Modeling the Effects of Flow Fluctuations on Trout Below Flaming Gorge Dam

Steve Railsback
Lang, Railsback, and Associates

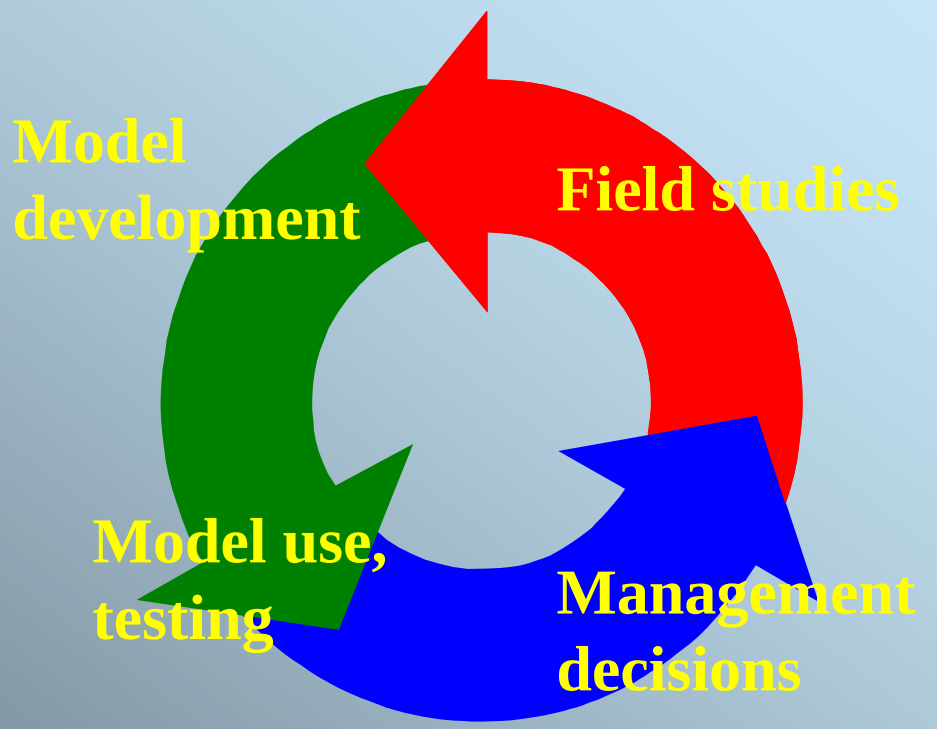
John Hayse and Kirk LaGory
Argonne National Laboratory

Gary Burton
Western Area Power Administration

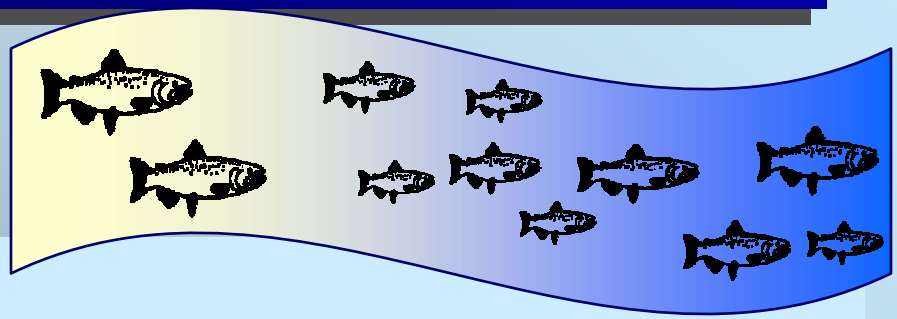
August 25, 2005

Application of Models to Environmental Management

- Models can:
  - Organize what we know (and still need to learn)
  - Identify important processes
  - Suggest field experiments
  - Predict response to management alternatives



What Are Individual-Based Models?



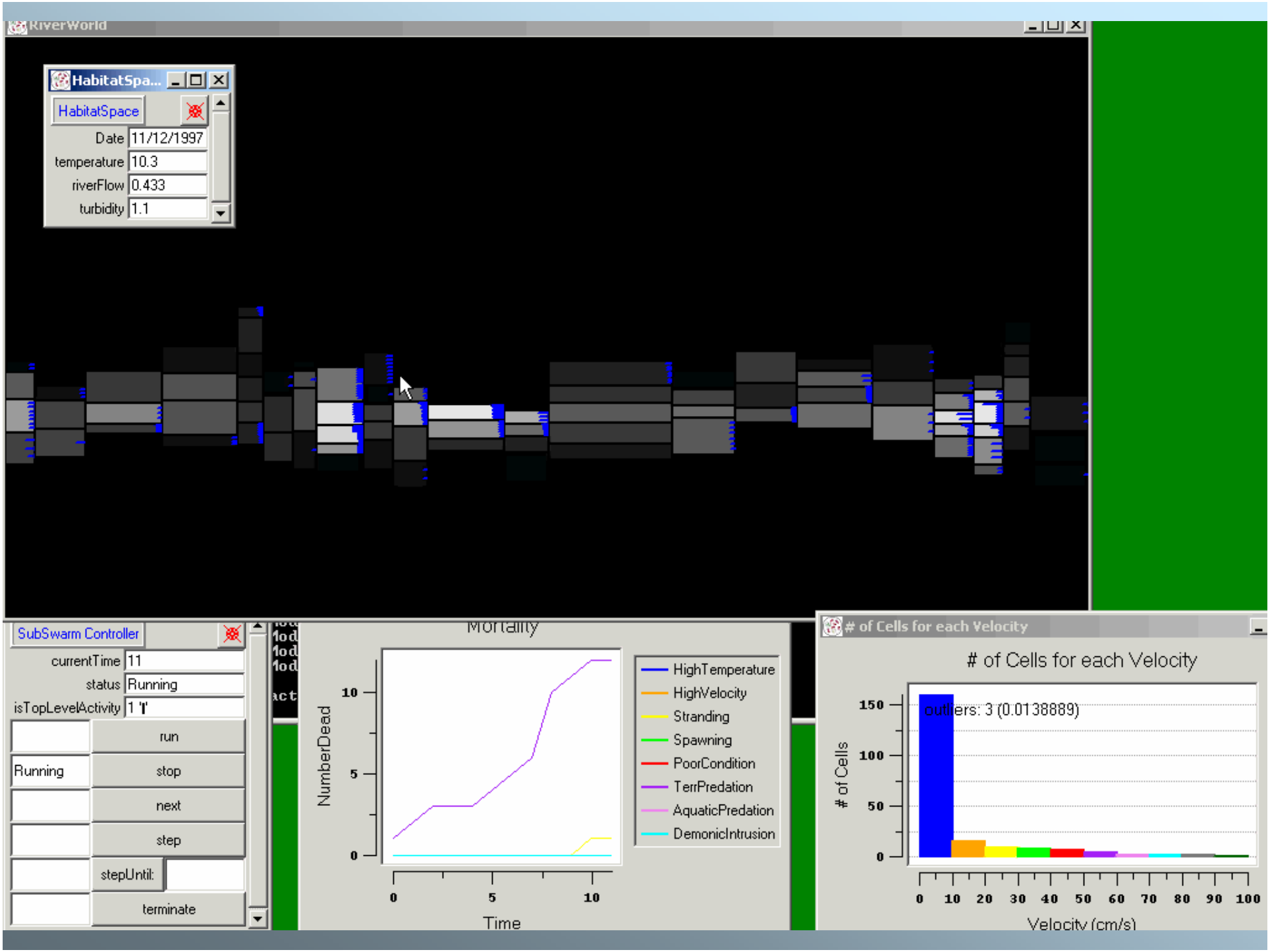
- IBMs simulate:
  - Key traits of *individual organisms*
    - physiology
    - behavior: how they adapt to change
  - The individuals' environment
  - The population dynamics that emerge as individuals interact with the environment and each other

Why Use IBMs for Instream Flow Assessment?

- IBMs let us predict the cumulative, interacting effects of:
  - Flow
  - Temperature
  - Food production
  - Competition and introduced species
  - Channel alteration & habitat restoration
  - etc.

The Green River Trout IBM

- Adapted from a model used since 1999
- Sponsored by: EPRI, US Forest Service, US EPA, others
- Has been applied in 8 other cases in the Western US
- Shown to reproduce a wide range of observed trout behavior at individual & population levels
- 8 publications in peer-reviewed journals on application of the trout IBMs
- More information: `www.humboldt.edu/~ecomodel`


RiverWorld
HabitatSpa...
HabitatSpace
Date 11/12/1997
temperature 10.3
riverFlow 0.433
turbidity 1.1
SubSwarm Controller
currentTime 11
status Running
isTopLevelActivity 1 't'
run
Running
stop
next
step
stepUntil:
terminate
Mortality
NumberDead
Time
HighTemperature
HighVelocity
Stranding
Spawning
PoorCondition
TerrPredation
AquaticPredation
DemonicIntrusion
# of Cells for each Velocity
outliers: 3 (0.0138889)
# of Cells
Velocity (cm/s)

Model Trout Do Four Things at Each Time Step

- Decide which habitat cell to occupy
- Decide whether to feed or hide
  - tradeoff between growth and mortality risk
  - decision made when flow changes by >10%; at dawn and dusk
- Feed and grow
  - rate is affected by velocity, depth, temperature, time of day
  - rate is limited by food production, competition
- Die (predation, starvation, …)
  - probability is affected by depth, velocity, hiding cover, fish size, body condition, time of day

Questions Addressed by the Model

1. How does the magnitude of daily flow fluctuations affect production of trout in the Flaming Gorge tailwater?
2. What are the relative effects of “double-peaking” (two load-following cycles per day) and single-peaking on trout production?

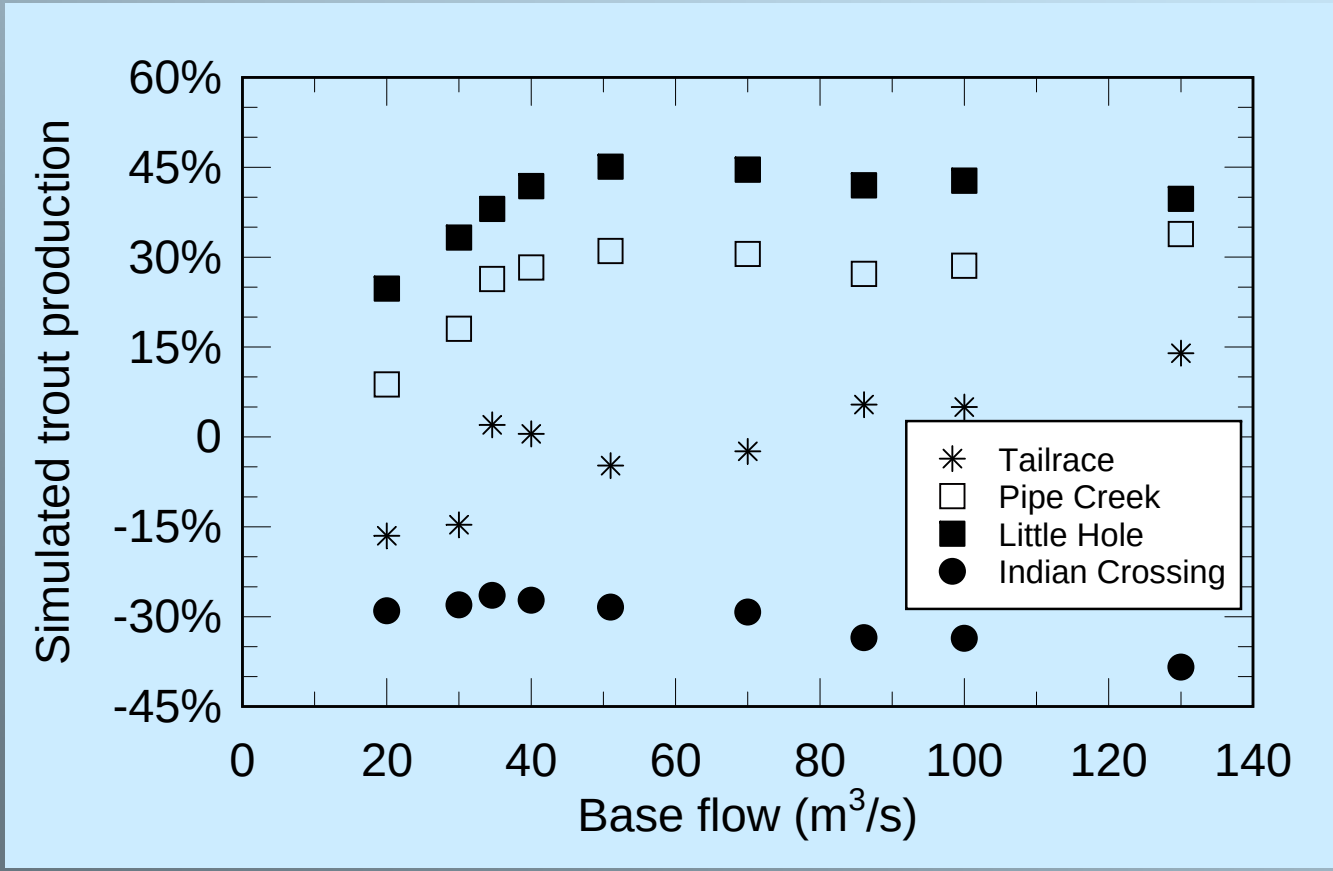
Trout Analysis Scope

- Four study sites: Tailrace to Indian Crossing
- One-year simulations
- Output = % change in population biomass
- Simplifications:
  - All trout treated as one species
  - No migration among sites
  - Spawning ignored (stocking was included)
  - Angling mortality ignored

Modeled Sites

Site	Site Length (m)	Distance downstream from Dam (km)	Number of transects in PHABSIM model
Indian Crossing	494	26	6
Little Hole	404	12	6
Pipe Creek	482	6	10
Tailrace	204	0.5	6

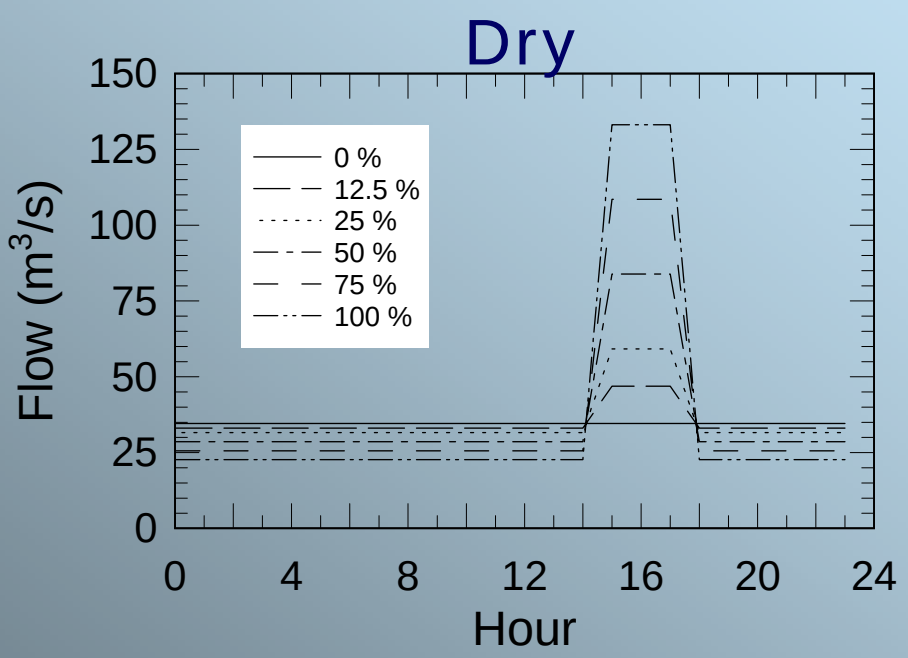
Trout Production: Differences Among Sites at Steady Flow

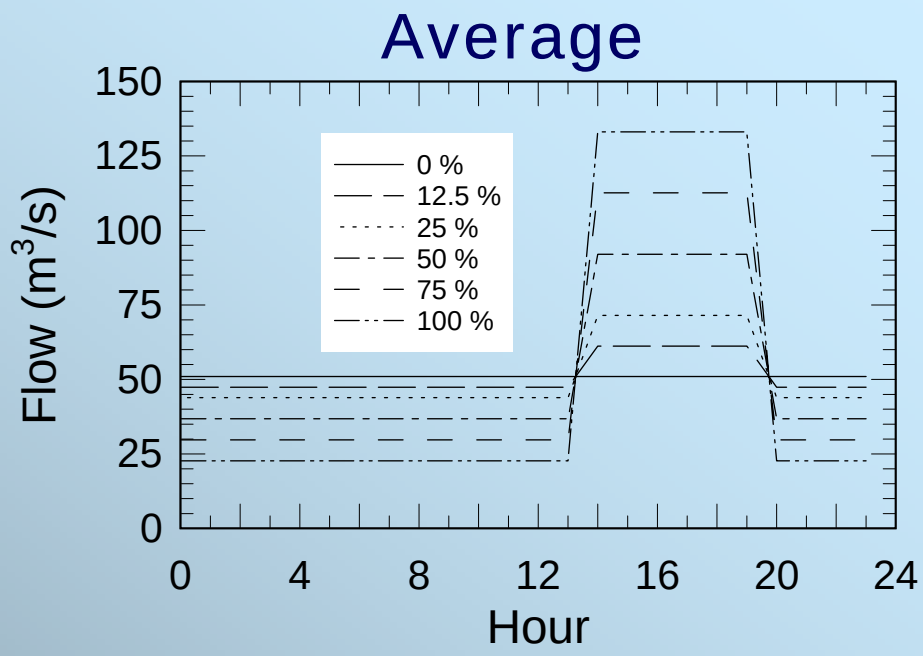


Question 1: How Does Trout Production Vary with Fluctuation Magnitude?

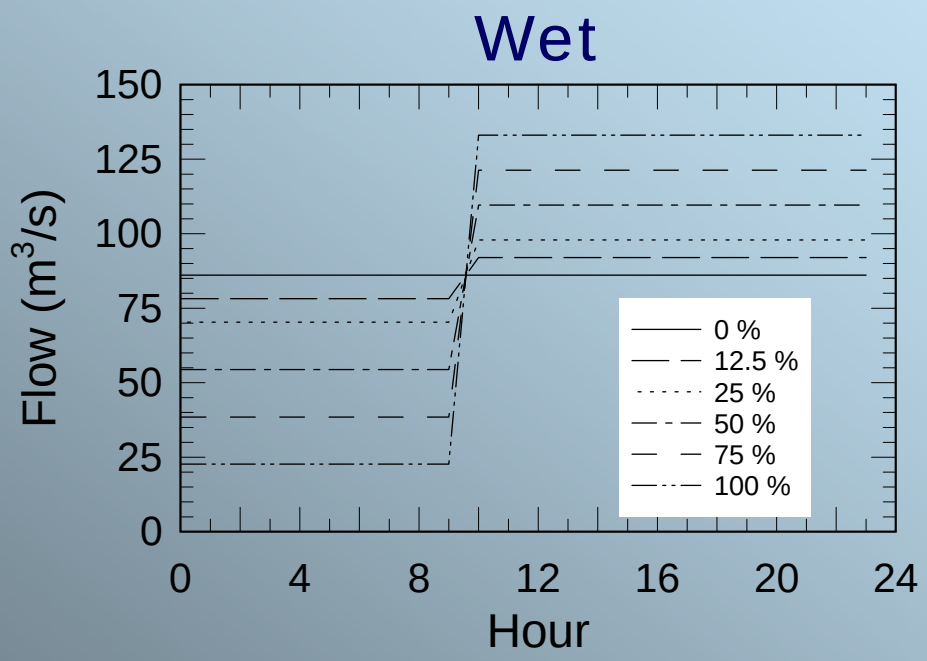
Flow Fluctuation Scenarios

Hydrologic Condition	Daily Mean Flow (m^3/s)	Hours on-peak
Dry	34.6 (1200 cfs)	3
Average	51.0 (1800 cfs)	6
Wet	86.1 (3000 cfs)	14

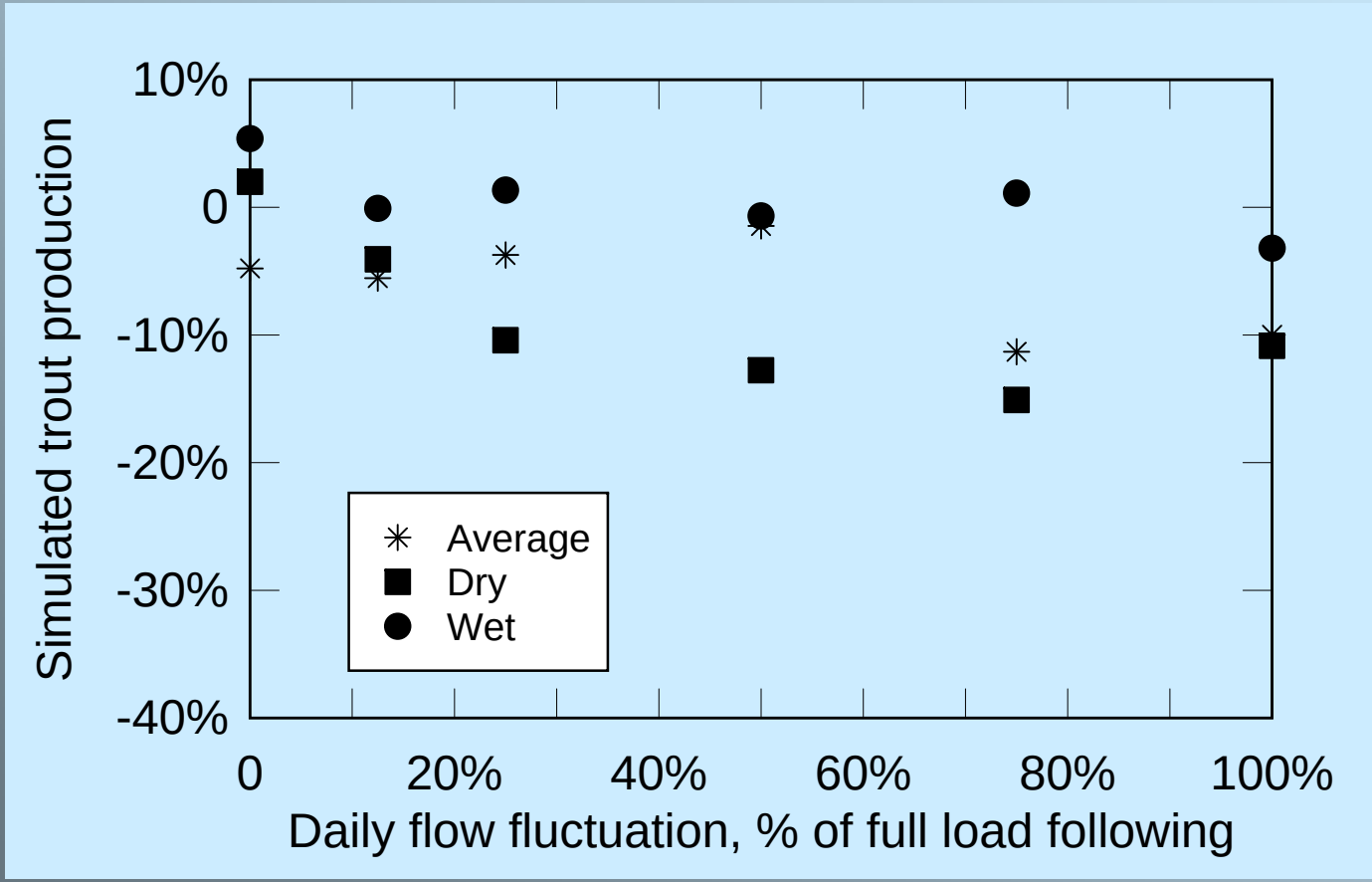




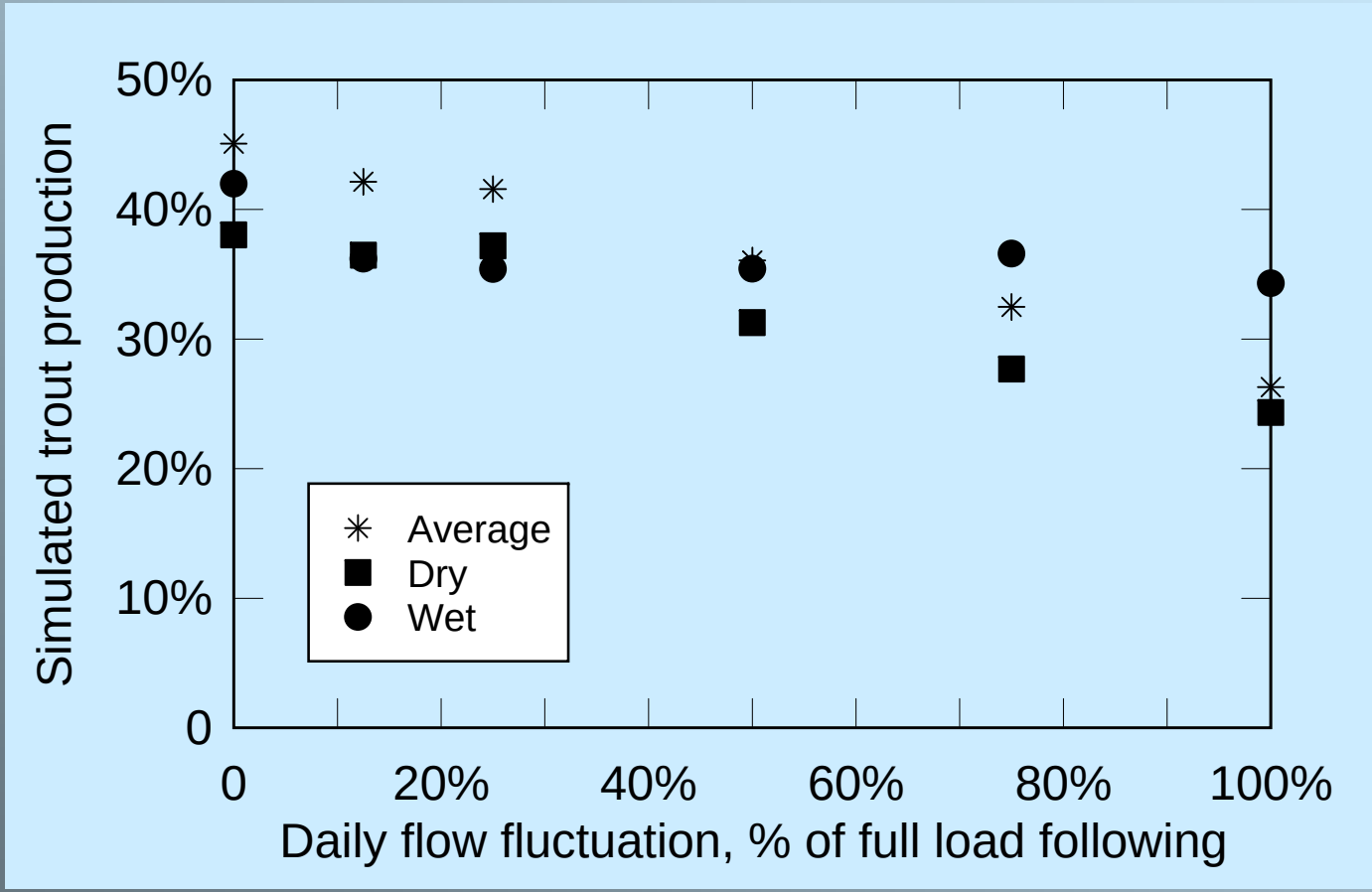
Hydrologic Condition	Daily mean flow (m^3/s)	Hours on-Peak
Dry	34.6	3
Average	51.0	6
Wet	86.1	14



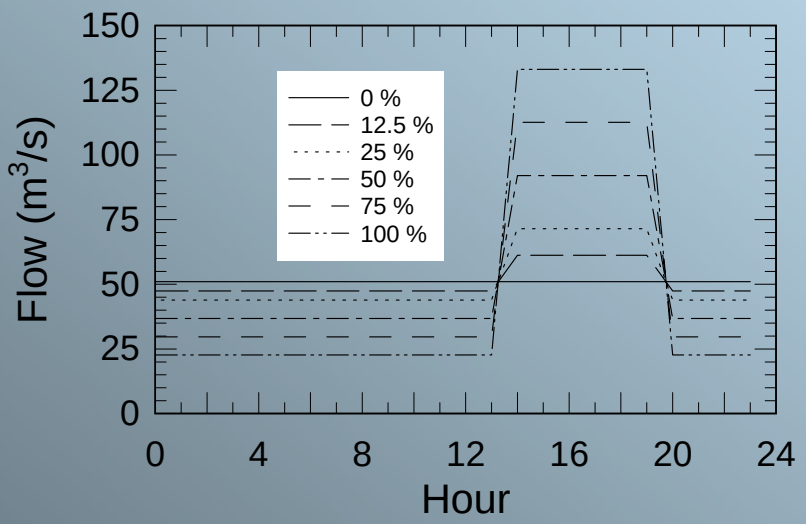
Flow Fluctuation Results: Tailrace



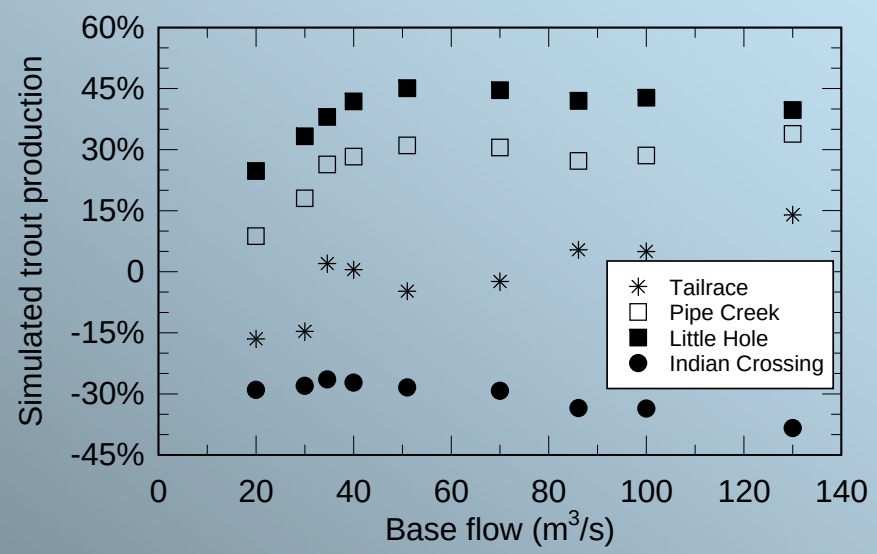
Flow Fluctuation Results: Little Hole



Flow Fluctuation Results: What's Going On?



Daily Hydrograph



Steady Flow Results

Flow Fluctuation Effects Are Dominated by Base Flow Habitat Quality

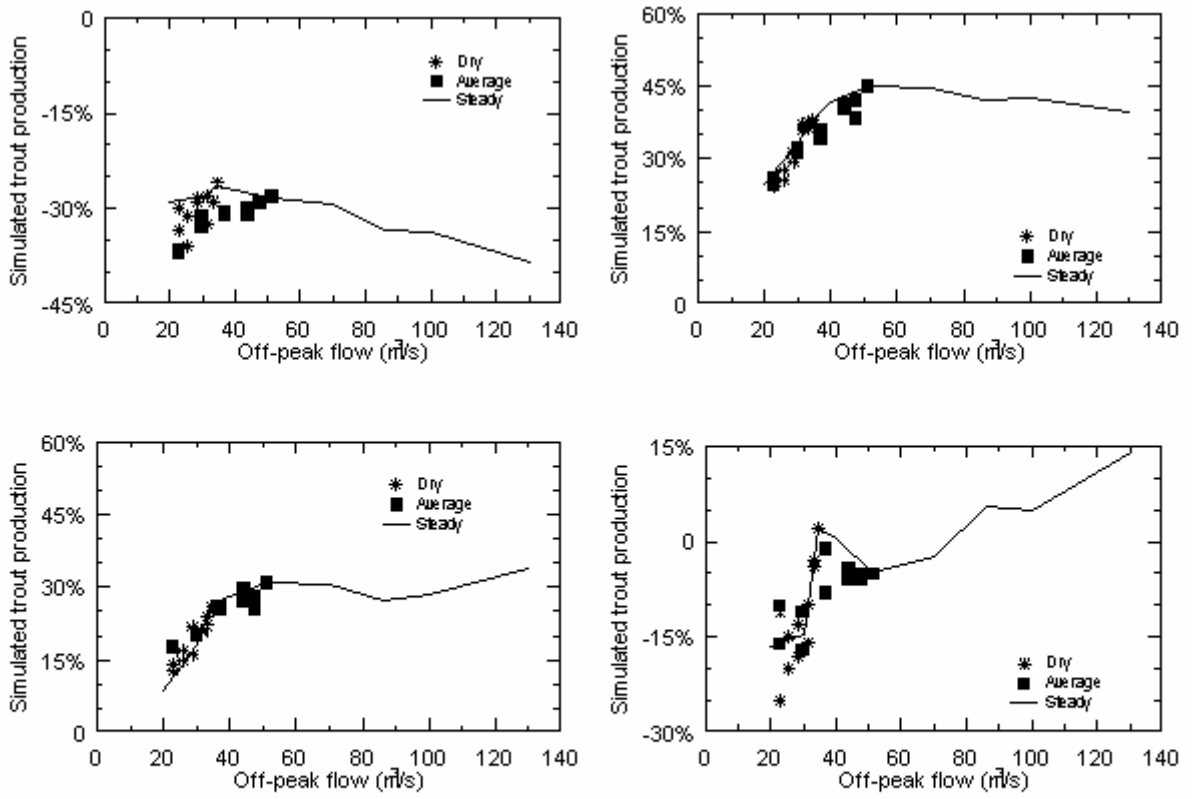
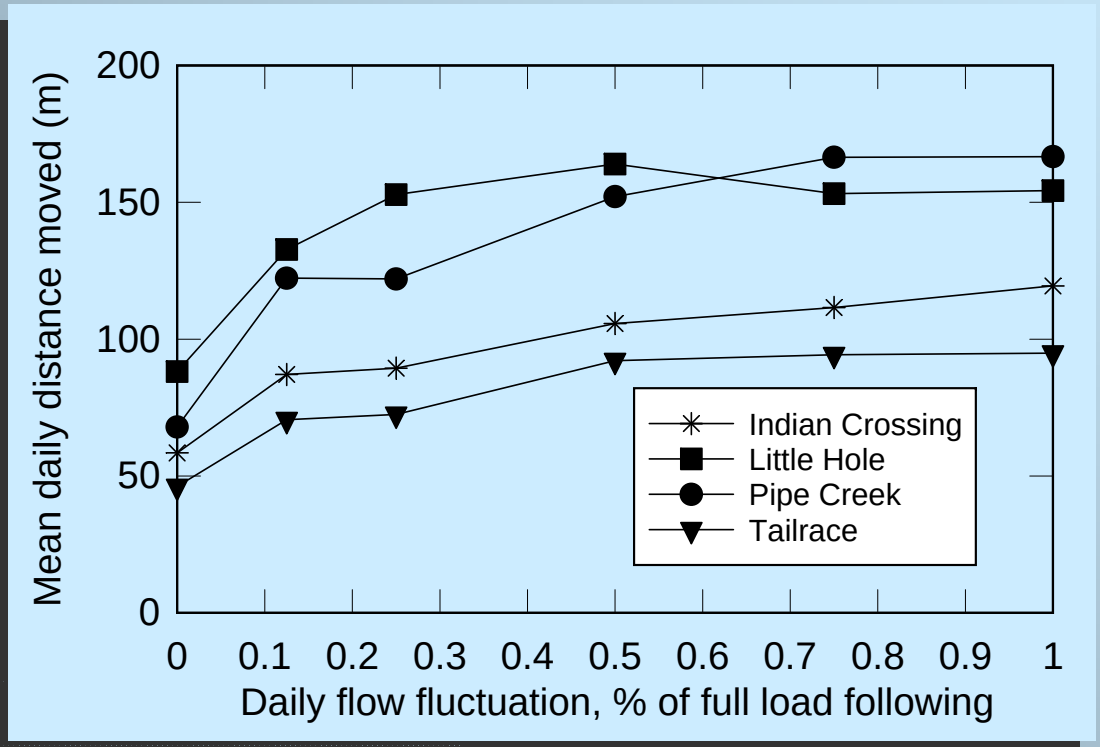


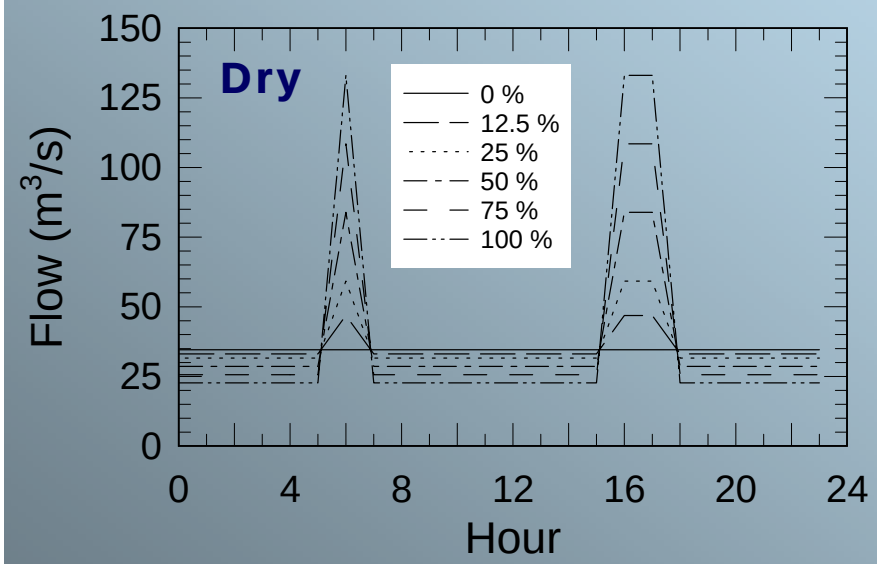
Figure 37. Simulated trout production vs. off-peak flow, for dry, average, and steady flow scenarios. From left to right, top to bottom: Indian Crossing, Little Hole, Pipe Creek, and Tailrace sites.

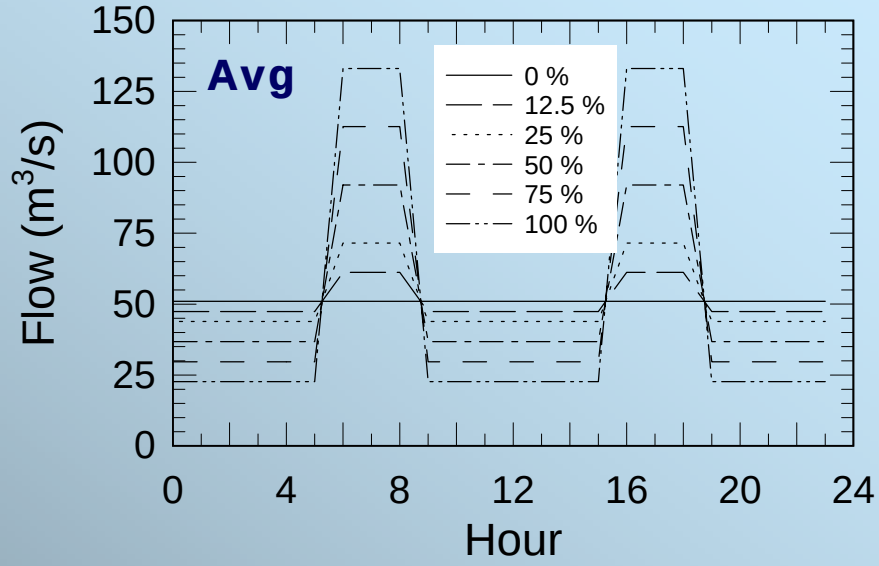
Flow Fluctuation Effects on Trout Movement

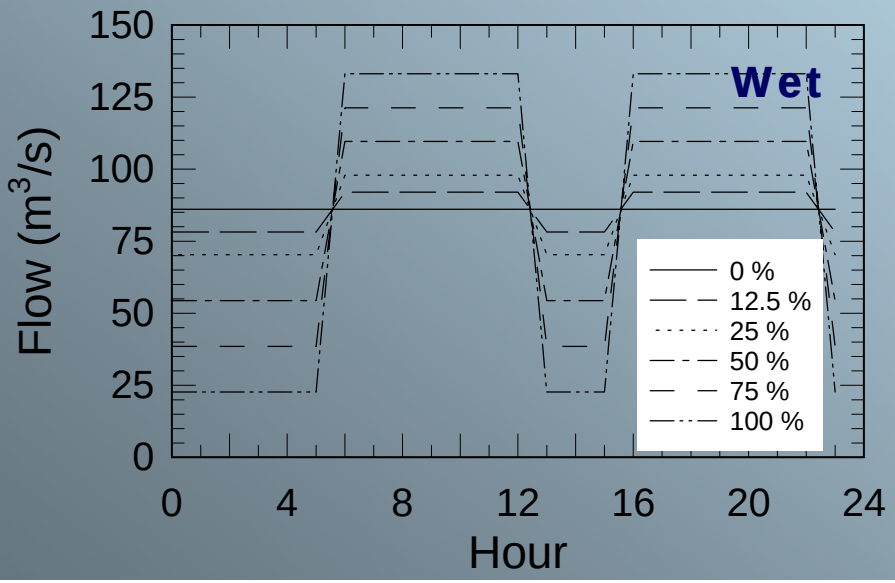


- In all cases, simulated trout moved less than 200 m per day
- A typical (40 cm) trout foraging at half its maximum sustainable swim speed would swim this distance in less than 7 minutes.

Question 2: Is there a Difference between the Effect of Double- and Single-peaking on Trout Production?

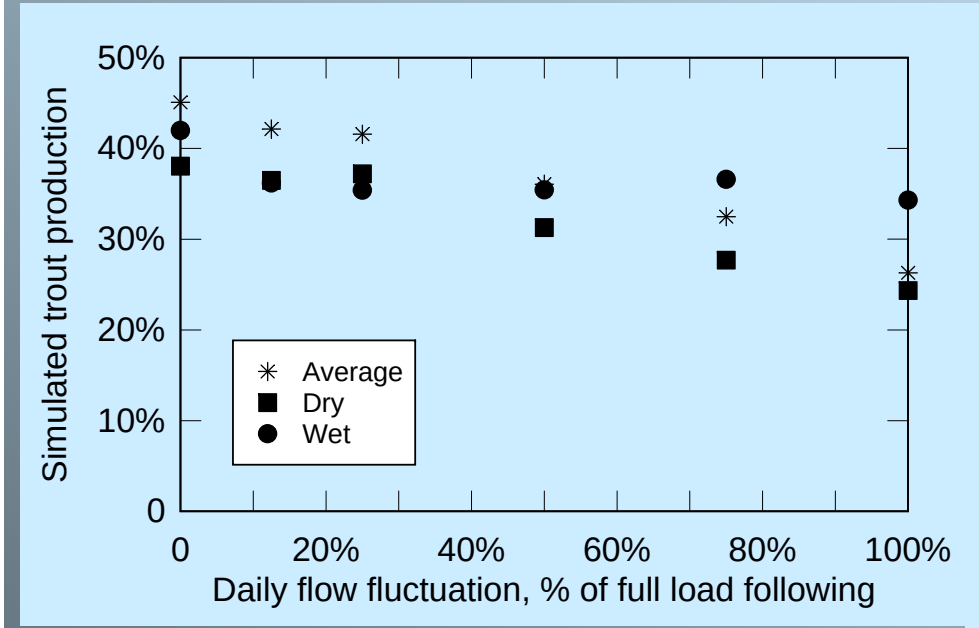




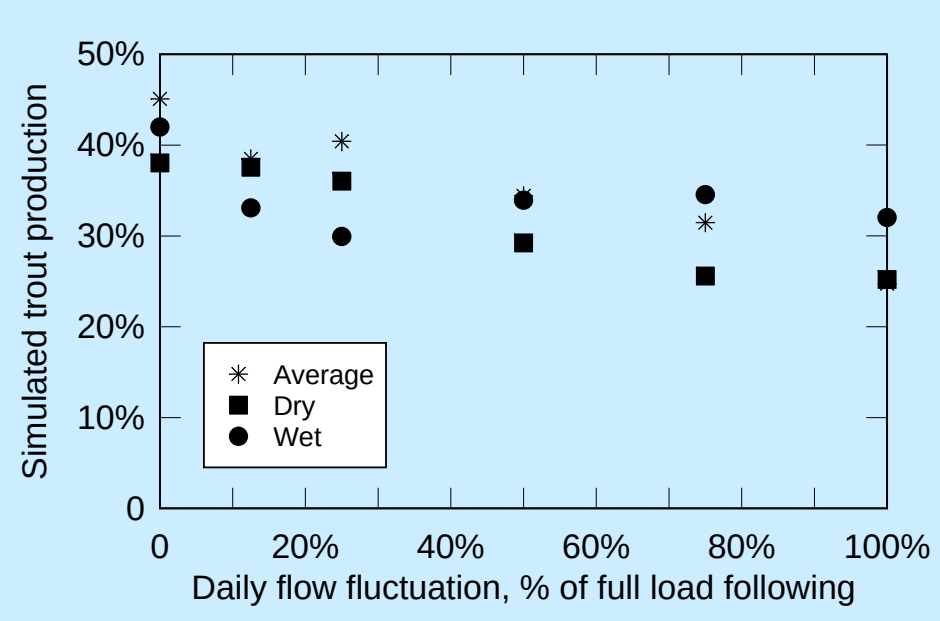


Double- vs. Single-peaking: Production at Little Hole

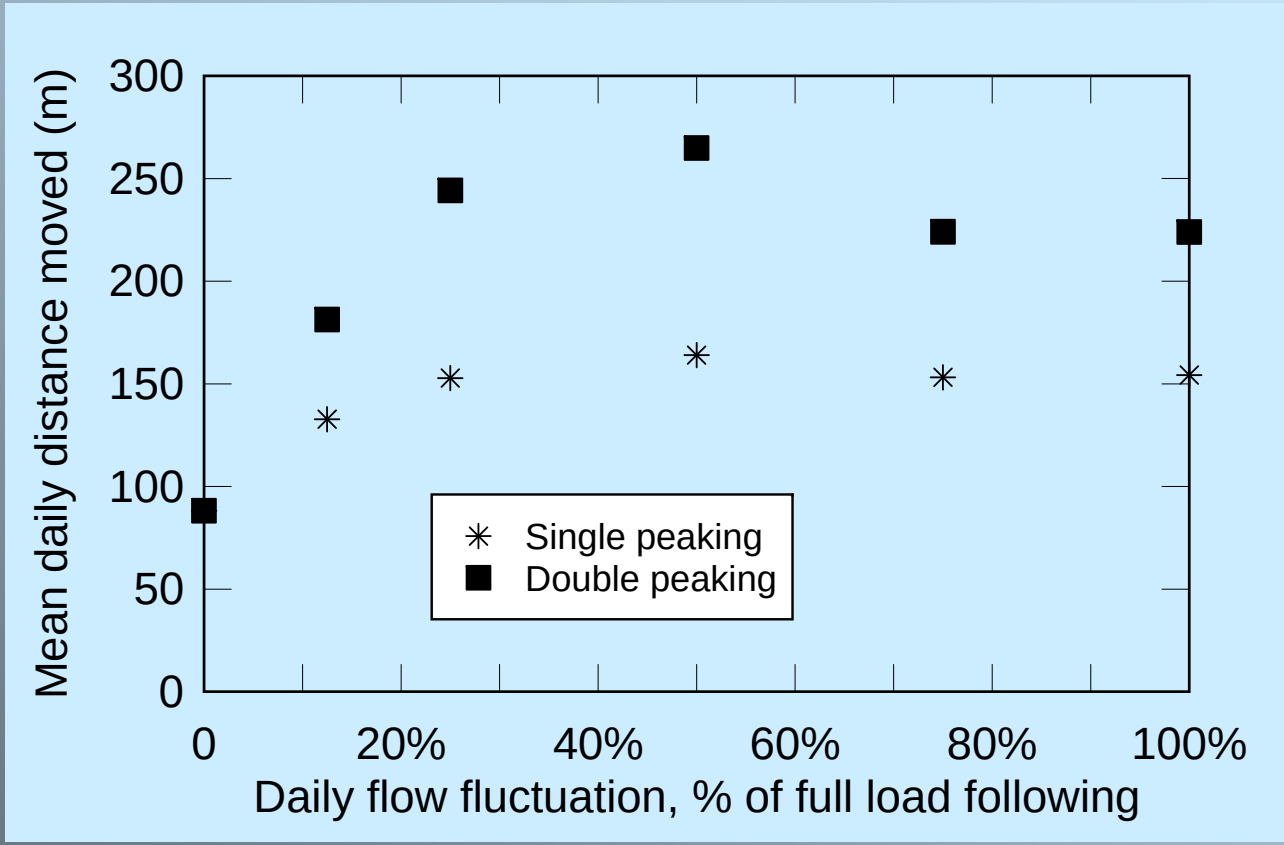
Single Peaks



Double Peaks



Double- vs. Single-Peaking: Movement at Little Hole

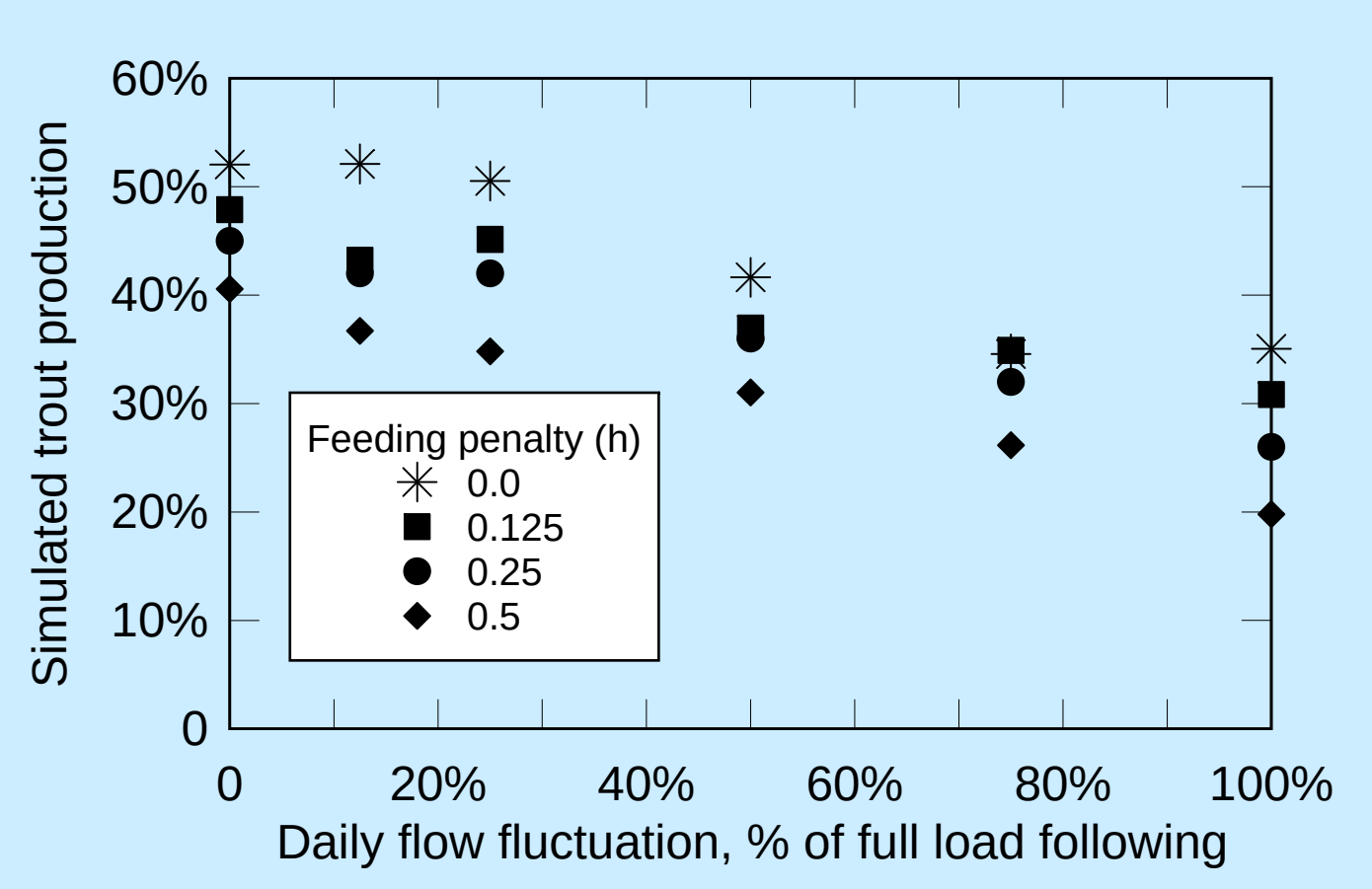


Double- vs. Single-Peaking: Conclusions

- There was a consistent but small (approx 2%) decrease in simulated trout production for double-peaking
- Effect was related to the assigned feeding penalty for movement
- Overall effects of fluctuations were still dominated by changes in base flow

Effect of Feeding Penalty

(Sensitivity of simulated trout production to feeding penalty parameter value, Little Hole site, average year)



Conclusions

- Model results suggest that the effects of fluctuations are relatively small at moderate levels of fluctuation (40 to 50%)
- Double-peaking has a modest incremental effect (about 2%) on trout production as compared to single peaks
- Fluctuation effects are dependent on hydrologic conditions (effects more pronounced under dry conditions)
- Effects are very site specific and depend on habitat availability at different flows

What Next?

- Other evaluations
  - Effects of ramping rates
  - Effects of other flow scenarios
- Field studies
  - Test model predictions (e.g., effects on feeding behavior and movement)
  - Determine the effects of flow fluctuation on food production and drift rates
- Application to other study sites in Green River and elsewhere