# Individual-based Fish Models for Regional Decision Making

Rollie Lamberson

Steve Railsback

*Department of Mathematics*

*Humboldt State University*

www.humboldt.edu/~ecomodel

# Overview

- Why (or why not) individual-based models?

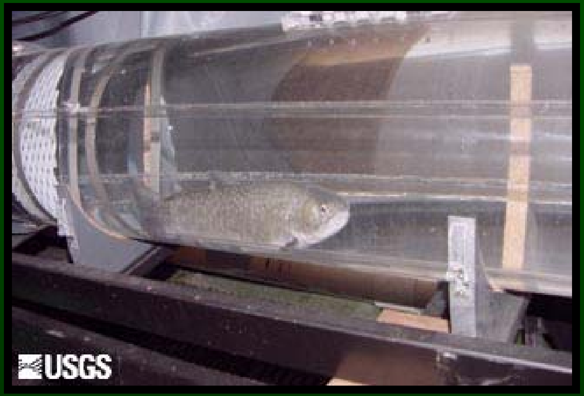
- *inSTREAM*: the individual-based stream trout research and assessment model
  - Description
  - Research progress

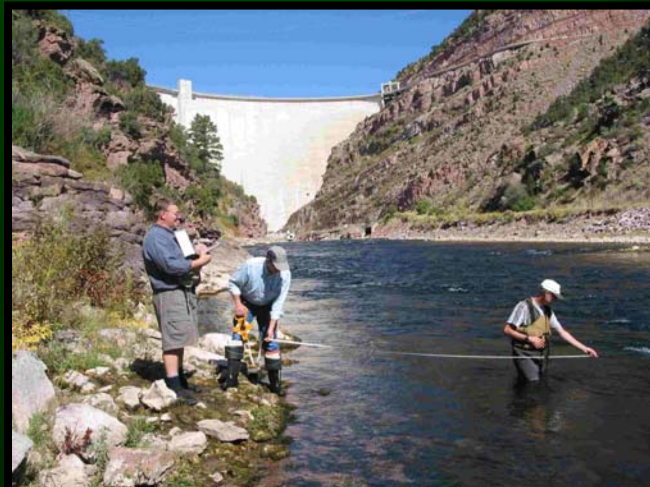
# Why IBMs for environmental management?

- Complex population/community responses to multiple stressors can *emerge* from simple models of:
  - Individual organisms
    - Physiology
    - Key behaviors

# Why IBMs for environmental management?

- Many kinds of information can be used to build and test models



# Why IBMs for environmental management?

- Many kinds of information can be used to build and test models
- Uncertainty does not always increase with model complexity

# Why IBMs for environmental management?

- Many kinds of information can be used to build and test models
- Uncertainty does not always increase with model complexity
- Models can be complex enough to address real management issues without requiring huge data sets for calibration

# Some limitations of IBMs

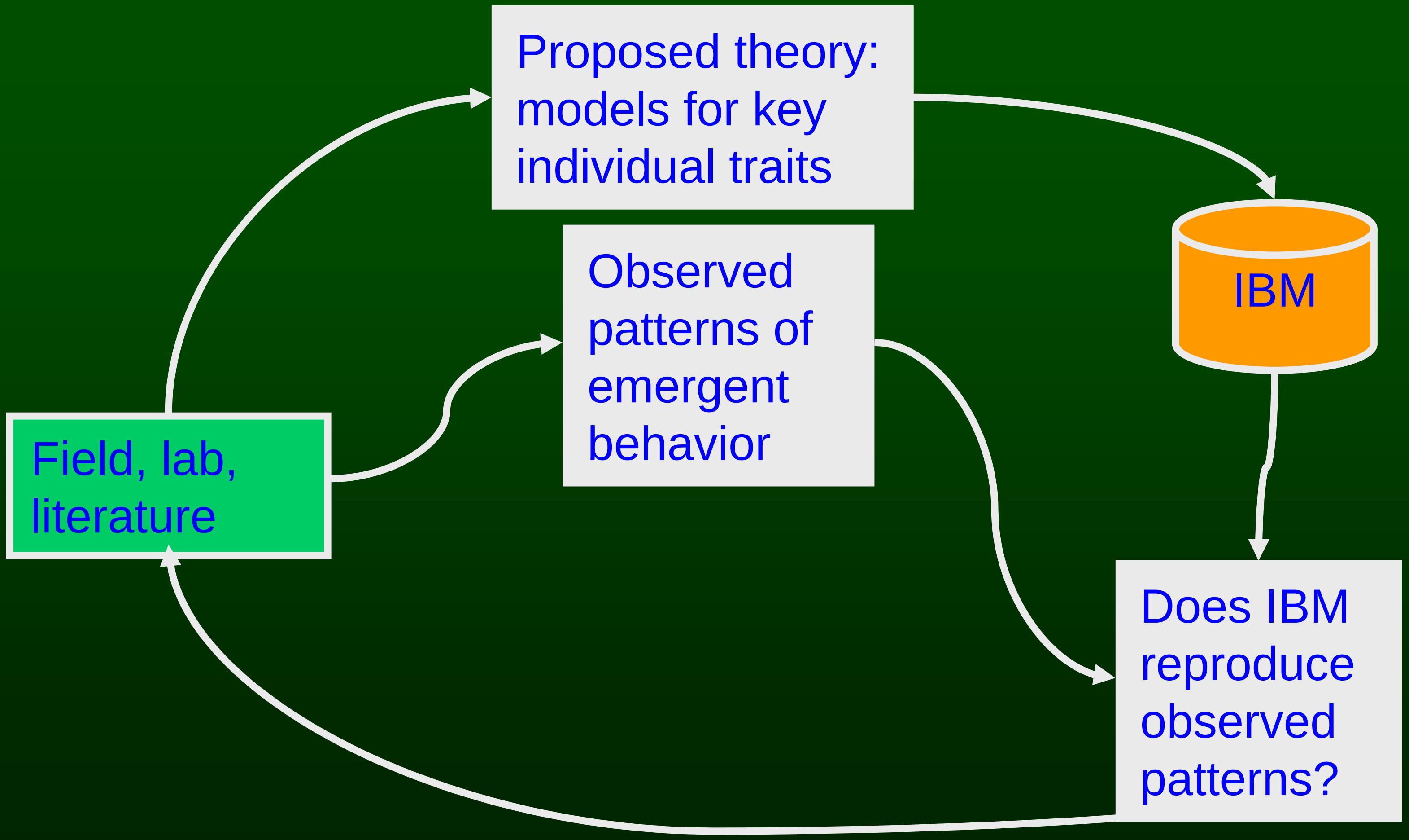
- A lot of knowledge about the organisms and system must be assimilated
- Software development and testing can be a major task
- The approach is new; lacks established theory
- Extensive model analysis is necessary

# What we're doing to advance the use of IBMs (1) Software

- EcoSwarm: extensions of Swarm for environmental modeling
- Identifying software R&D priorities

# Advancing the use of IBMs (2): Theory

*= models of individual behaviors that explain population-level phenomena*



# Developing Theory for IBMs: Examples

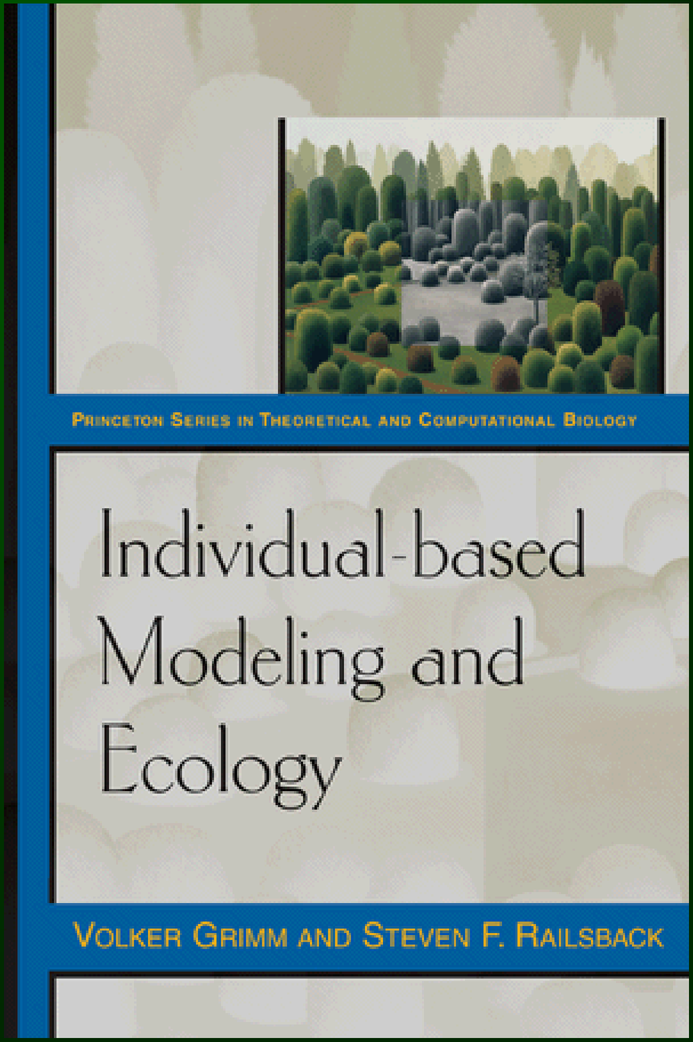
- How do trout select microhabitat?
  - Railsback, S. F., and B. C. Harvey. 2002. Analysis of habitat selection rules using an individual-based model. *Ecology* **83**:1817-1830.
- How do trout decide whether to feed vs. hide, during day vs. night?
  - Railsback, S. F., B. C. Harvey, J. W. Hayse, and K. E. LaGory. 2005. Tests of theory for diel variation in salmonid feeding activity and habitat use. *Ecology* **86**:947-959.
- (A review)
  - Grimm, V., et al. Pattern-oriented modeling of agent-based complex systems: lessons from ecology. *Science*, in press.

# Advancing the use of IBMs (3) Instruction

- Math 697 at HSU
- Workshop at the 2005 RMA World Conference
- 1-week workshop at Univ. Helsinki, Sept. 2005

# Advancing the use of IBMs (4)
# The Book

- Grimm & Railsback 2005, Princeton Univ. Press



# The Individual-based Stream Trout Research and Environmental Assessment Model (*inSTREAM*)

- Objective:
  - Understand and predict how river management actions affect salmonid populations

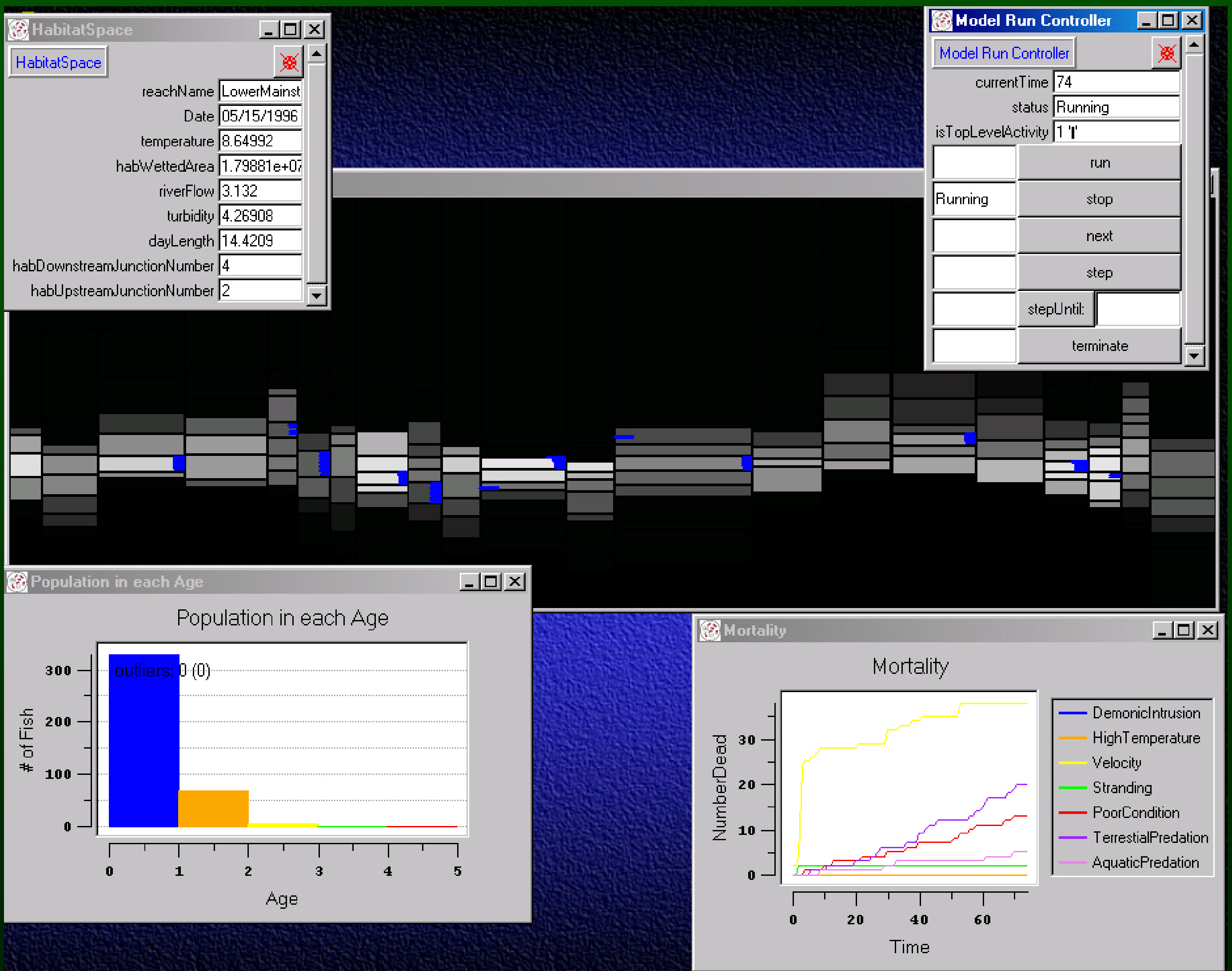
# *inSTREAM*: Approach

- Model how population status
  *(abundance, production, persistence ... )*

  emerges from environment
  *(flow, temperature, turbidity, channel shape... )*

  and biological processes
  *(physiology, competition, adaptive behavior ...)*

# Demo

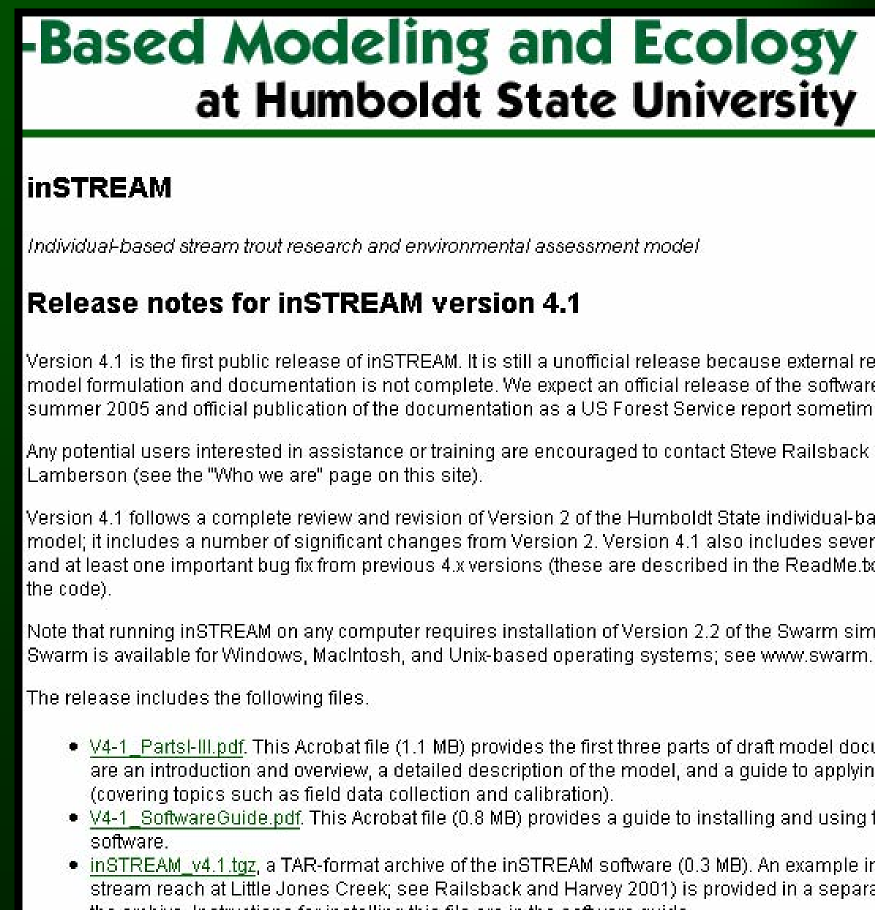

HabitatSpace
reachName LowerMainst
Date 05/15/1996
temperature 8.64992
habWettedArea 1.79881e+07
riverFlow 3.132
turbidity 4.26908
dayLength 14.4209
habDownstreamJunctionNumber 4
habUpstreamJunctionNumber 2
Model Run Controller
currentTime 74
status Running
isTopLevelActivity 1 '1'
run
Running
stop
next
step
stepUntil:
terminate
Population in each Age
outliers: 0 (0)
# of Fish
0
100
200
300
0
1
2
3
4
5
Age
Mortality
NumberDead
0
10
20
30
0
20
40
60
Time
DemonicIntrusion
HighTemperature
Velocity
Stranding
PoorCondition
TerestialPredation
AquaticPredation

# 2005 Progress Update

- STAR Grant Tasks
  - Develop methods for regional analysis
  - Conduct demonstration assessment
  - Analyze uncertainty and sensitivity

# Progress (1): Public Release of *inSTREAM*

- Preliminary release, May 2005
  - Software
  - Documentation


-Based Modeling and Ecology
at Humboldt State University

**inSTREAM**

*Individual-based stream trout research and environmental assessment model*

**Release notes for inSTREAM version 4.1**

Version 4.1 is the first public release of inSTREAM. It is still a unofficial release because external re
model formulation and documentation is not complete. We expect an official release of the software
summer 2005 and official publication of the documentation as a US Forest Service report sometim

Any potential users interested in assistance or training are encouraged to contact Steve Railsback
Lamberson (see the "Who we are" page on this site).

Version 4.1 follows a complete review and revision of Version 2 of the Humboldt State individual-ba
model; it includes a number of significant changes from Version 2. Version 4.1 also includes sever
and at least one important bug fix from previous 4.x versions (these are described in the ReadMe.tx
the code).

Note that running inSTREAM on any computer requires installation of Version 2.2 of the Swarm sim
Swarm is available for Windows, MacIntosh, and Unix-based operating systems; see www.swarm.

The release includes the following files.

- V4-1_PartsI-III.pdf. This Acrobat file (1.1 MB) provides the first three parts of draft model docu
are an introduction and overview, a detailed description of the model, and a guide to applyin
(covering topics such as field data collection and calibration).
- V4-1_SoftwareGuide.pdf. This Acrobat file (0.8 MB) provides a guide to installing and using t
software.
- inSTREAM_v4.1.tgz, a TAR-format archive of the inSTREAM software (0.3 MB). An example ir
stream reach at Little Jones Creek; see Railsback and Harvey 2001) is provided in a separa

- Final release as Forest Service report, 2006

# July 2005 Training Class

- Researchers from:
  - Federal & state agencies
  - Colleges
  - Consulting firm

# Progress (2): Uncertainty and Sensitivity Analysis

(MS thesis, P. Cunningham)

- Traditional approaches for analyzing parameter interaction are infeasible:
  - Many parameters
  - Long execution times
  - Stochasticity may mask (or exaggerate) parameter sensitivity
  - Sensitivity of *what*? The model produces many outputs

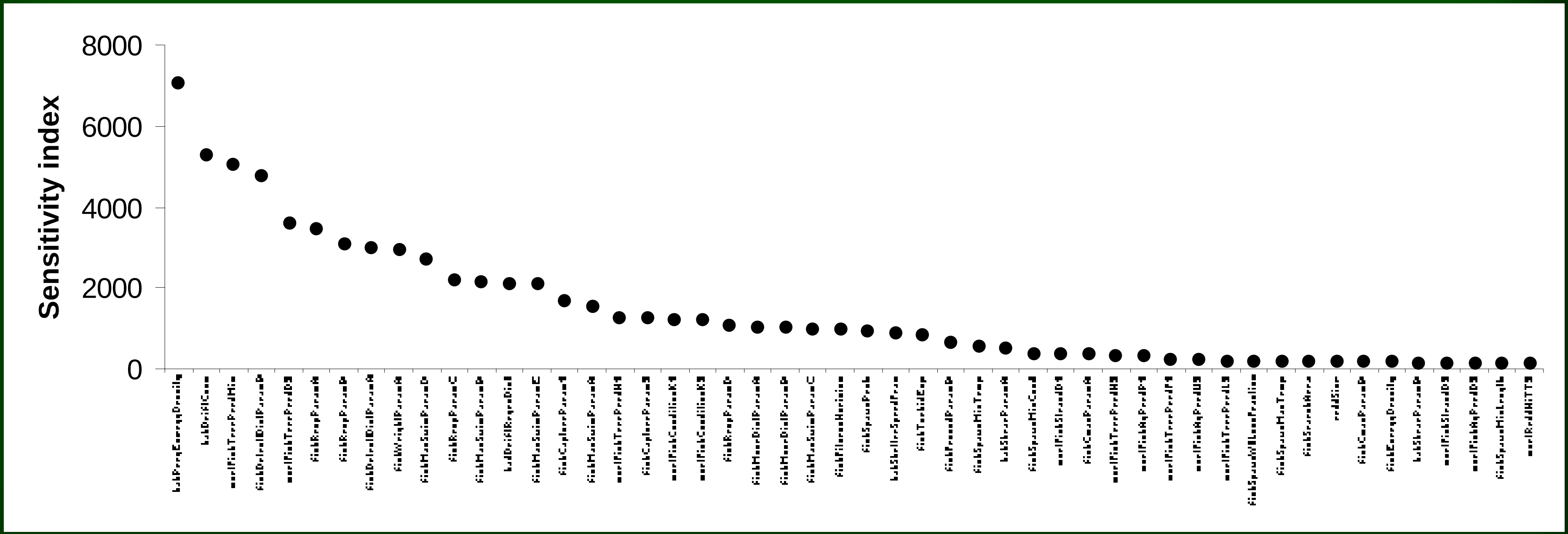
# Sensitivity Analysis Strategy

1 Analyze sensitivity of adult trout biomass to each parameter, individually

2 Analyze sensitivity of adult trout biomass to the 10 most important parameters, including interactions

3 Analyze sensitivity of *management decisions* to parameter uncertainty:
*How does uncertainty in key parameters affect the ranking of management alternatives?*

# Parameter Uncertainty Results: Individual parameter analysis

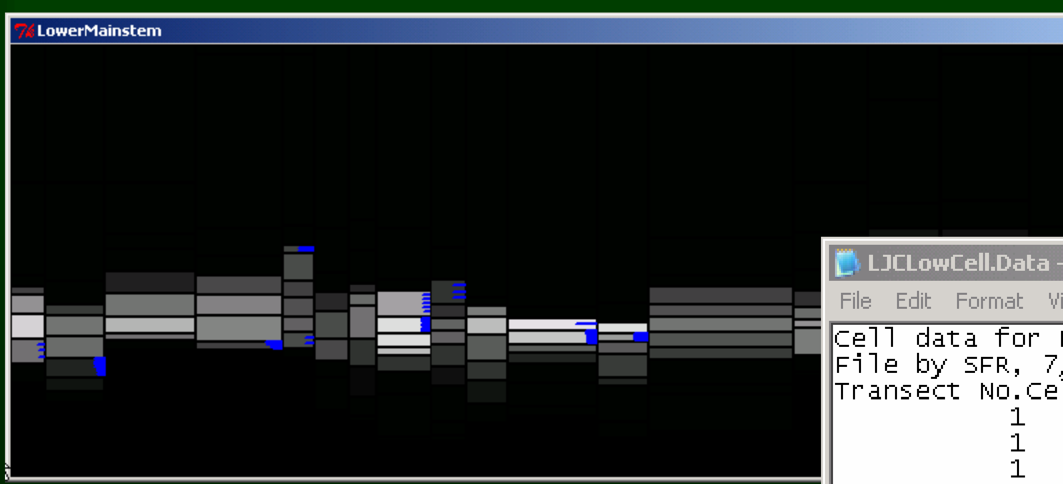


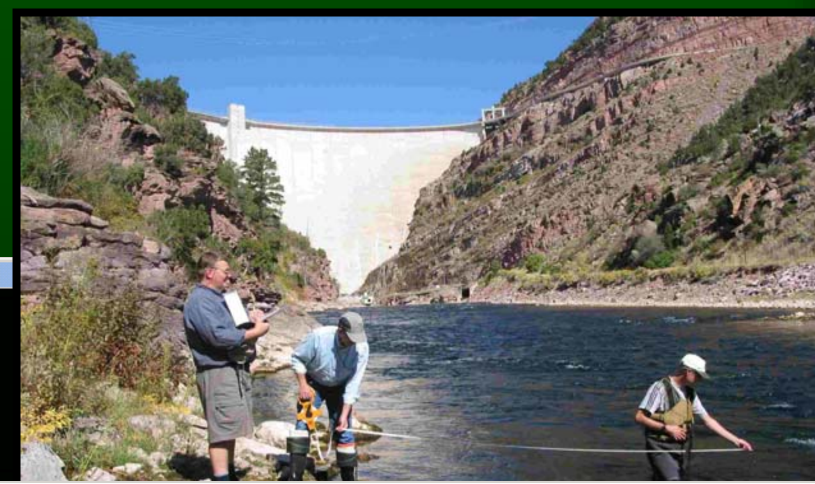

- Winners:
  - Food production & capture
  - Predation risk
  - Respiration

# Progress (3): Methods for Regional Analysis

(MS theses, G. Butcher & M. Parrish)

- Can we synthesize site-specific input
  - that represents habitat throughout a watershed
  - using existing data sets?



LJCLowCell.Data - Notepad

File Edit Format View Help

```
Cell data for Little Jones Creek, Lower site
File by SFR, 7/21/99Updated with FracSpawn 4/13/2000
Transect No.Cell No.UpstreamX    LeftY FracShelt DistToHid FractSp
             1        1        5.0    15.0      0.00      0.00     0.00
             1        2        5.0    25.0      0.00      2.50     0.00
             1        3        5.0    26.2      0.50      0.60     0.00
             1        4        5.0    27.1      0.20      0.40     0.00
             1        5        5.0    29.3      0.30      0.50     0.00
             1        6        5.0    32.0      0.20      1.50     0.20
```

# Methods for Regional Analysis: Additional Objectives

- How sensitive are model results to uncertainty in habitat input?

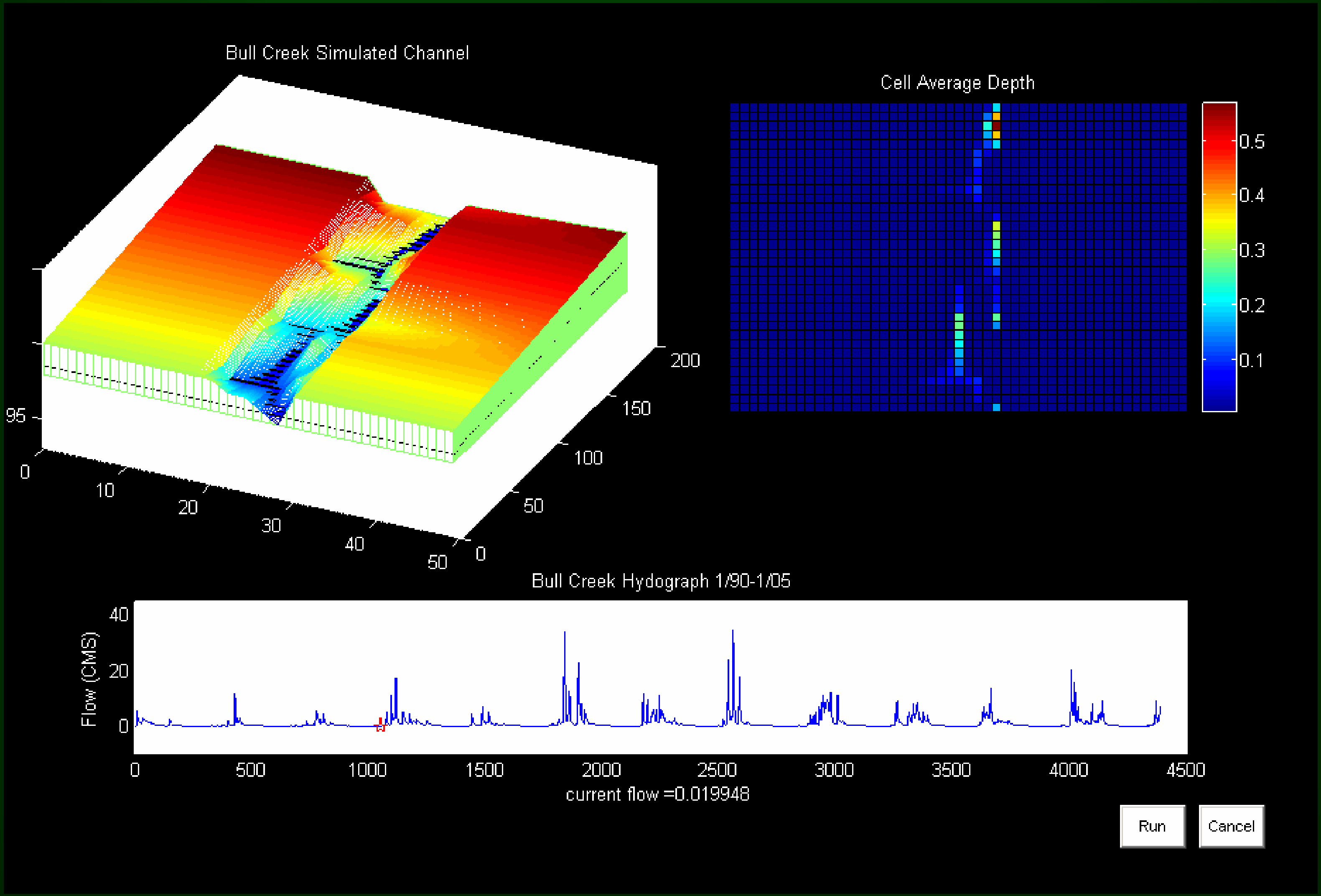
- How do model dynamics and sensitivities change within, among watersheds?

# Methods for Regional Analysis: Approach

- Build stochastic models of stream topography from:
  - Stream habitat survey data
  - Digital elevation maps
  - Channel shape data collected from the watershed

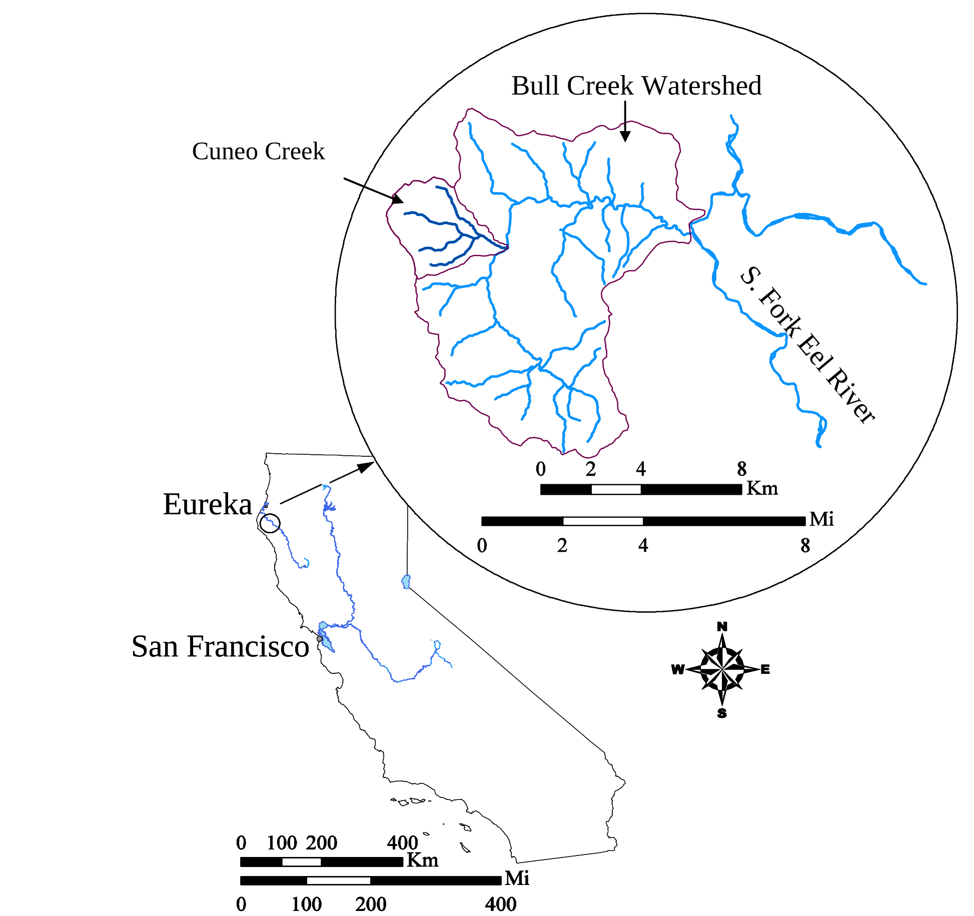
- Use simple hydraulic models to estimate depth, velocity vs. flow

- Input: Gradient and drainage area for a site
- Output: An artificial stream channel with representative habitat characteristics



# Progress (4): Demonstrate inSTREAM's Application to Management Issues

- Conducted collaboratively by USDA Forest Service, Redwood Sciences Lab



# Bull & Cuneo Creeks

Historically important salmonid spawning
Extensive restoration underway

# South Fork Eel River

- Steep decline in salmon
- Extreme sedimentation
- Controversial flow diversion
- Recent invasion by pikeminnow

Some unique qualities...

# Demonstration Assessment: Status

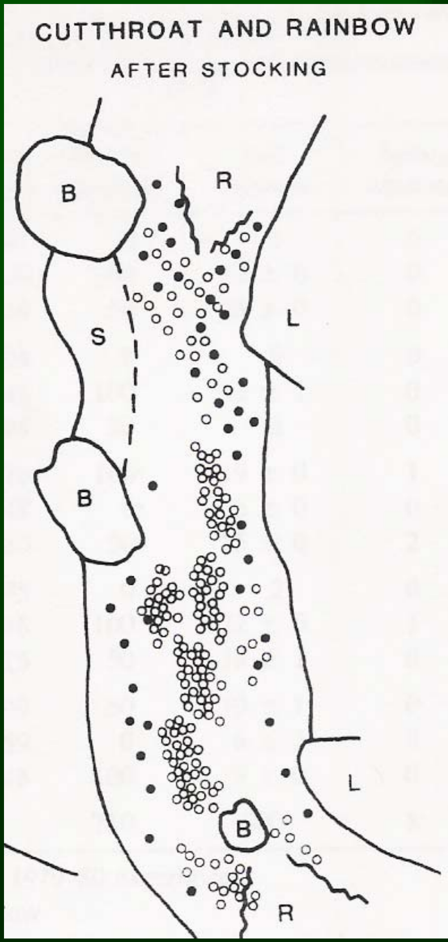
- Field data collection nearly complete
- Model calibration and analysis in 2006
- Developing a version of *inSTREAM* driven by 2-D finite-element model of river hydraulics

# Example Management Research Application: Interaction of Hatchery and Wild Salmonids

- Hatchery-raised salmonids typically have low survival and unnatural behavior
  - But can disturb and displace wild fish
- If we change hatchery practices to improve survival of stocked fish, would effects on wild fish increase?

# Interaction of Hatchery and Wild Salmonids: Methods (1)

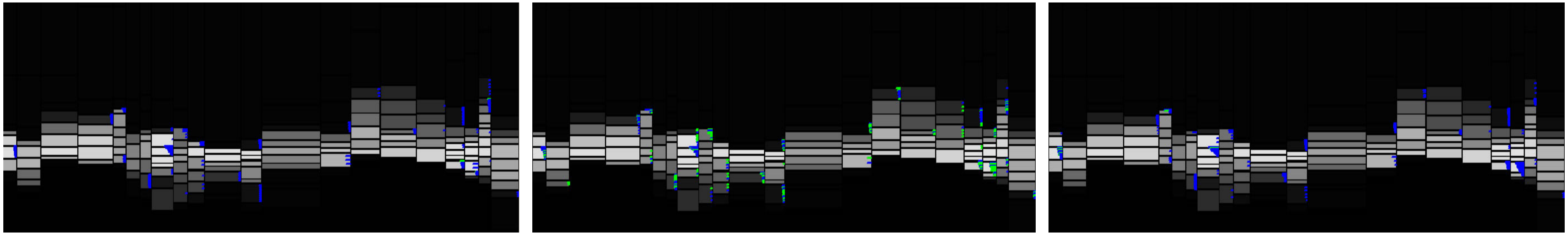
- Modify hatchery trout behavior to determine what differences explain observed interacton patterns




Petrosky, C. E., and T. C. Bjornn. 1988. Response of wild rainbow (*Salmo gairdneri*) and cutthroat trout (*S. clarki*) to stocked rainbow trout in fertile and infertile streams. Canadian Journal of Fisheries and Aquatic Sciences **45**:2087-2105.

# Methods (2): Simulate response of wild trout to:
- Hatchery trout
- Hatchery trout given more natural behaviors

- 0 to 500 hatchery fish "stocked" into the middle of 3 stream reaches
- Wild trout respond by emigrating to the other reaches
- Repeated using hatchery fish having traits more like wild trout

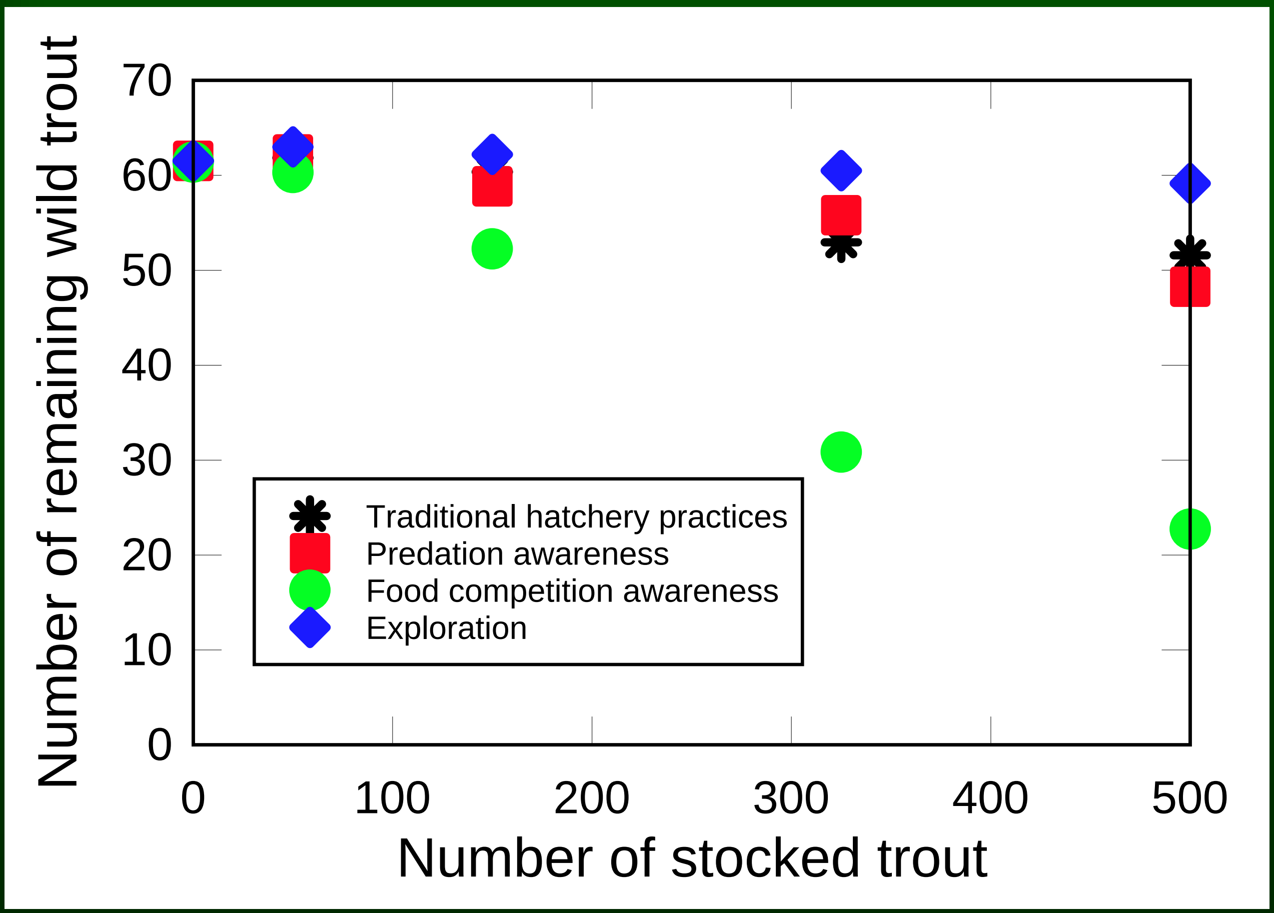


# Interaction of Hatchery and Wild Salmonids: Results (1)

- Patterns of hatchery trout behavior such as:
  - Low dispersal
  - High local densities in mid-channel habitat little used by wild trout

- can be reproduced by taking away their traits for:
  - considering predation risk in habitat selection
  - considering food competition in habitat selection
  - exploring habitat

# Interaction of Hatchery and Wild Salmonids: Results (2)




- Impacts increase dramatically when we make hatchery fish aware of food competition

- More info:

`www.humboldt.edu/~ecomodel`