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
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- Uncertainty does not always increase with model complexity
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- 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

Proposed theory: models for key individual traits

Observed patterns of emergent behavior

Field, lab, literature

IBM

Does IBM reproduce observed patterns?
Developing Theory for IBMs: Examples

• How do trout select microhabitat?

• How do trout decide whether to feed vs. hide, during day vs. night?

• (A review)
Advancing the use of IBM's (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
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

- 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?
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 interaction patterns.

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:

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