Potential Application of an Individual-Based Model to the Glen Canyon Trout Fishery

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Presentation to the Glen Canyon Dam Technical Working Group

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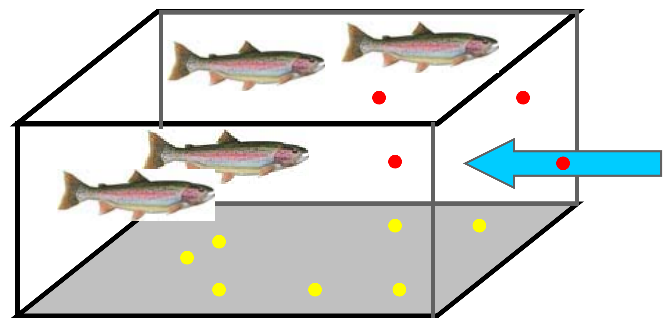
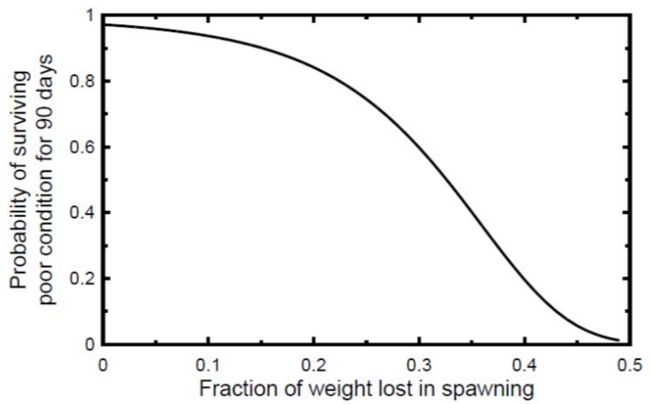
Objectives of this Presentation

- Describe an Individual-Based Model (inSTREAM-SD) that has been applied successfully to a number of fisheries-related problems including within the Colorado River Basin
- Illustrate inSTREAM's application to Flaming Gorge
- Discuss potential application to Glen Canyon
  - Evaluation and design of trout management flows
  - Assessment of impacts of equalization flows and appropriate management responses
  - Understanding factors leading to current population status

Individual-Based Model Approach

- Computationally track individual fish in space and time
- Use simple, mechanistic models based on well-understood relationships that are based on the literature or site-specific information
- Estimate status of overall population by aggregating information for all individuals
- inSTREAM reproduces many observed patterns of movement response to risk, food, competition, and temperature





Benefits of Individual-Based Models

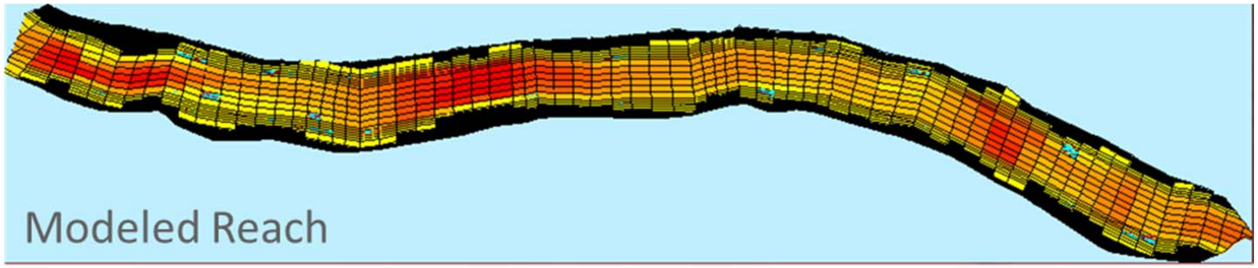
- Identify critical uncertainties that affect model results
- Understand consequences of beliefs and assumptions
  - Applying the model leads to understanding (e.g., identifying beliefs that are incompatible with data)
- Plan adaptive management experiments and foresee consequences
- Design good management policies

The inSTREAM-SD Family of Individual-Based Salmonid Models for River Management

- Developed by Steve Railsback (Humboldt State University) and Bret Harvey (USFS)
- 15 years of development and use
- Applications at 40 sites
- Funding from 8 federal and power industry agencies
- Examples:
  - EPA-STAR: Application of fish IBMs to regional decision making
  - Cutthroat trout at Little Jones Creek, California
  - Effects of dam operations on rainbow and brown trout downstream of Flaming Gorge Dam
  - Instream flow studies for McCloud River hydroelectric project, California
  - Evaluation of Chinook salmon habitat restoration, instream flows, and temperatures in Clear Creek, California
- http://www2.humboldt.edu/ecomodel/

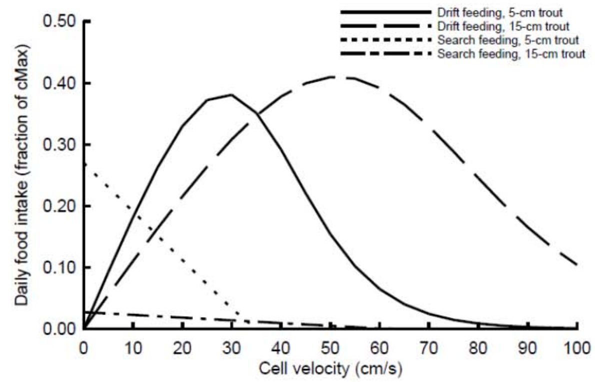
General Approach of inStream-SD

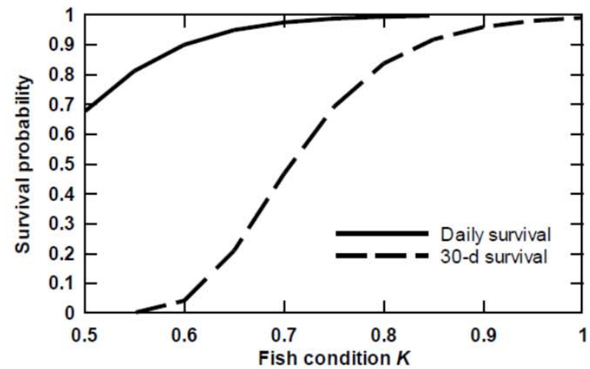
- Habitat represented as 2-D array of cells each with velocity and depth specific to flow volume (channel geometry and hydraulic model)
- Multiple time steps per day: day, night, when flow changes
- Population dynamics over time and space emerge from individual differences in:
  - Location
  - Activity (feeding or hiding)
  - Growth
  - Survival
  - Spawning

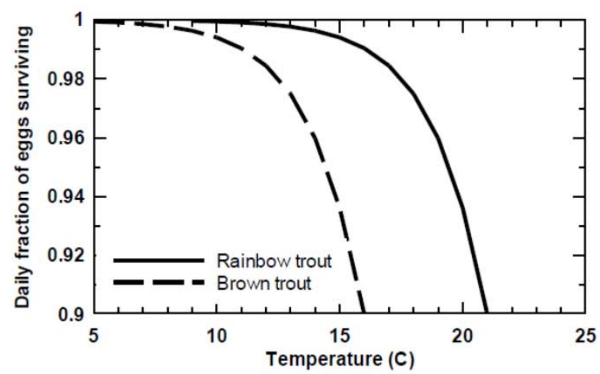


Factors Affecting Growth, Mortality, and Spawning

- Growth
  - Food availability
  - Abundance of larger fish
  - Velocity and depth
  - Turbidity and temperature
  - Fish size
- Mortality
  - Aquatic and terrestrial predation, angling
  - Starvation and disease
  - Stranding
  - High temperature
- Spawning
  - Availability of habitat
  - Extreme high or low temperature
  - Stranding
  - Scouring
  - Superimposition





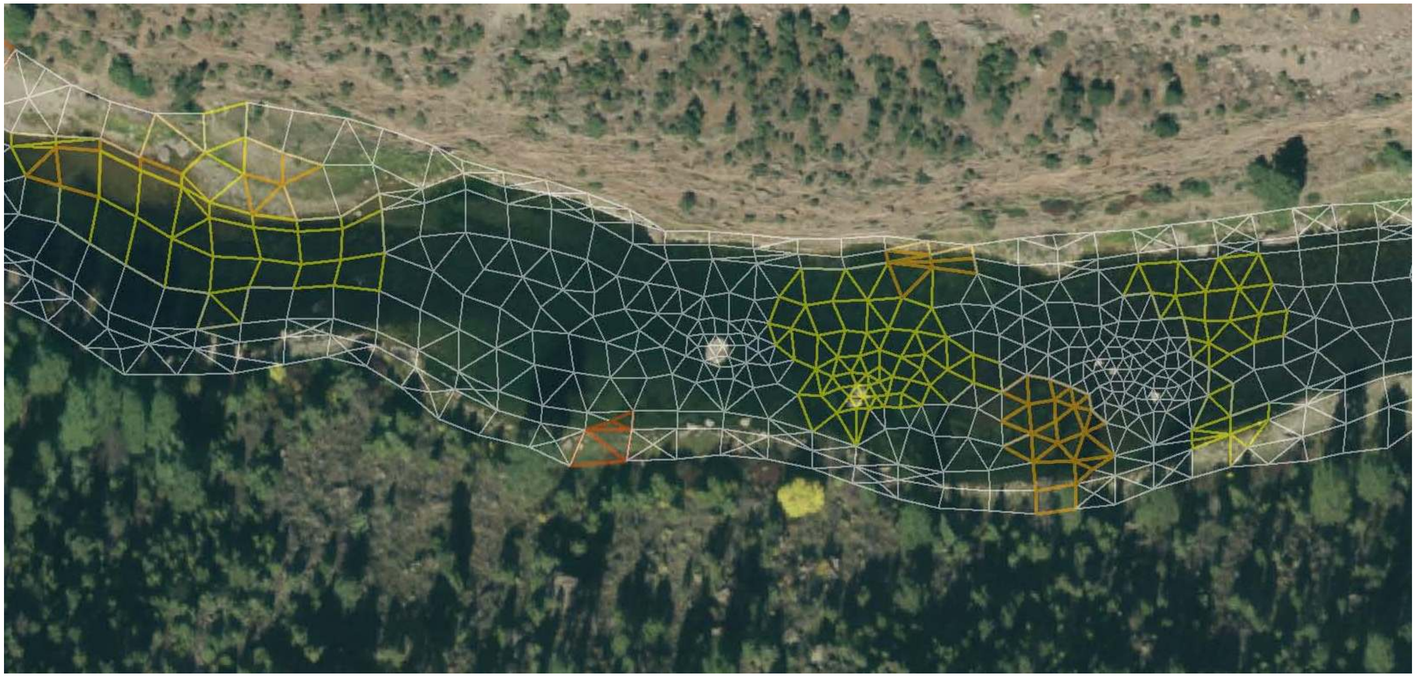


Application of inSTREAM-SD at Flaming Gorge Dam

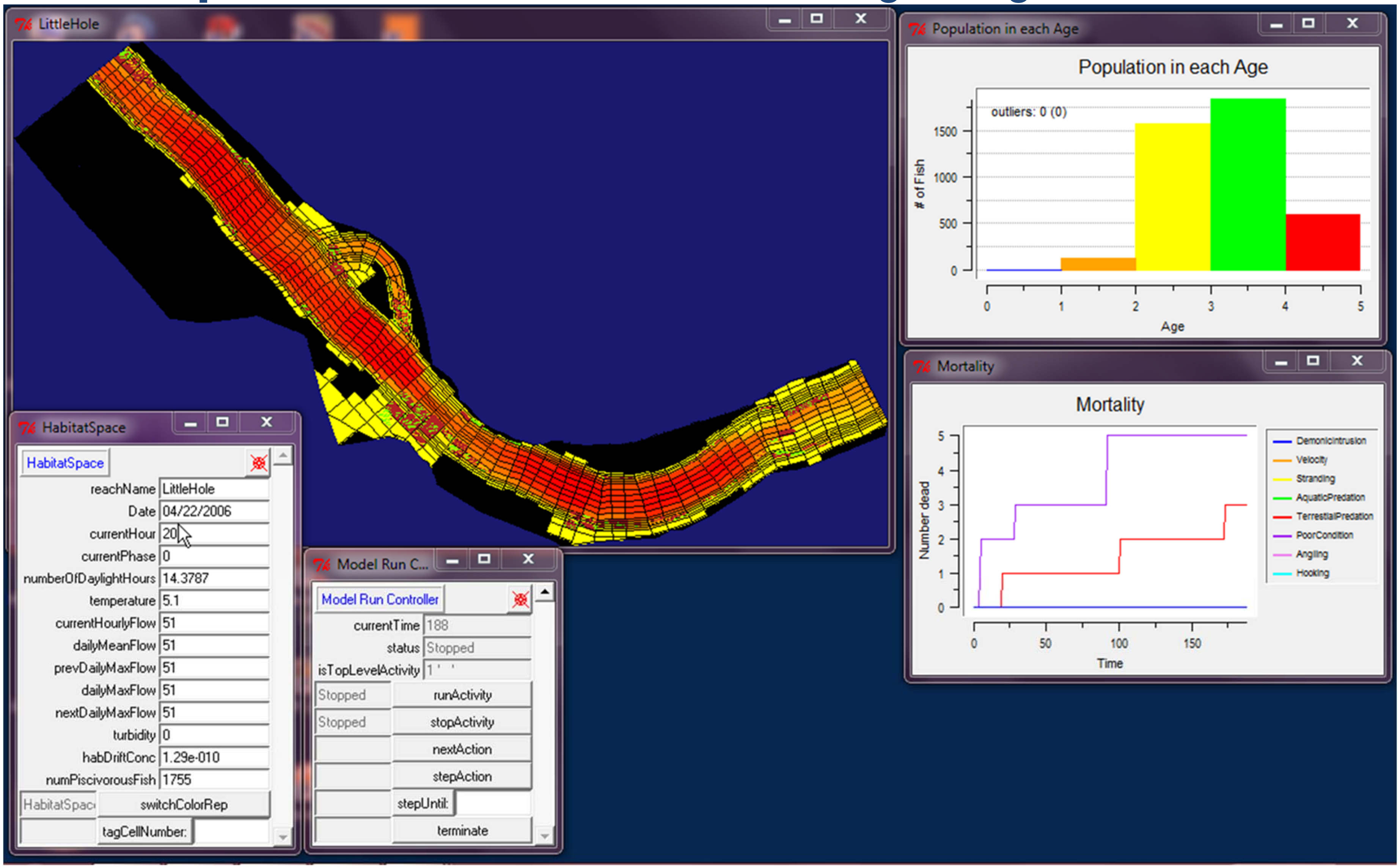
- Originally developed at Flaming Gorge Dam as a tool to address ongoing management issues:
  - What are the effects of fluctuations on trout?
  - What are the effects of winter double-peaking on trout?
  - How do these effects vary according to hydrologic condition?
- www.langrailsback.com/FlamingGorge

Flaming Gorge Model

- Three, 1-km study sites below Flaming Gorge Dam
- Channel morphology data collected using acoustic Doppler
- Study site divided into cells that differ in depth, velocity, and other habitat characteristics important to fish



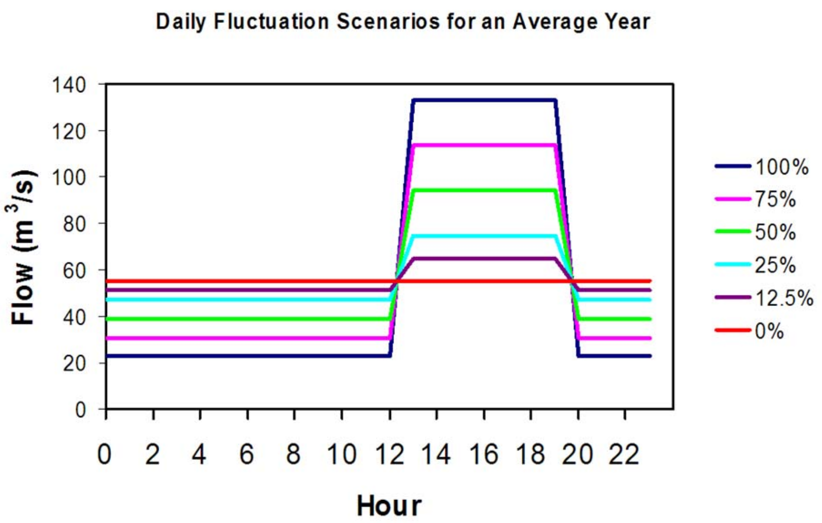
Example Screenshot from Flaming Gorge Model



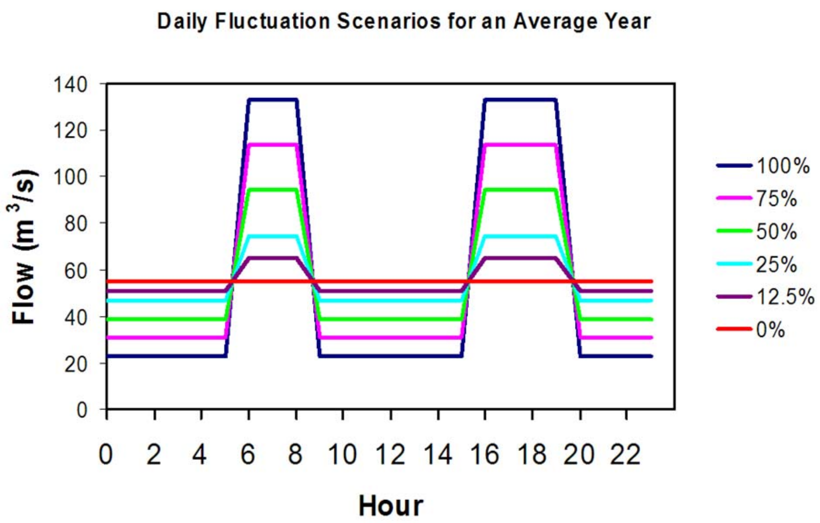
Flaming Gorge Test Scenarios

- Three hydrologic conditions
  - Dry (mean daily flow 34.6 m^3/s, 3 hr on peak)
  - Average (mean daily flow 51.0 m^3/s, 5 hr on peak)
  - Wet (mean daily flow 86.1 m^3/s, 14 hr on peak)
- Six levels of fluctuation: 0, 12.5, 25, 50, 75, 100% of maximum

Single Daily Peak

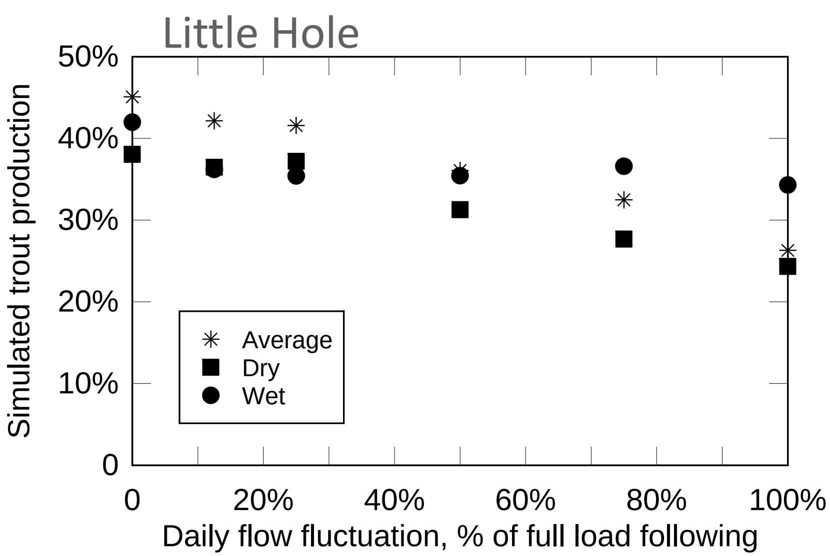


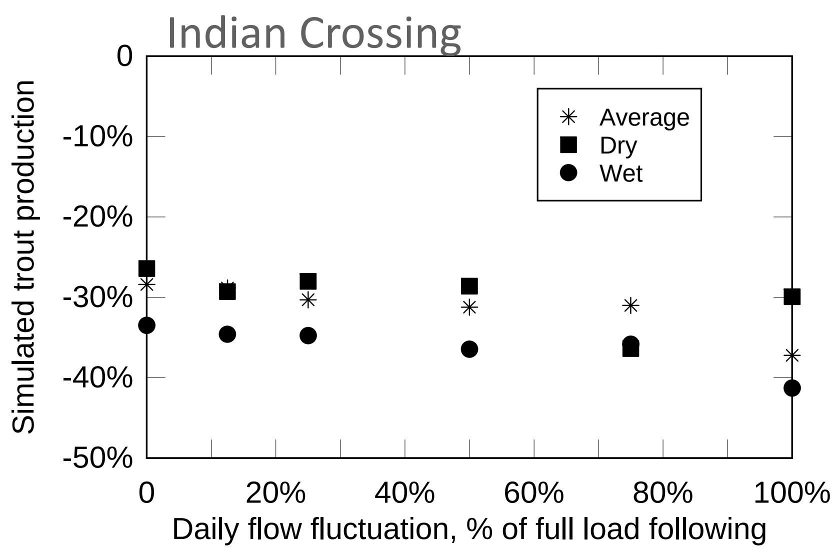
Double Daily Peak



Important Findings of Flaming Gorge Model Simulations—Single-Peak Fluctuation Effects

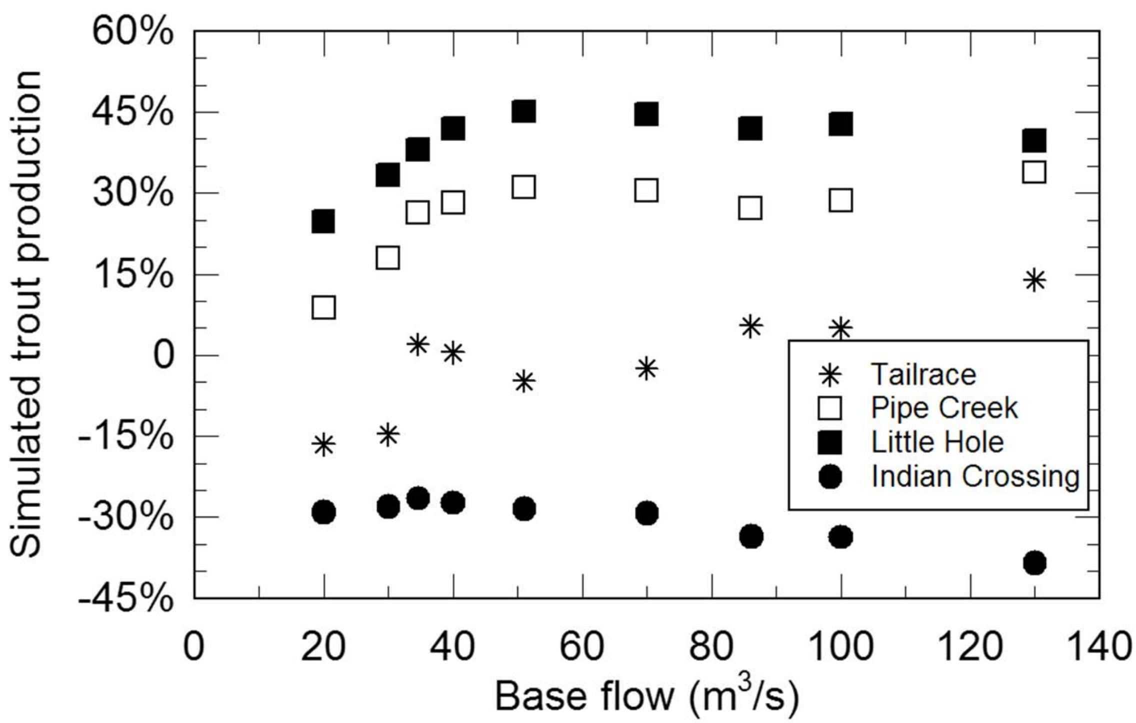
- Effects are site-dependent (e.g., almost no effect at Indian Crossing site)
- Effects are dependent on hydrologic conditions (greater effect in dry years)
- Relatively minor effects until fluctuations reach 50% or more

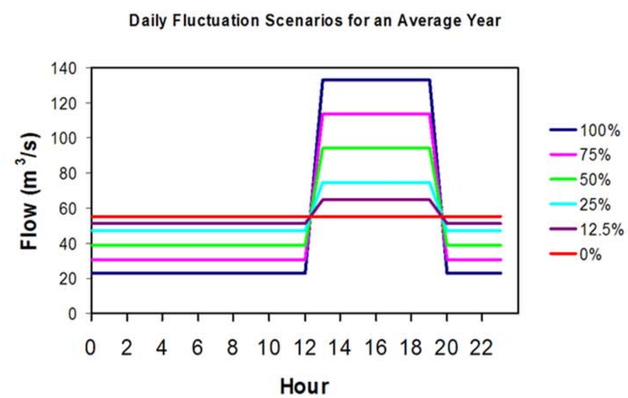




Important Findings of Flaming Gorge Model Simulations—Single-Peak Fluctuation Effects (Cont.)

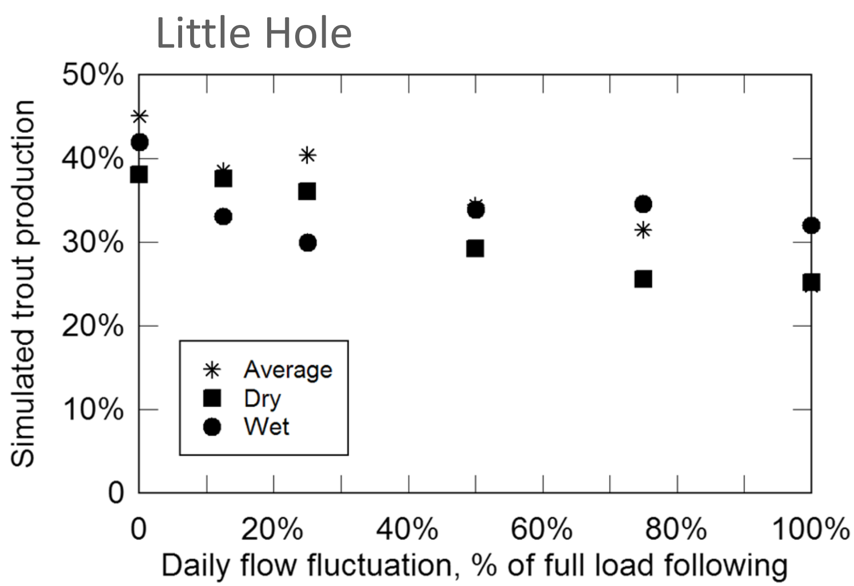
- Predicted effects on production result from:
  - Site-specific differences in habitat availability at low flows and the amount of time flows are in this range
  - Fluctuation effect on feeding

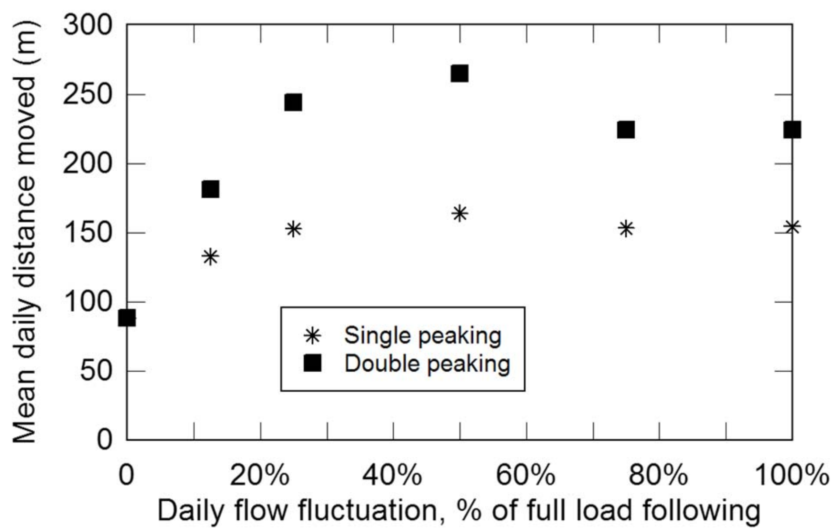




Important Findings of Flaming Gorge Model Simulations—Double-Peak Fluctuation Effects

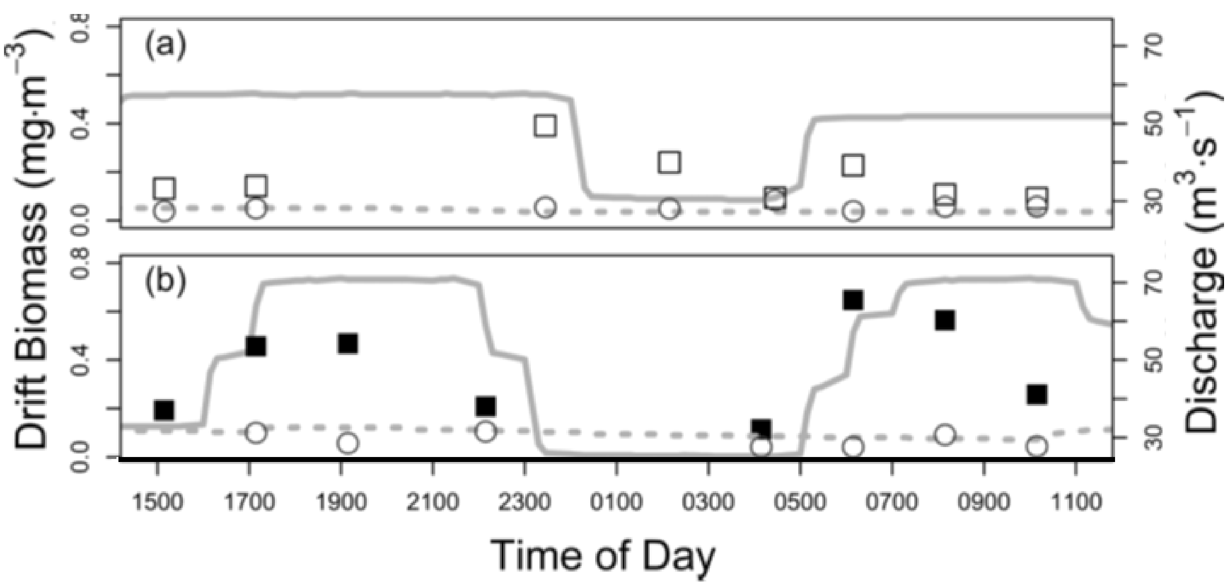
- Results were very similar to those of the single-peak experiment
- Small (about 2%), but consistent decrease in production
- Modeled effect results from feeding disruption and increased movement at time of fluctuation





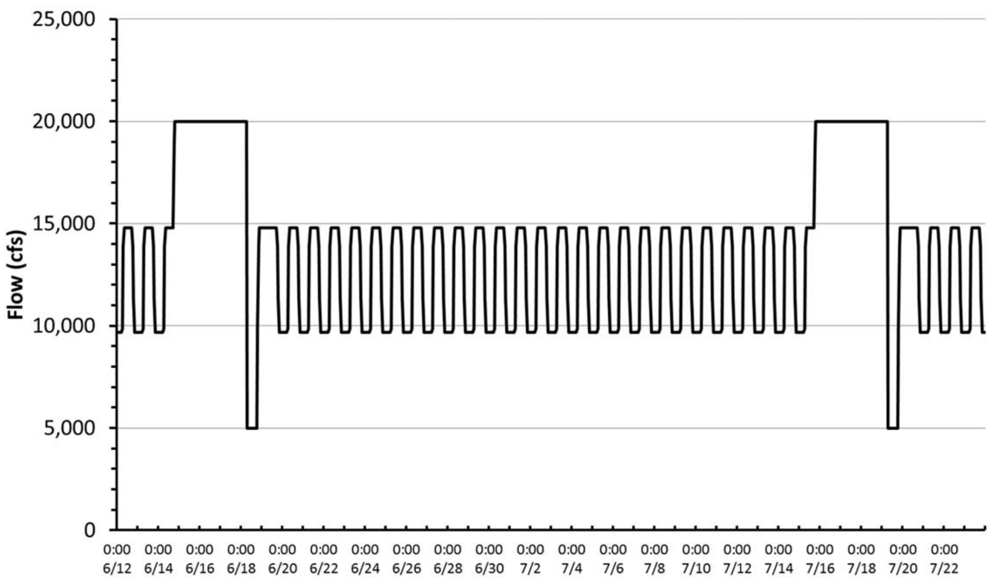
Flaming Gorge Model Simulations—Application to Adaptive Management

- Initial simulations prompted development of a 5-year study plan to:
  - Perform analysis of condition data from 1990-2014 to examine effects of flows on condition
  - Test effects of fluctuation on drift abundance
  - Test effects of fluctuations on foraging behavior and diet
- Results of study were used to change operations and update the model



inSTREAM-SD Could Be Used at Glen Canyon to Evaluate a Number of Important Flow Effects

- Effects of hydropower operations on mortality of eggs and age-0 trout and subsequent effects on adult population characteristics (number, size distributions)
- Effects of trout management flows on mortality of redds and age-0 trout
  - Number and timing of cycles
  - Magnitudes and durations of high flows and low flows
  - Trigger levels



inSTREAM-SD Could Be Used at Glen Canyon to Evaluate a Number of Important Flow Effects (Cont.)

- Effects of equalization flows on trout production
- Effects of low summer and steady flows (e.g., before and after HFEs) on trout production
- Effects of HFEs on trout production
- Understanding factors leading to current population status
  - Sequence of flows
  - Changes in food abundance and quality

Next Steps

- Determine level of interest in application at Glen Canyon
- Can the model be modified for application at the Glen Canyon scale?
- Identify reaches of interest within Glen Canyon
- Assess availability of data
  - Channel geometry and hydraulic modeling
  - Habitat variables (cover, spawning gravel, velocity shelters)
  - Minimum age and length for spawning
  - Range of dates for spawning
  - Length-weight regression parameters
  - Angling pressure
- Identify important modeling questions to be addressed by the model

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