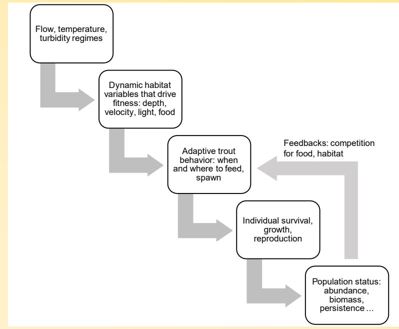
Summary Model Description

How InSTREAM and InSALMO Work

Steve Railsback

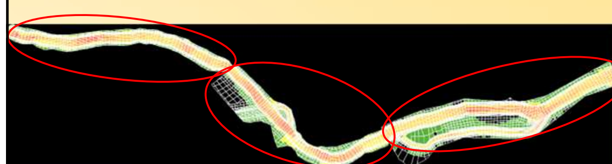
The big picture: Key mechanisms linking flow & temperature to individual fitness



What happens each time step

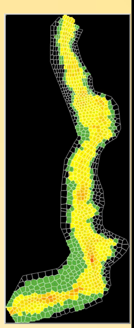
- Habitat updates
- Fish actions – in size hierarchy
  - ➢ Select activity (feed vs. hide) and habitat cell
  - ➢ Survive or die
  - ➢ Grow
  - ➢ Spawn
- Redd actions—eggs:
  - ➢ Develop
  - ➢ Survive or die
  - ➢ Emerge into new fish
- Output

Spatial scales: Reaches and cells



Reach and cell characteristics

- Reach variables (inputs):
  - ➢ Flow
  - ➢ Temperature
  - ➢ Turbidity
- Flow-dependent cell variables:
  - ➢ Depth
  - ➢ Velocity
  - ➢ Light intensity
  - ➢ Food availability
- Static cell variables:
  - ➢ % area providing drift feeding velocity shelter
  - ➢ Number of hiding places (concealment cover)
  - ➢ Distance to escape cover
  - ➢ % area with spawning gravel



Time scales: 4 time steps per day

- Most model events are executed at each of 4 “light phases”: dawn, day, dusk, night
- The duration of each phase is calculated from date, latitude
  - ➢ *Sorry, can’t use InSTREAM in the Arctic or Southern Hemisphere*
- Time-series inputs (flow, temperature, turbidity) can be daily, hourly, weekly...

Habitat updates

- Update time and light:
  - ➢ Set simulation time to end of the next light phase (dawn, day, dusk, night)
  - ➢ Calculate average surface light for time step
- Read in new flow, temperature, turbidity for each reach
- Cell updates:
  - ➢ Calculate depth, velocity from flow
  - ➢ Calculate light intensity from surface light, depth, turbidity
  - ➢ Set food availability from velocity

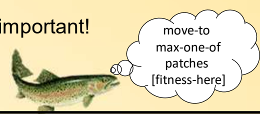
Fish action 1: Activity and habitat selection

- The alternatives:
  - ➢ Either feed or hide*
  - ➢ In any cell within a radius that increases with fish size
- The fishs' objective:
  - ➢ Maximize expected future survival of both predation and starvation
  - ➢ Considering the growth and risk experienced in the previous 3 light phases (over 1 full day)
- Normally: Fish select the alternative that provides positive growth and lowest predation risk

*And, for salmon juveniles, migrate downstream

This adaptive behavior is based on:

- Modern ecology: Population dynamics depend strongly on tradeoffs, especially growth vs. risk
- Salmonid literature: Fish adaptively decide how often to feed at what times of day, as a growth—risk tradeoff
- Salmonid drift feeding models: Growth depends on drift concentration, fish size, velocity, velocity shelter, depth, temperature
  - ➢ But predation risk is also important!



Activity and habitat selection depends on:

- Food availability: Low food → more predation mortality
- Predation risk: Higher risk → lower growth
- Competition: Higher abundance → lower growth
- Fish size: Larger size → dominance → higher growth and survival → larger size
- Anything that affects growth or risk

Survival: Overview

- Mortality sources:
  - ➢ Predation by terrestrial animals (birds, otters, etc.)
  - ➢ Predation by fish (other trout, warmwater spp.)
  - ➢ Low condition (starvation, disease)
  - ➢ Acute high temperature
  - ➢ Stranding
- Each fish's *probability* of surviving each mortality source is a function of fish and habitat variables
- Whether a fish lives or dies is stochastic

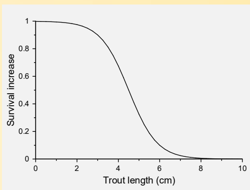
```
if random-number > probability [die]
```

Terrestrial & fish predation

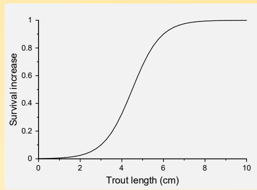
- For each kind of predation:
  - ➢ One parameter controls overall predation intensity
  - ➢ Functions control how risk depends on characteristics of the fish and its habitat

Predation functions: Fish length

- Terrestrial predators

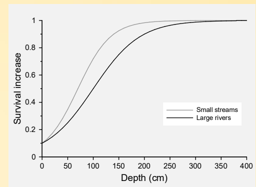


- Fish predators

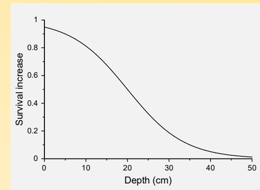


Predation functions: Depth

- Terrestrial predators



- Fish predators

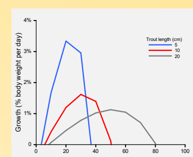


Predation risk also depends on:

- Hiding vs. feeding
- Velocity (reduces visibility to terrestrial predators)
- Light -- less risk in
  - ➢ dusk, night, dawn
  - ➢ deep cells
  - ➢ high turbidity
- Distance to escape cover
- Temperature (higher risk of fish predation at higher temperatures)

Feeding and growth: Two feeding modes

- Drift feeding: growth varies with
  - ➢ Fish size
  - ➢ Velocity
  - ➢ Light & turbidity
  - ➢ Drift food concentration



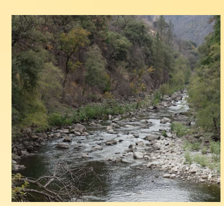
- Search feeding: usually is best only for
  - ➢ Small fish
  - ➢ Low velocities
  - ➢ Low light

Competition

- Model fish select habitat and feed in descending size order (length-based hierarchy)
- As each fish selects its cell and activity, its food (or hiding place) is subtracted from what is left in the cell for smaller fish
- Therefore, the behavior (and growth and survival) of each fish depends on what the larger fish do

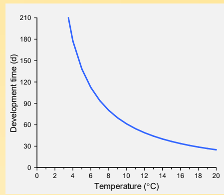
Spawning

- Female trout can spawn when all criteria are met
  - ➢ Minimum age, length, condition
  - ➢ Date range (e.g., April 1 – June 30)
  - ➢ Temperature range
  - ➢ Flows are moderate and steady
  - ➢ Random coin flip
- Each female produces 1 redd
- Redd variables:
  - ➢ Number of surviving eggs
  - ➢ Development status (0.0 to 1.0)



Redd development

- Daily increment in development depends on temperature
- When development reaches 1.0, surviving eggs turn into new fish (or superindividuals)



Redd survival

- Some or all eggs may die each time step due to:
  - Low temperature
  - High temperature & disease
  - Dewatering
  - Scour
  - Superimposition

Superindividuals

- For computational efficiency, newly emerged trout can be represented as “superindividuals”
- Each superindividual represents *n* trout
- Superindividuals split into individuals when they reach a length threshold

```
; Superindividual parameters
set trout-superind-max-rep        (list    10     ) ; The maximum number of trout represented
set trout-superind-max-length     (list    5      ) ; The length (cm) at which superindividual
```

It seems very complex...

- InSTREAM is a collection of “submodels”
  - Surface light
  - Hydraulics
  - Drift feeding
  - Fish predation
  - ...
- Each submodel has been developed, tested, and documented separately
- Submodels are easily modified or replaced
- It’s all in the User Manual