water quality
  - Rice canals and salinity
- Is mercury a credible threat to successful reproduction?
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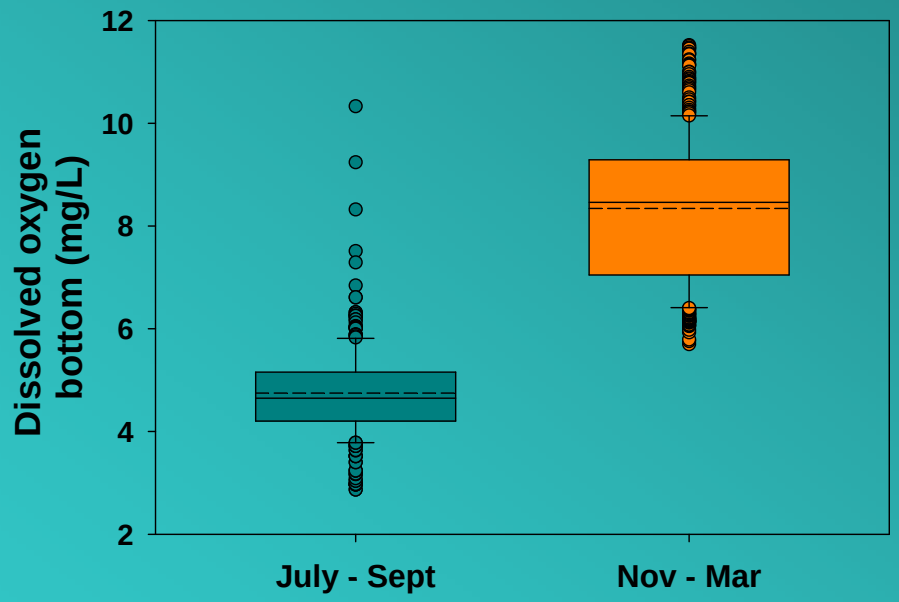
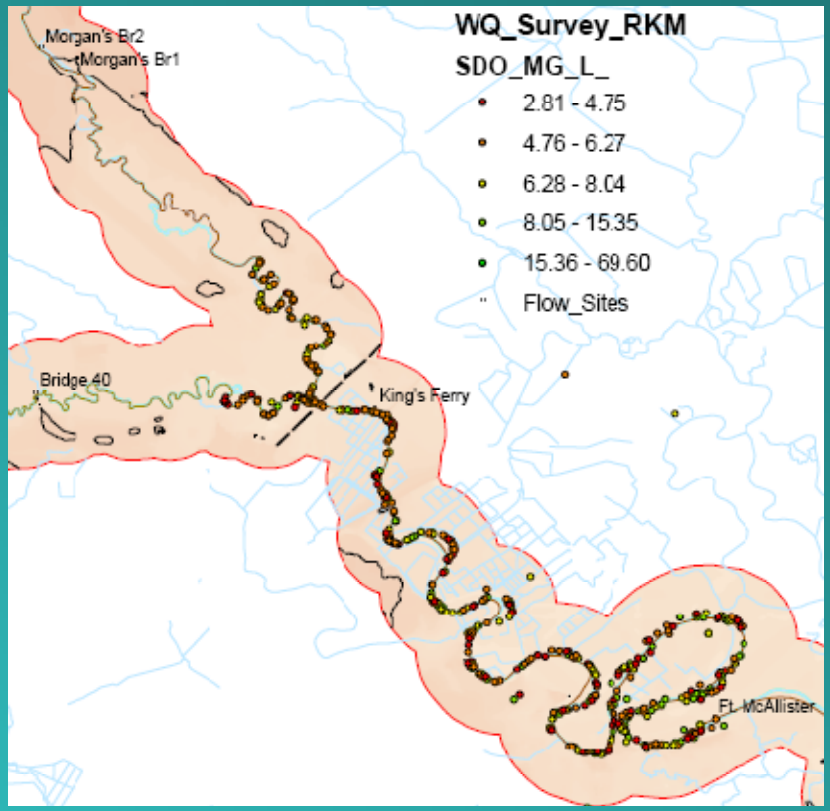
Ogeechee River water quality data

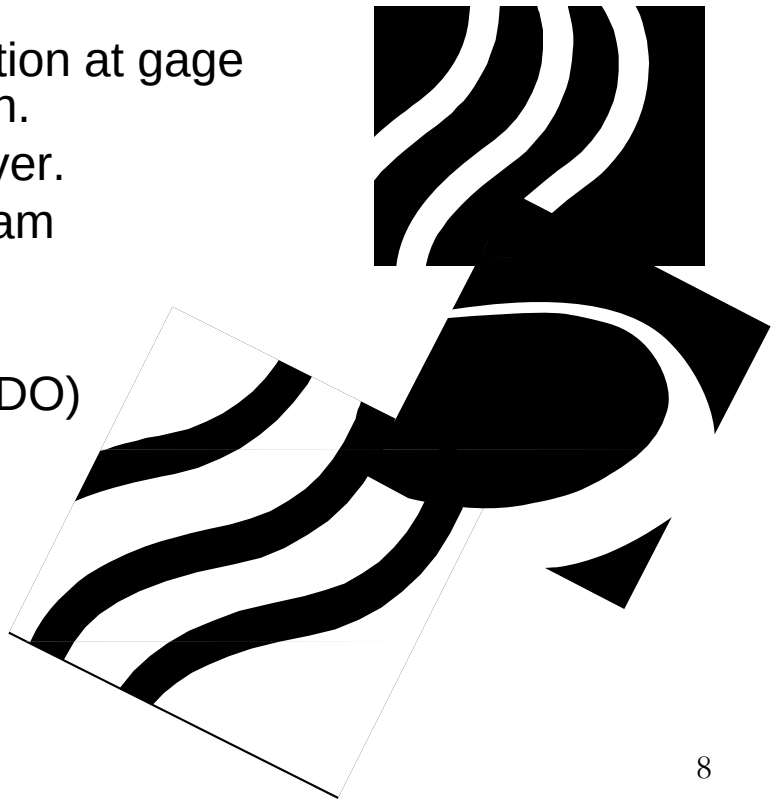




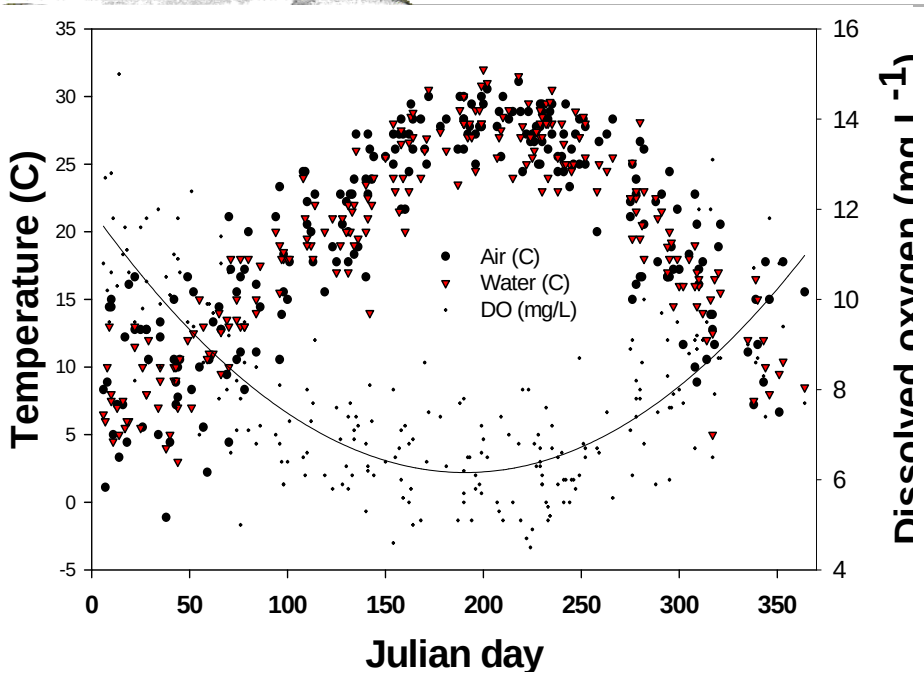
- Lowest DO
  - Summer months
  - Below Canoochee confluence
  - Early morning

Hydrodynamic water quality model

- EFDC (Environmental Fluid Dynamic Code)
- 3D implementation with few lateral and vertical boxes.
- Input requirements:
  - Installation and monitoring of staff gages
  - Accurate measurement of zero-stage elevation at gage locations to simulate water surface elevation.
  - Depth transects at intervals up and down river.
  - USGS flow gage data only available upstream
  - Tidal lower boundary conditions
  - Biological parameters
  - Calibration data (stage, wetted width, T, S, DO)
- Calibration
  - Water surface elevation
  - Temperature
  - Salinity
  - Dissolved oxygen (not implemented)



Empirical water quality model



$$S(x,Q) = Ssw\left(1 - \frac{x}{x + \mathrm{e}^{\left(\frac{Salina + SalincQ}{Salinb + SalindQ}\right)}}\right) + \varepsilon.$$

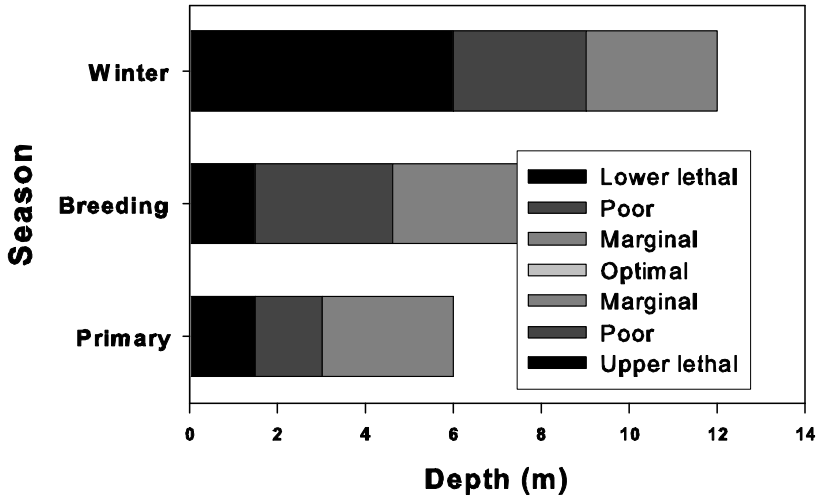
$$T_w(day) = w_0 + w_t T_{air}(day) + \varepsilon,$$

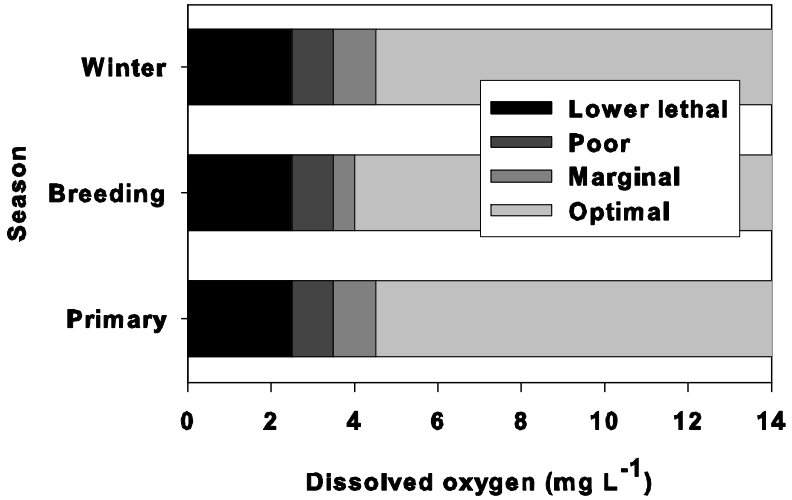
$$T_{air}(day) = T_{avg} + (T_{max} - T_{avg}) \sin\left(\frac{2\pi}{365}[day - J_0]\right) + \varepsilon$$

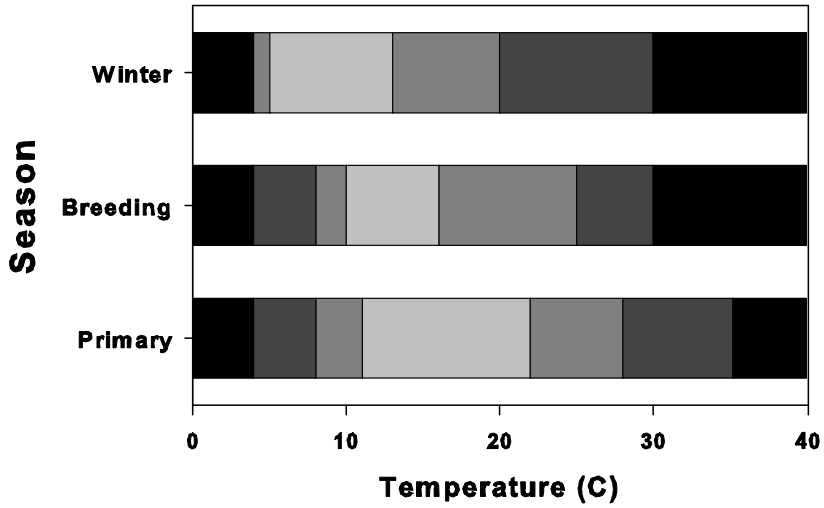
$$DO = \begin{cases} v_{0,Can} + v_{S,Can} S + v_{Qc} Q_{Can} + \varepsilon, Canoochee \\ v_{0,Og} + v_{S,Og} S + v_{Qt} Q_{tot} + v_{T,Og} T_w + v_x X + v_p pQ + \varepsilon, Ogeechee \end{cases}$$

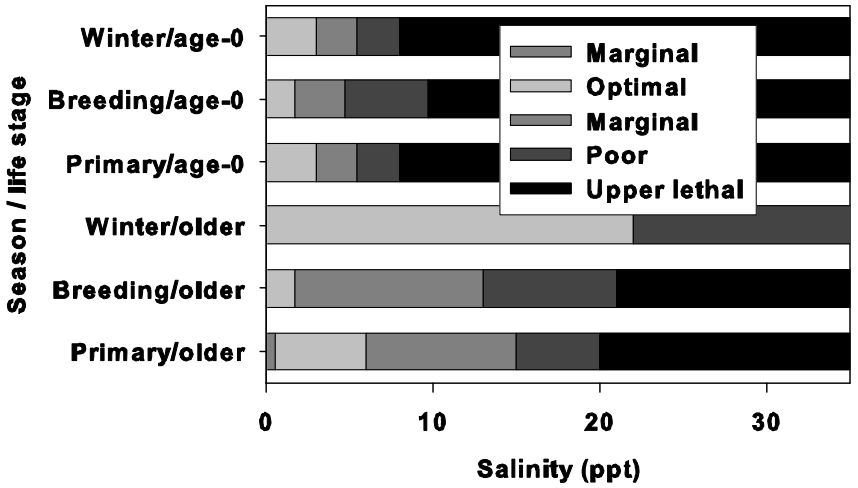
- Weekly surveys of surface and bottom salinity, temperature, and DO throughout 2007-2009
- Salinity relationship fitted to data collected by MAREX in lower river (no rice-canal influence).
- Seasonal, but little spatial, variation in river temperature.
- DO predicted from T, S, and Q

Habitat influences growth, movement, & survival







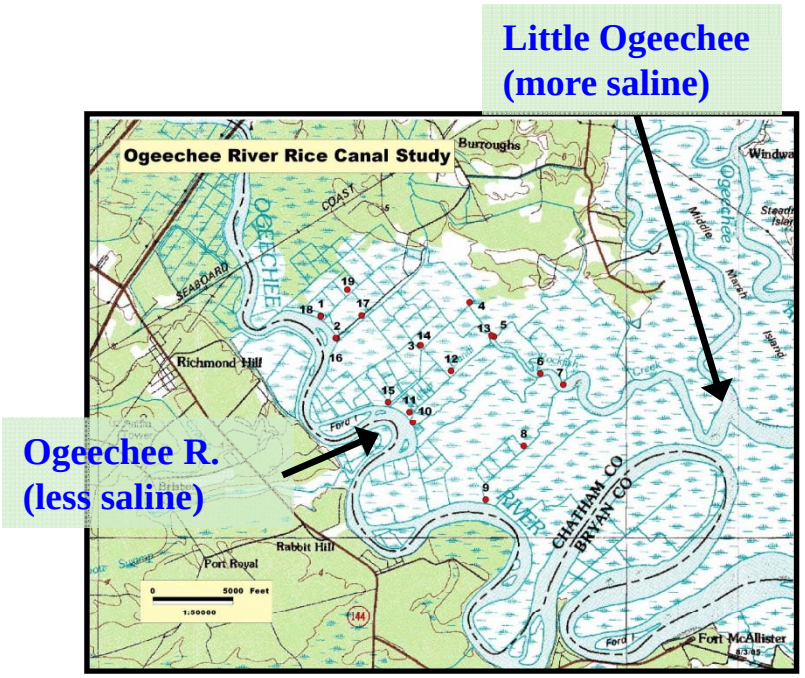


- **Static vs. dynamic (=f(Q,T)) habitat quality**
- **Growth-based individual movement decisions**

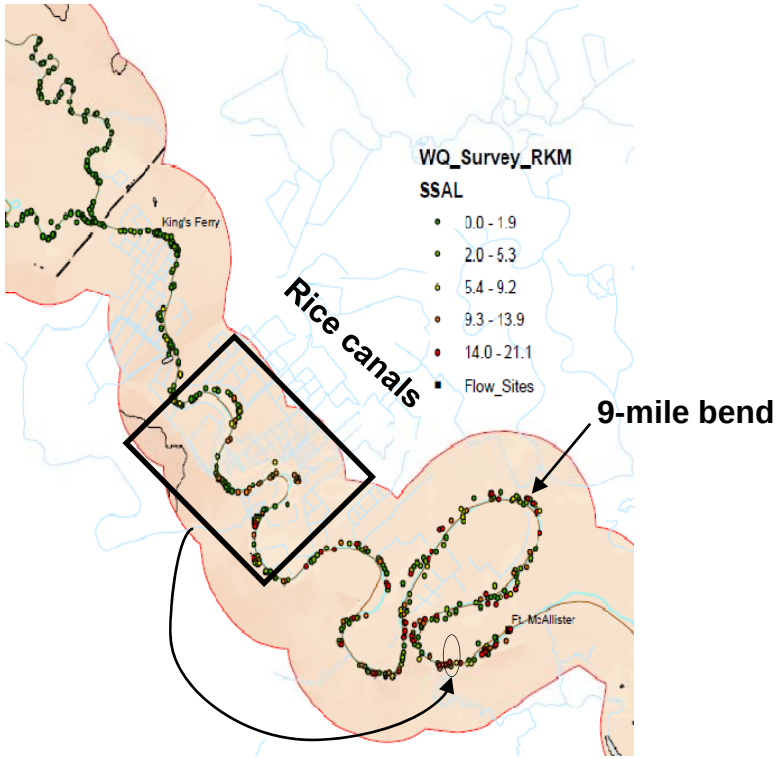
Results – *Habitat*

- Is habitat limiting?
  - Rice canals and salinity?
  - Summer water quality?

Do rice canals degrade SNS rearing habitat?



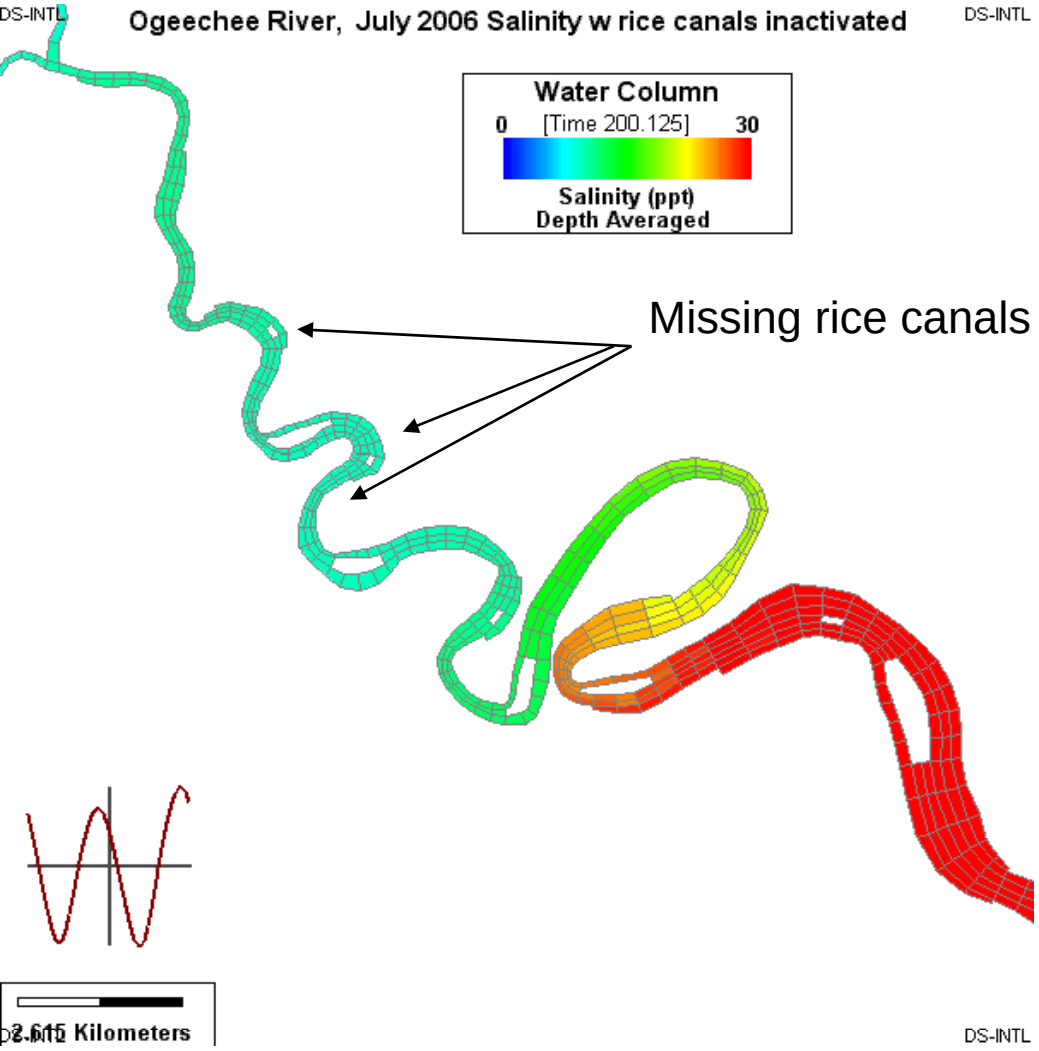
Source: Keith Gates, UGA Marine Extension Service

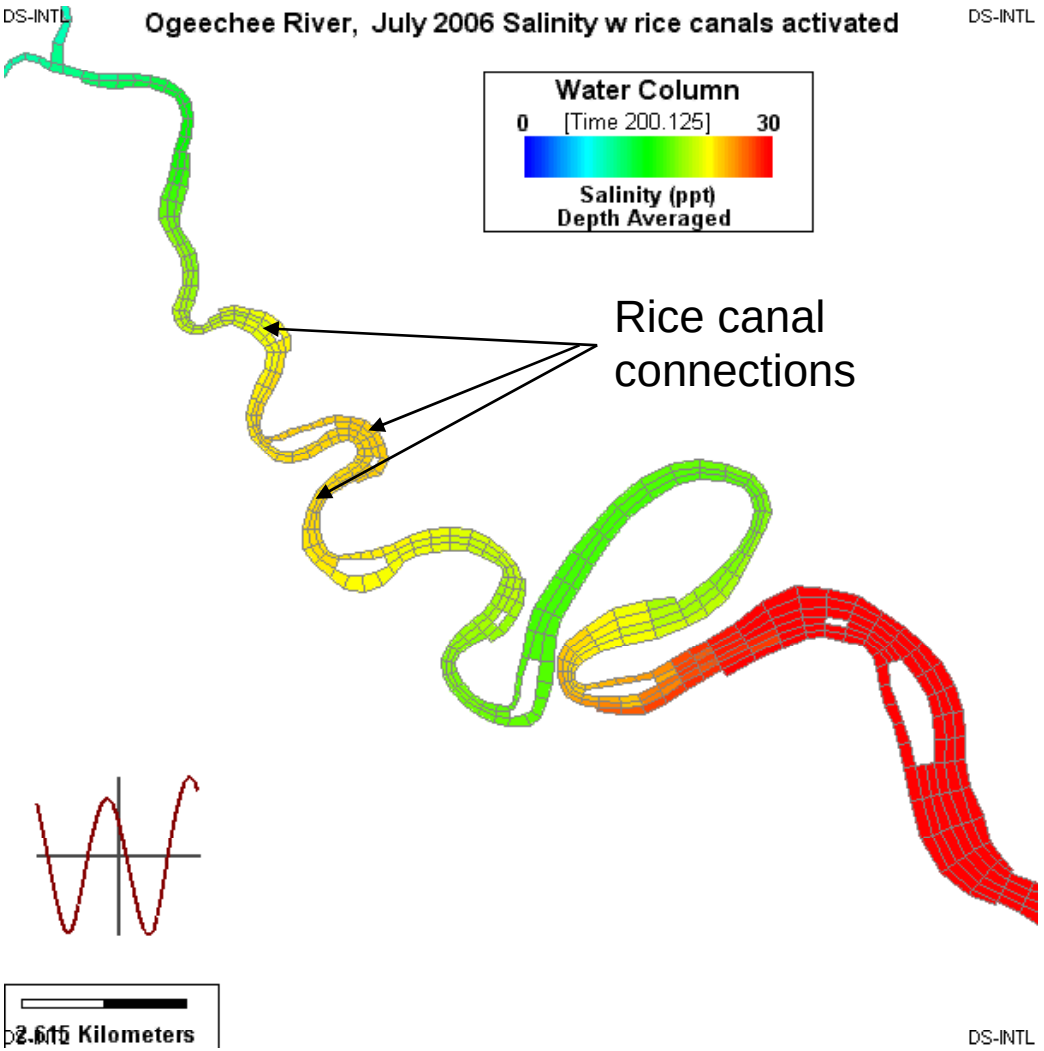


- Field data show increase in salinity above 9-mile bend.
- Calibrated EFDC with and without data near canals
- Used EFDC to identify a downstream location with similar salinity.

EFDC rice-canal scenarios

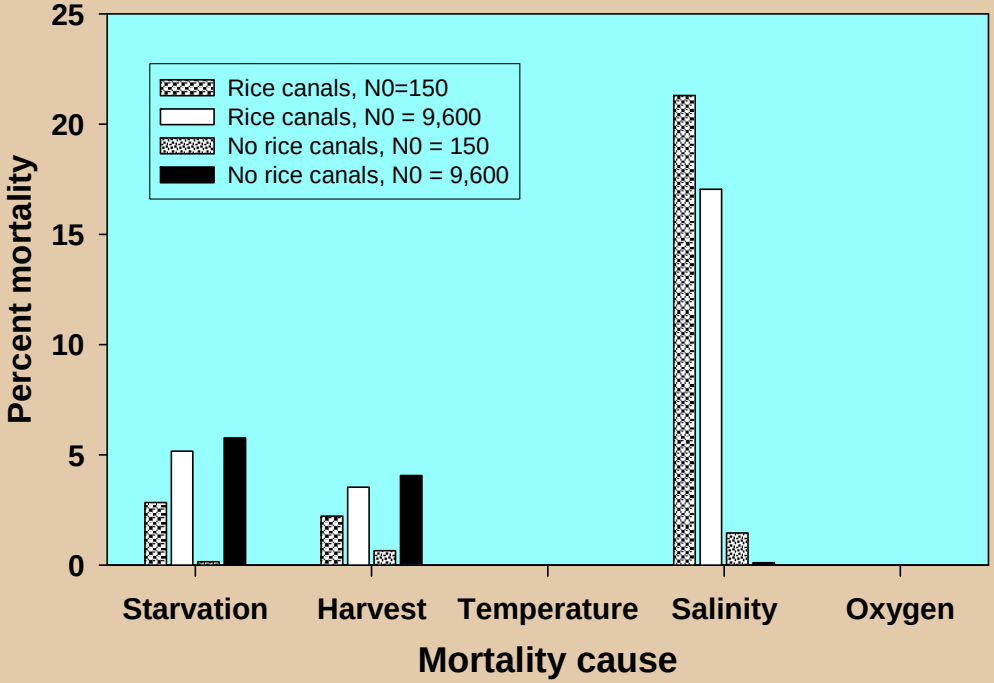
4-day simulations (July 2006)

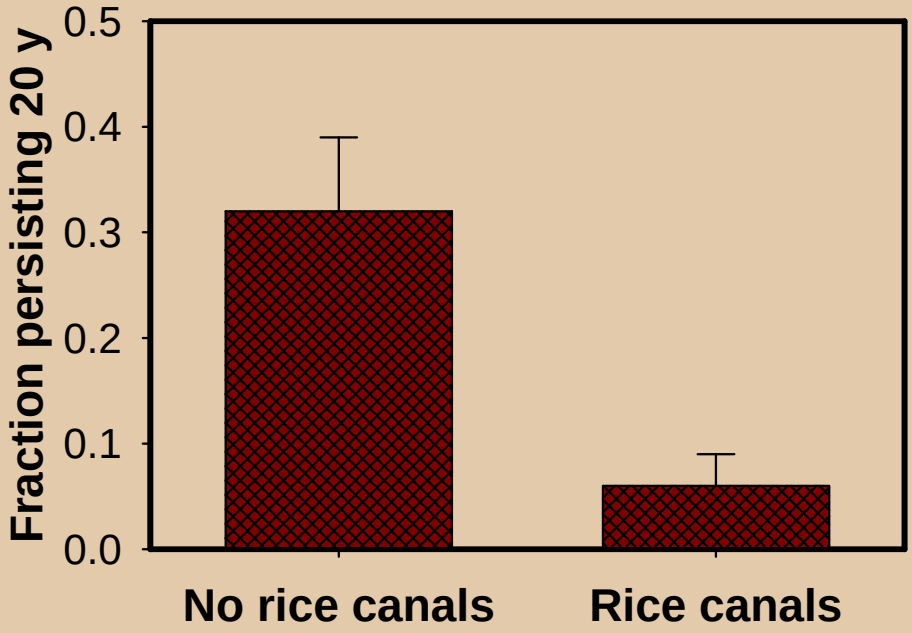




www.ornl.gov/~zij/projects.html

Results – *Rice canals*



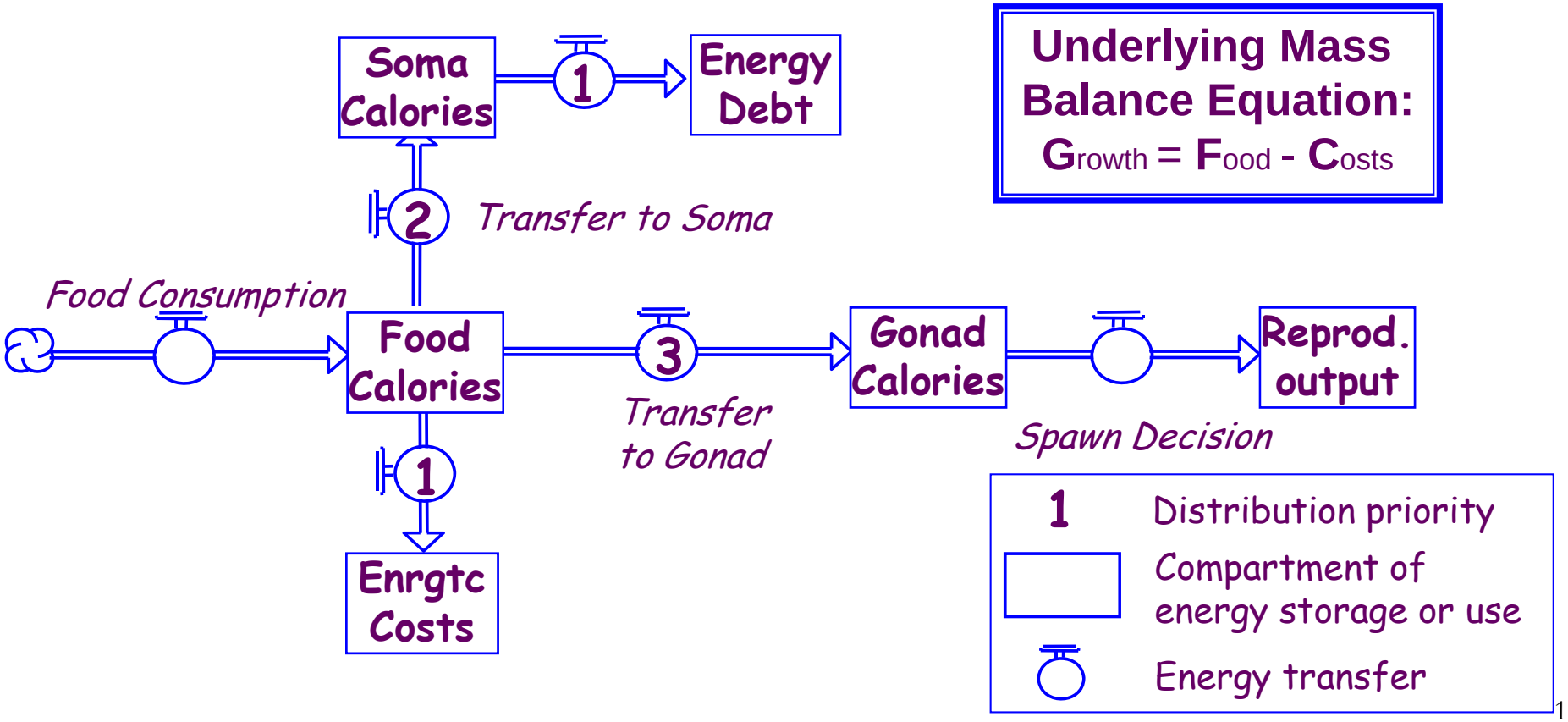


Results – *Habitat*

- Is habitat limiting?
  - Rice canals and salinity?
  - Summer water quality?

Shortnose sturgeon bioenergetics

Objective: Evaluate the effects of various environmental factors (e.g., temperature, food, salinity, DO) on growth & reproduction.



Results – *Bioenergetics model*

Baseline Simulation

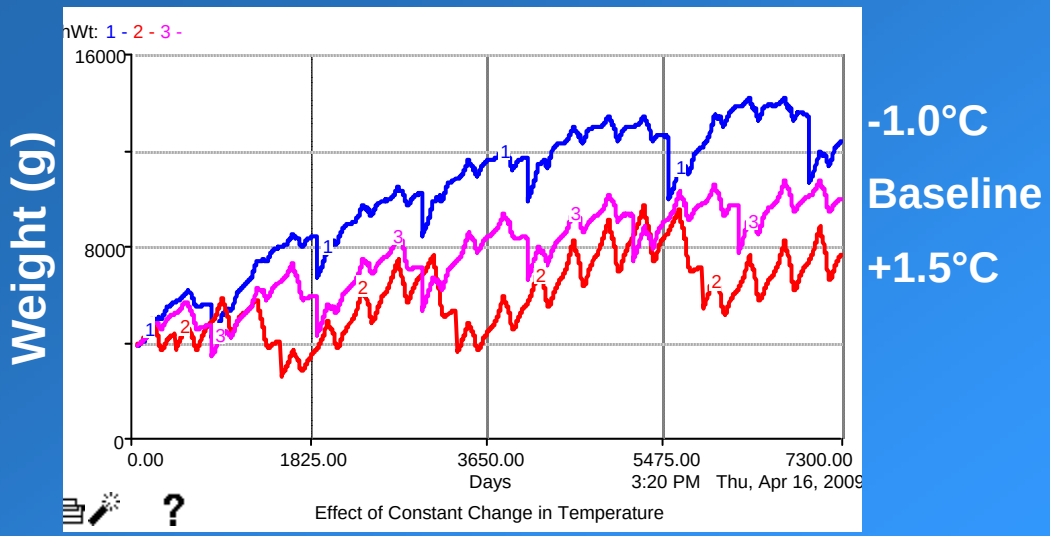
- 20-yr simulations
- Ogeechee R average temperatures
- one female shortnose sturgeon
- initial age = 8 y
- calibrated to observed lengths & weights

- Higher female weights and fecundities in colder years.
- Elevated temperatures resulted in longer predicted intervals between spawning events.

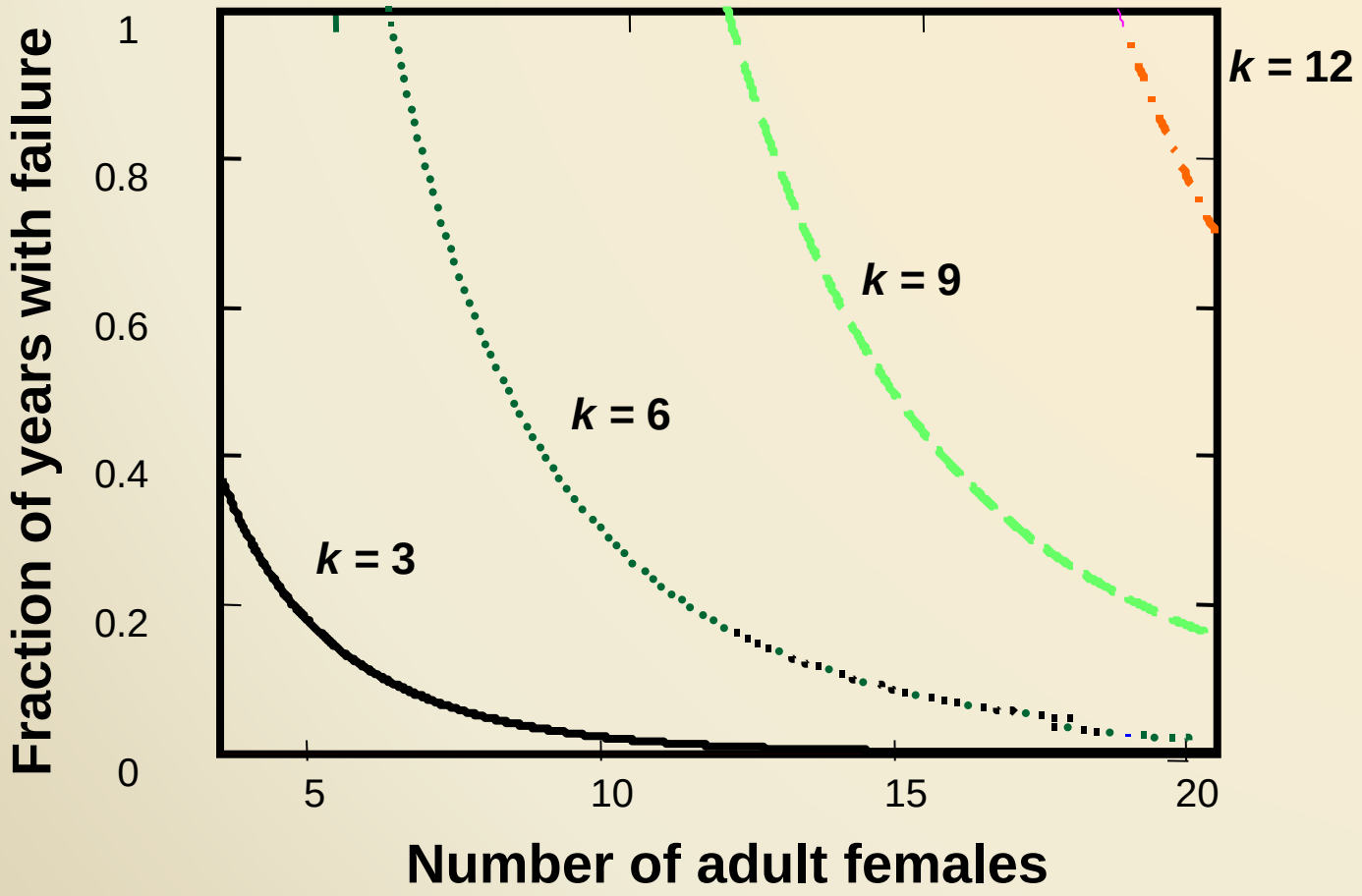
Reproductive response

	Spawning events	Eggs produced
-1.0°C	6	679K
Baseline	6	590K
+1.5°C	4	318K

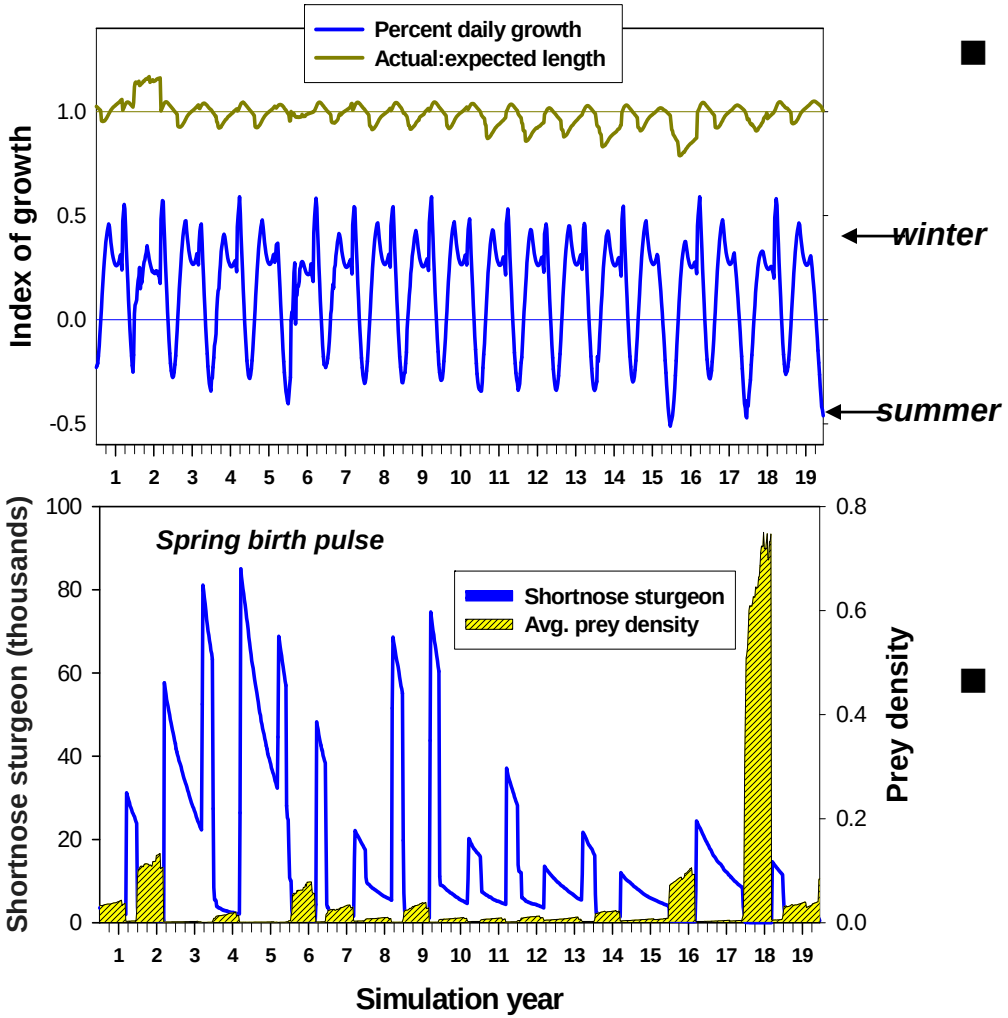
Effect of temperature



Why spawning interval, *k*, matters



Results *PVA-simulated growth*



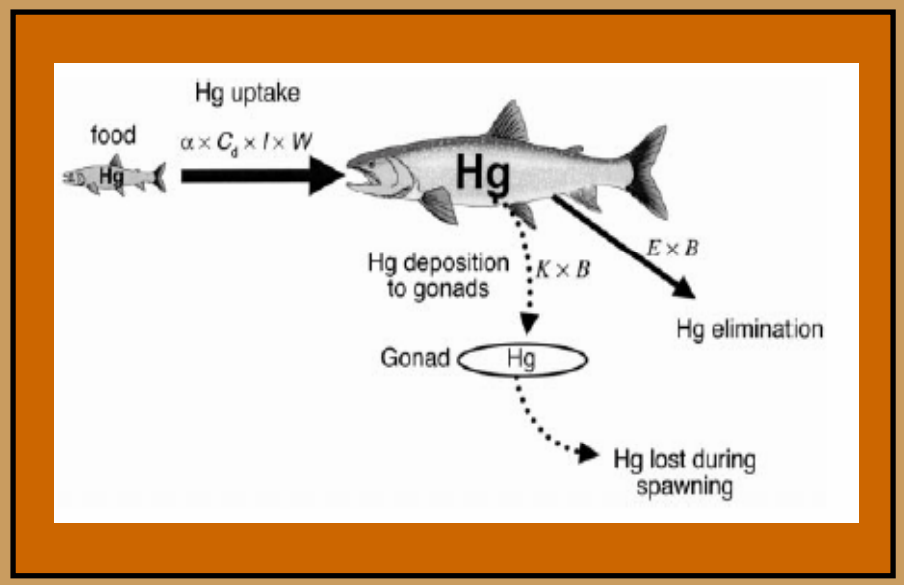
- **Methods**
  - Prey parameters calibrated to shortnose age-length relationships
  - Movement stimulated by deterioration in individual's growth
  - Starvation simulated when individual's condition falls below a threshold.
- **Results**
  - Negative growth in summer; small growth check in winter
  - Typical predator-prey dynamics
  - Starvation in summer

Research questions

- Is the Ogeechee population limited by spawner numbers?
  - Given adequate habitat, what is minimum viable population size?
- Is the Ogeechee River population limited by habitat?
  - Summer water quality
  - Rice canals and salinity
- Is mercury a credible threat to successful shortnose sturgeon reproduction?
- Is incidental harvest mortality as by-catch in the commercial shad fishery limiting the population?

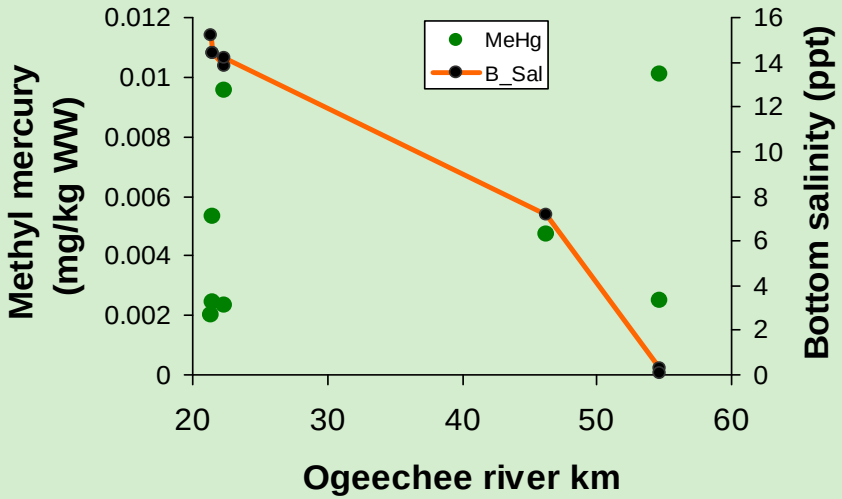
Mercury

Is mercury a threat to successful reproduction?

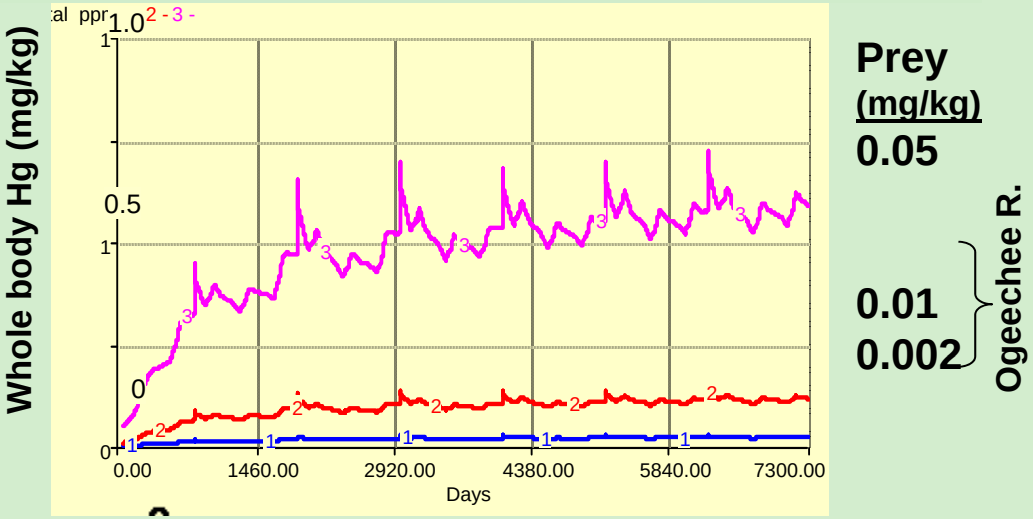


- **Salt-freshwater interface is a site of increased availability of MeHg, as are wetlands.**
- **Field sampling of [Hg] and [MeHg] in prey: amphipods from locations varying in salinity in the interface zone.**
- **A Stella model for mercury bioaccumulation for female sturgeon was used to predict egg concentrations.**

Results – Mercury



Effect of prey [MeHg] on sturgeon [Hg]



- **MeHg in amphipod prey was variable (0.002 to 0.010 mg/kg wet weight), with no obvious pattern in response to salinity (left, orange line).**

- **Concentrations predicted to be in shortnose sturgeon for these prey levels were below the EPA threshold of 1 mg/kg total mercury.**

Research questions

- Is the Ogeechee population limited by spawner numbers?
  - Given adequate habitat, what is minimum viable population size?
- Is the Ogeechee River population limited by habitat?
  - How much suitable habitat is required for persistence?
    - Summer water quality
    - Rice canals and salinity
- Is mercury a credible threat to reproduction?
- **Is incidental harvest mortality as by-catch in the commercial shad fishery limiting the population?**

Incidental Harvest

Is by-catch in the shad fishery limiting the population?

Counted nets via surveys of the Ogeechee River throughout the season when legal, including days of the week when shad fishing is not permitted.

The PVA model predicted harvest mortality risk of individual spawners based on:

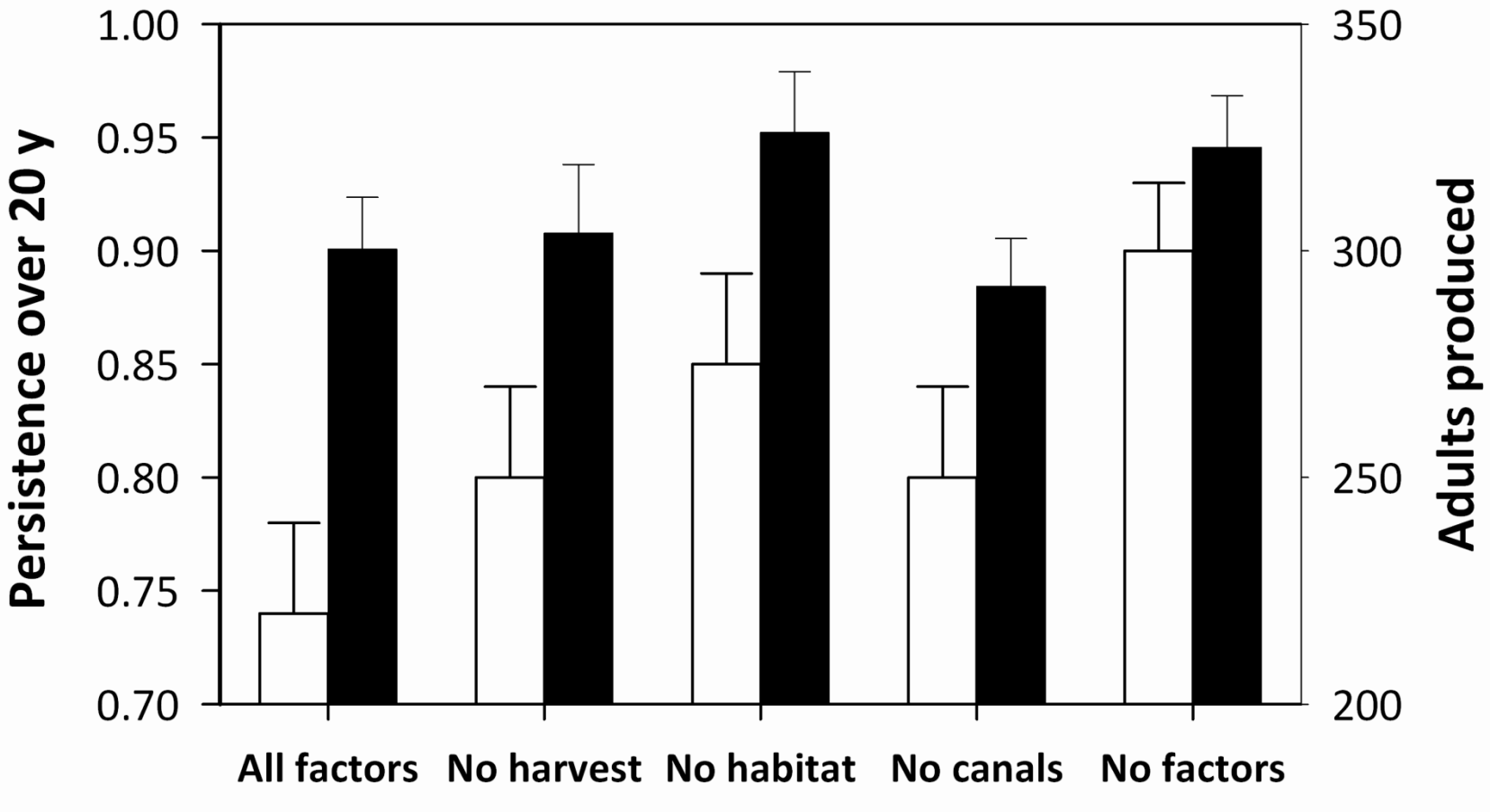
- **Simulated upstream spawning migration**
- **Simulated capture (net encounters).**
  - **Whether or not the date falls within the fishing season and one of two legal days;**
  - **Number and spatial distribution of nets at time of migration;**
  - **Proportion of river width spanned by nets**

- **If captured, simulated mortality – 16-36% of shortnose sturgeon captured in shad nets died in a two year study by Collins et al. (1996).**

- **Is avoidance behavior adequately represented? Different assumptions about avoidance can be made.**

Source: J. Fleming, GA-DNR

Results



Fraction of 100 replicate populations (white) that persisted and the average number of adults produced (black) and over a twenty year period for each of five scenarios in which factors were removed. Values presented are for an initial population size of 225 individuals. Error bars indicate ±1 SE among replicate scenarios.

The end, but wait…

Agriculture

Urban development

Military land management

Military point sources

Rice canals

Sediment loss & siltation

Limited summer habitat

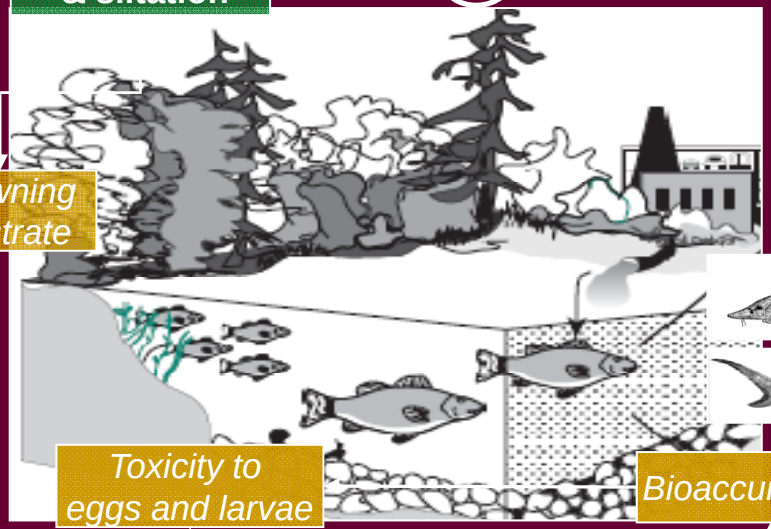
Increased salinity

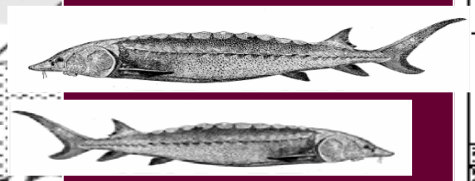
Upstream migration of saltwater interface

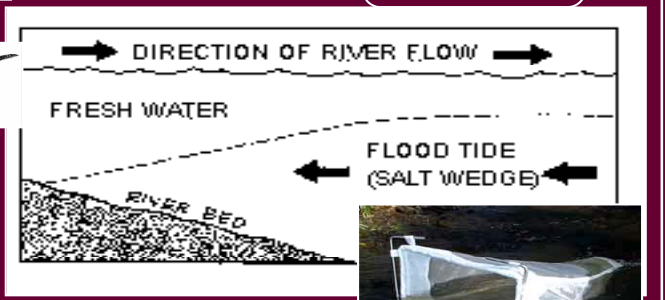
Groundwater pumping

Low dissolved oxygen & High temperature

Spawning substrate







Toxicity to eggs and larvae

Bioaccumulation

Mercury toxicity

"Incidental" harvest

Watershed effects

Methylation at salt-freshwater interface

Other relevant modeling approaches white sturgeon

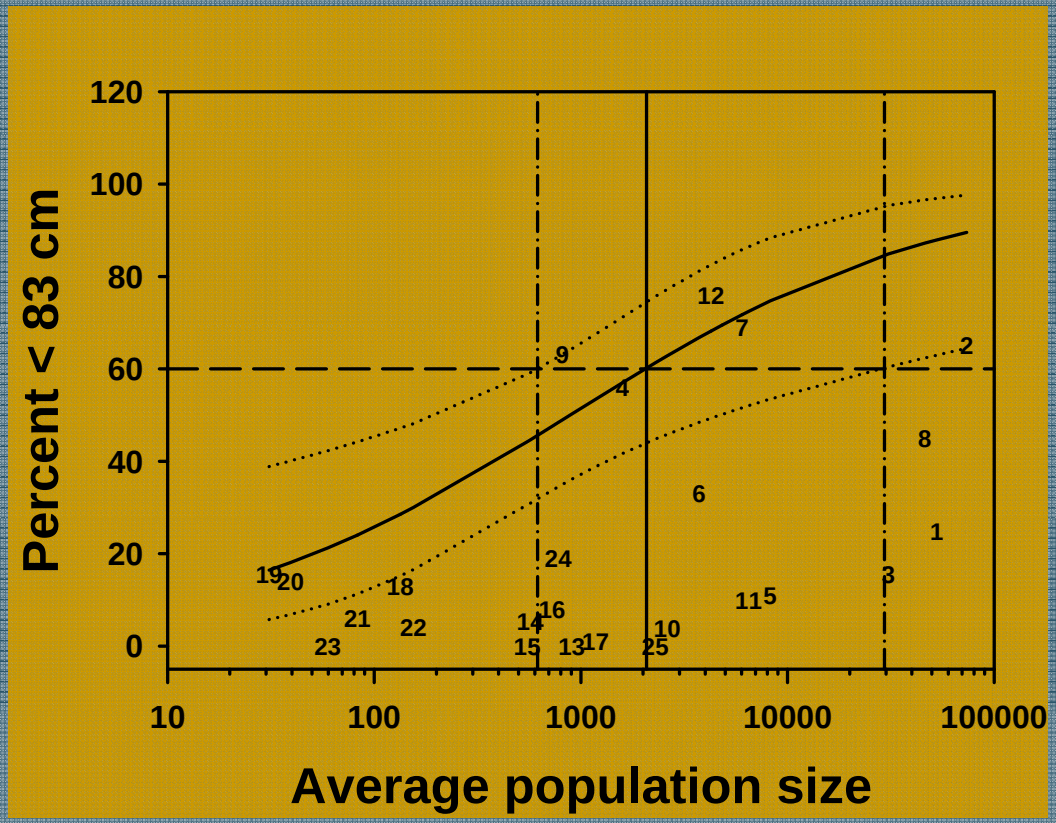
- Dam-created meta-population modeling
  - Evaluate reconnection options
  - Demographic and genetic population responses
- Empirical range-wide assessment
  - Trend-based
  - Recruitment-based




Reconnection Summary

- Low entrainment mortality risk
- Protect the donor population
  - Set translocation policies based on capture effort.
  - Monitor donor populations – the response of the donor indicates net metapopulation response.

Empirical recruitment-based MVP



- Premise: MVP = N such that recruitment index < 60%.
- Quantile regression

Populations included are 1=Below Bonneville, Lower Fraser River, 2=Bonneville Reservoir, 3=John Day Reservoir, 4=Lower Granite Reservoir, 5=McNary-Hanford Reach, 6=Middle Fraser River, 7=Below Hells Canyon, Snake River, 8=The Dalles Reservoir, 9=Upper Fraser River, 10=C.J. Strike Reservoir, 11=Little Goose Reservoir, 12=Lower Monumental Reservoir, 13=Kootenai River, 14=Nechako River, 15=Priest Rapids, 16=CJ to Swan Falls, Snake River, 17=US-Canada Border below Keenleyside Dam, 18=Wanapum, 19=Wells Reservoir, 20=Rocky Reach, 21=Lower Salmon to Bliss Dam, 22=Brownlee Reservoir, 23=Arrow Lake, 24=Shoshone Falls to Upper Salmon Dam, 25=Lake Roosevelt.

Acknowledgements

- Shortnose modeling: SERDP
  - ORNL Advisors: Pat Mulholland, George Southworth
  - Water quality analysis: Katy Smith (MAREX)
  - Mercury analysis: Patrick Pang (CEBAM).
  - EFDC modeling support by Dynamic Solutions, LLC.
- White sturgeon modeling: Idaho Power
- DOE Waterpower program

More information at www.ornl.gov/~zij

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