To be a salmon in a river

Steve Railsback

Lang Railsback & Assoc., and California Polytechnic State University Humboldt

To narrow the question...

- What does a juvenile salmon:
	- ➢Need
	- ➢Fear
	- ➢Know innately
	- ➢Learn
	- ➢Remember
	- ➢Sense
	- ➢Control and decide?

To support my assertions:

• Bret Harvey, US Forest Service Research

InSTREAM 7 User Manual: Model Description, Software Guide, and **Application Guide**

Prepared by:

Steven F. Railsback Lang Railsback & Associates Arcata, CA

Bret C. Harvey Pacific Southwest Research Station **USDA Forest Service** Arcata, CA

Daniel Ayllon Department of Biodiversity, Ecology and Evolution Complutense University of Madrid, Spain

Last updated: August 9, 2022

This document is in preparation for publication as a General Technical Report of the USDA Forest Service. Pacific Southwest Research Station.

InSTREAM and InSALMO: ~25 year of building, testing, revising, using IBMs of stream salmonids

ECOLOGICOL MODELLING Ecologiat McGrillig 123 (1999) 73-49 where are assigned areas dimensional providers and Movement rules for individual-based models of stream fish Steven F. Railwhack **, Roland H. Lamberson ⁶, Bret C. Harvey 5, Walter E. Duffy⁺ Vilage Battled & Assessor, 200 Californi Assess, Areas, 274 1997). This Renational of Mathematics, Mandoldt State Concentry, Avenue, CA 97572, USA **Brancout Kimmon Eatherwood, 125 Alexan Warner, Answer 124 81171, 126.4** ⁴ Cromrattol Fishmite Research 1941, Week-MI State Vetermite, Arneal, CA 97321, 1754 Resolved 22 September 1990; meanwel in revoud from 22 April 1990, assumed 16 May 1990. Besiech 7 April 2023 | Revised 27 Am 2022 | Alcognet 28 Art 2021 Abstract FOW THE WAVE - DAMA WILEY **IN Business** signized from **RESEARCH ARTICLE** Movement the assurant that more. InSTREAM 7: Instream flow assessment and management allow fish's novimbring model for stream trout cause weeks any Hoopers a fisk to all Steven F. Raisback¹ | Daniel Aylon² | Bret C. Harvey³ 0 both starts oneygy round mpectation **Thousand of Malayanta, Husball Ra** size of last Abduart Unventy and Ling Rations and disordates spreach is **NVAL CARDINA VSK.** Medicinistic, institutional based description members have items used for -125 years has on made you **Mariaky of Bridge, Dispositional of** ownsee will know instatuto of 'habitat ustability' wasks, ad fighted 7 to the Science B.S. **Biologically** Engineer and Excitation ne Vinierety of Material (ESR) lotest of our individual-based medals for predicting the effects of flow and sensess-Motril, Span. **Krowolds** 14 ture regimes on stream salesmed psolutrities. Unlike PHAISPA for other rections. **Tailo Garboni Romid Nation (2004** based on habitat "guality." e.g., as not cate of energy intekel, wSTREAM mechanics." Renet Salem, Aristo Salemine, USA cally manuage specific effects of flow and troperature intustility itsers, and how Move F. Rahibalo Designeerd of How offer to continue this testable productions of organizing mosquers with as short-Mathematics, Hamboldt Stute Ethiopistic and dates; relative sharehous of realistic trace species, and perceiverer; Int TREAM 7 is Larg Ratcher Land Associates, Ancien CA the first continue to also recognized the state better code bitmes, due which workships

Endor Ave. 200 pp. 91-40

total

dist

TEL NAC

TESTS OF THEORY FOR DIEL VARIATION IN SALMONID FEEDING ACTIVITY AND HABITAT USE

freezis F. Razmage, "Bart C. Harvey," Jun W. Havie," and Eng. E. LaGoky! Trans Batched & Associated TW California Assoc. Assoc. California RFUT USA.

Comp Matter & American, 231 California Company, American Company, 1798 (Reprint Defense Jackson)
History District Company, 1798 (Reprint Defense Jackson), 1798 (Reprint Defense Jackson), 1799 (Reprint Defense Jackson), 179

Above The races valuable whethap whether to thropy thangs the or suplicit a critical fitners problem: at sight, predation vide are limite but feeling in him efficient. Hatchet
velocities in a classify related problem: the best between for occurrent foreging could be too video during deceases, and informe that is safe and production in develops way. So parenthesities is apply. We puse a theory that arrested missale refect the combination of distance and apply arrivery checking ver inding), and helpers in European Special control of the state of the material special control in European means a mean in approximate in the presence of the control products and the present of products and the factory and the control of the state of th $\begin{array}{l} \frac{\partial^2 u}{\partial t^2} \\ \frac{\partial^2 u}{\partial t^2} \\ \frac{\partial^2 u}{\partial t^2} \end{array}$

Steven F. Raihboch, Boet C. Hiervey, and Janne L. White

stelle bight centred, constitutes that also produced many residents.

Facultative anadromy in salmonids: linking habitat, individual

A Replace Moduling and management of facultating maintenances colorated in complicated by their infiltration elser students as

or entailed life baskeries. Corrent total likeury for this ferloving assumes to distribute serve the strategy of being highest represent reproducent motion for door not profit; low-paysingles foref communities are has a stream's mush production meetal from
An istudenty decision and kalmatooptitions. Our autorities hand population mated reprosent proveds gro

anademio dorstansi annos enso el fathilat ana competition. Es inicialmente promovia libas nanno consol consol and careeral - pa

conditions, we experient from excep situations presides which it produces were a modern and form many of three choosing and

nevers must poolsoten company with reducing lookwater naveral. Sawii praduction padoul at high government and moder-

In protection goal loss builded due chanks are to present pay to losar payments and to play graph moved due reproductive, many offer an problem and

po consent les compasses à l'Alistic de la population, misse la probazion de souscenois, date se cour d'un desse,
Abstract à la débate « la pres à l'assessine et des madistans de l'astract base madia de pagale mi har la pa

er de la convenience. Don't des expériences de entralizion étaux legandhes vérigéne les conditions du cryénemes trade autrès est

in about were of the function. Only to value
for the full annual state of the state of the state of the state of the
matter of the state of the state of the state of the state of the state
and the state of the state of th

Senage: La modélapine et la présente sales entre la academie Douturier sent compliquers par la saparité de ces présent

ald challed one cycle building upon ante around-turned one inhibiters. To inhumber channique and our quit conservent or comparativeness register on

life history decisions, and population-level consequences

LAMATRACY is to be a summer to have negative of to to on psychiature and communities, but are no offices of the . (Photo in moster and an alumn seattle, For desire his hardes in accessor power offs a married at column sell another

 Φ_0 . This is a moment state of happening in Weinspieler (Figure), and is a moment state of the stat 1977 - Premerican girêd Josefuan (Salaman Sarang 1983 bû, 1871)
1980 - P. 2000 American Philaden Roberta

A free depositor and a for a trees

Bow West Auto (1991)

Policinal million is Way Colora Library
Indianalizations, conclude an initiate listing

EFFECTS OF PASSAGE BARRIERS ON DEMOGRAPHICS AND STAHLITY. PROFIETIES OF A VIRTUAL TROUT BORD ATION.

B.C. BARVEY' and E. P. BARRBACK'

7 (1934 Funer lanks, Furth Joshuar Rowsell, Ballac, Arran, CA'Bona, 238.

¹ John Millsfield & Alexandre Arrona California ATA

TODA NACUSAT pros (1788) 8170 miles

ARTICLE

ARTICLE

Importance of the Daily Light Cycle in Population-Habitat Relations: A Simulation Study

Steven F. Railsback*

Long Ballebark and Associates, 250 California Avenue, Arcotts, California 95521, 3554.

Bret C. Harvey

U.S. Forest Service, Pactfic Southwest Research Station, 1700 Baynon: Drive, Areata, Colliborat 95521, USA

Daniel Ayllón

Department of Bodiversey, Ecology and Evolution, Furnity of Bodogy. Complaintae University of Madrid. Madesi 20040. Spoint

distant

Review

Trait-mediated trophic interactions: is foraging theory keeping up?

Steven F. Railsback^{1.2} and Bret C. Harvey³

Numbered State Driversity, Department of Mathematics, 1 Harpst Street, Austa, CA 16521, USA. Lang Railsberg & Associates, 259 California Avenue, Anses CA 00021, USA "Lang Farsbeek & Associates, 250 California Avenue, Angels, CA 00021, USA.
"Langed Stanic Disputation of Agriculture Forest Service, Factle Inschauset Research Station, 1700 Standard Direct
Angels, CA 00021, USA.

theory that works is community contents, for popula-
toos of unique individuals each making trade-offs herecent detailined at tretion was tall 400 food nowed resear behavior of ethers. Such theory is recovery to repro- depends on the desity of problem land previous, it face the trait mediated trigitis interactions room recoga sedespread and strong. Game theory non muchty their truth is g, inductor, lit-harters decisions.

Many enabogists before that there is a lask of foreging ... trophic interactions'. Clusted models of interaction: severa trophic levels, such as predator-proy population thyramics, avesare that effects are 'density methods' that in, the rate of which is prefator psynistics consumer presin new widely accepted that produints also come proy to

ISBE

Cell

Belowhard Bridges (2009), 1410; 1970 (1981) Automative Industrial Artists

Original Article

Contingent trade-off decisions with feedbacks in cyclical environments; testing alternative theories

Steven F. Rabdssdt. * ** Bret C. Harvey," and Dartiel Ayllón*

Lang Raisbeck & Associates, 250 California Ave., Arcata, CA 96521, USA "Department of Mathematics, Humboldt State University, Arosta, CA 95521, USA, FLS. Forest Service, Pacific Southwest Research Station, 1700 Baywew Dr., Arcata, CA 95521, USA, and *Complichmea University of Madnel (UCM), Paculty of Biology, Department of Biodiversity, Ecology and Evolution, Cluded Universitaria s/n, E-28040 Madrid, Spain

Brooked 13 September 2010, polent 5 Just 1970, relevant alcosing 15 Just 1970, account 14 Just 1970, Achievem Avenue (4 July 2000, 2000)

The main idea of InSTREAM:

- Individuals make adaptive decisions
- to improve their *expected future fitness* ➢Growth and survival of starvation ➢Survival of predation ➢Reproductive output

The main idea of InSTREAM:

- Individuals make adaptive decisions
- to improve their *expected future fitness* ➢Growth and survival of starvation ➢Survival of predation ➢Reproductive output
- In a complex, changing world where optimization is impossible

Modeling Populations of Adaptive Individuals

Steven F. Railsback and Bret C. Harvey

What does a juvenile salmon need? Food & growth

• The standard model: Drift feeding

Hughes & Dill 1992

Growth from drift feeding varies with:

- Water velocity
- Fish size
- Temperature
- Light
- Turbidity
- Depth
- Velocity shelters

Drift feeding is not the whole story!

• In pools, fish search for food

Drift feeding is not the whole story!

• In turbidity too high for drift feeding, fish capture prey moving along the bottom

Feeding and growth: Competition is important!

- In simulation results, we very often see a negative relation between abundance and size
	- ➢Every feeding option offers different growth, survival probability
	- ➢So every bigger competitor reduces your growth or survival
- You cannot understand populations by looking at *individual* or average growth

Feeding and growth: Food availability is more important than anything!

- Food intake is by far the most important factor driving growth
- When we consider tradeoff behaviors, more food gives fish the scope to avoid risk
- (Populations are *always* "food limited")

FIG. 3. Simulation results for (a) adult abundance and (b) population biomass in the standard (\Box) , fixed activity (\blacksquare), weak habitat selection (O) and no-hierarchy (\blacklozenge) scenarios. Note that both axes are logarithmic. *, abundance and biomass were zero at the lowest drift-food concentration in the weak-habitat-selection scenario. Because of their low and hence more variable values, results for the first three food availability scenarios (drift concentrations 0.5, 1.0 and 2.0×10^{-4} g m⁻³) are means of five replicate simulations differing only in the model's random number sequence.

Published 2011. This article is a U.S. Government work and is in the public domain in the USA. Journal of Fish Biology 2011, 79, 1648-1662

What does a juvenile salmon fear?

• To understand population dynamics *and behavior*, we need to know why animals die!

Transactions of the American Fisheries Society 142;621-627, 2013 American Pollentes Society 2013 1935/c; 0002-8487 prim / 1548-8659 online DOI: 10.1060/00025687.2012.766485

NOTE

Seasonal and Among-Stream Variation in Predator **Encounter Rates for Fish Prey**

Bret C. Harvey[®] and Rodney J. Nakamoto

U.S. Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, California 95521, USA

Abstract

Recognition that predators have indirect effects on prey populations that may exceed their direct consumptive effects highlights the need for a better understanding of spatiotemporal variation in predator-prey interactions. We used photographic monitoring of tethered Rainhow Trout Oncorkyachas mykiss and Cutthroat Trout O. clarkii to quantify predator encounter rates for fish in four streams of northwestern California during winter-spring and summer. To estimate maximum encounter rates, provide the clearest contrast among streams and seasons, and provide an empirical estimate of a key parameter in an individual-based model of stream salmonids, we consistently placed fish in shallow microhabitats that lacked cover. Over 14-d periods, predators captured fish at 66 of the 88 locations where fish were placed. Eight species of birds (including two species of owls) and mammals were documented as capturing fish. Thirty-six percent of the predator encounters occurred at night. Predator encounter rates varied among streams and between seasons; the best-fitting model of survival included a stream x season interaction. Encounter rates tended to be higher in larger streams than in smaller streams and higher in winterspring than in summer. Conversion of predator encounter rates from this study to estimates of predation risk by using published. information on capture success vielded values similar to an independent estimate of predation risk obtained from calibration of an individual-based model of the trout population in one of the studystreams. The multiple mechanisms linking predation risk to population dynamics argue for additional effort to identify patterns of spatiotemporal variation in predation risk.

Predators affect prey populations directly by consumption and indirectly through a variety of nonconsumptive effects, such

predation to prev population dynamics highlights the need for understanding the magnitude of predation risk and its spatiotemporal variation. For stream fishes, high rates of fish consumption by various endothermic predators have been observed (e.g., Alexander 1979; Heggenes and Borgstrøm 1988; Dolloff 1993), along with significant annual variation in the presence-absence of important predators. A variety of studies have addressed the influence of local habitat features (e.g., cover, depth, and water velocity) on predation risk, while advances in long-term monitoring of tagged fish have allowed large-scale studies of survival in general (e.g., Berger and Gresswell 2009; Xu et al. 2010). However, both in general and for purposes of fish population modeling (e.g., Railsback et al. 2009), it would be useful to know more about reach-scale and shorter-term temporal variation in predation risk.

In this study, we sought to examine spatiotemporal variation in predator encounter rates for fish occupying four streams in northwestern California. Our specific objectives included detection of seasonal and diel patterns in predator encounters and the identification of predators. We also sought to empirically estimate a parameter in the individual-based stream trout model of Railsback et al. (2009). This model utilizes a stream reachscale parameter that represents the minimal rate of survival of predation risk from nonaquatic predators. Because this parameter cannot be routinely measured and is highly uncertain, it is commonly adjusted in the model calibration process to match model results to empirical observations.

Key predators: Other fish

• Predators:

➢Other salmonids ➢Piscivorous fish (pike, bass...)

- Highest risk:
	- ➢Small salmon
	- ➢Deeper water
	- ➢Warmwater piscivores
	- ➢High temperatures

Birds

• Osprey, raptors

Photos by Mike Anderson, Arcata CA

Birds

- Cormorants
- Mergansers
- Highest risk:
	- ➢Larger salmonids ➢Shallow, clear water ➢Daytime ➢Winter?

Otters

- Highest risk: ➢Everyone ➢Any where ➢Any time
	- ➢Likely episodic in small rivers

Anything will eat a fish!

Harvey & Nakamoto 2013 Screech Owl

Back to: Feeding and growth What does a salmon need?

- **NOT** habitat that maximizes growth
- **BUT** safe habitat that provides positive growth

➢Shallow water when small ➢Deep water when large ➢Nearby escape cover ➢Places to hide when not feeding ➢Dark times / places

What does a juvenile salmon know innately? **Friviron Biol Fish**

- Risky habitat
- Harvey & White 2017: No matter how much food was available, juvenile steelhead would not use depths < 20 cm
- Other studies: fry avoid risky habitat as soon as they emerge

DOI 10.1007/s10641-017-0585-2

Axes of fear for stream fish: water depth and distance to cover

Bret C. Harvey · Jason L. White

Received: 15 August 2016 / Accepted: 6 February 2017 C Soringer Science+Business Media Dordrecht (outside the USA) 2017

Abstract To better understand habitat-specific predation risk for stream fish, we used an approach that assumes animals trade off food for safety and accurately assess risk such that predation risk can be measured as a foraging cost: animals demand greater harvest rates to occupy riskier locations. We measured the foraging cost of predation risk for juvenile salmonids within enclosures in a natural stream at locations that varied in water depth and distance to cover. Measurements relied on a food delivery apparatus and direct observations that allowed estimation of "giving-up" harvest rates - food delivery rates at which animals left the feeding apparatus. Juvenile steelhead about 120 mm fork length exhibited sharp increases in giving-up harvest rate with decreasing water depth and refused to use the feeding device even when offered extreme food delivery rates in water <20 cm deep. Giving-up harvest rates were less affected by the distance to cover. Assuming the gradients we observed in giving-up harvest rates reflect predation risk, the results of this study can be applied to spatially explicit models of stream fish populations that incorporate risk into both habitat selection and mortality due to predation.

Introduction

Habitat selection by animals can incorporate multiple demands, such as food acquisition and predator avoidance, which may present trade-offs under some conditions. Recognizing the influences of multiple demands can be important in understanding and modeling habitat selection. For example, Gilliam and Fraser (1987) successfully predicted habitat selection by a streamdwelling minnow under experimental conditions, using a rule that incorporated both foraging rate and predation risk. Railsback and Harvey (2002) found that in modeling habitat selection by a stream salmonid, only a selection criterion that incorporated both food acquisition and sensitivity to predation risk completely reproduced a set of widely observed patterns of behavior. Recent field observations that models of habitat selection that include both food acquisition and factors that may influence risk are superior to models including food acquisition alone (e.g., Kawai et al. 2014) correspond with the results of Railsback and Harvey (2002). Successful modeling of habitat selection is critical for predicting population-level phenomena using spatially explicit,

(C) Crucklan

What does a juvenile salmon know innately?

• Gowan (2007):

➢Trout were poor at finding *food* ➢but use velocity as a cue for food

➢Readily used shallow habitat if it had velocity*

Salmon *seem* to rely on cues

- Velocity as a cue for food
- Depth as a cue for safety
- Overhead motion as a cue for risk ➢Except...

Hatchery happy dance!

Emotions may be plastic?!

How well do salmon learn?

- Both Gowan and Harvey & White found it difficult to teach trout to use feeders ➢Only 5 of 17 individuals learned ➢Average of 12 days to learn
- Trout seem able to detect nearby predation events
- Angling: "trout that had been fished previously were more likely to be scared by anglers or required smaller, low-profile flies before being caught than naïve trout"—Young and Hayes 2004
- Hatchery fish clearly have different cues for risk, food...

Why would you take a lawnmower when you go fishing?

© Field and Stream

Why would you take a lawnmower when you go fishing?

What lawnmower fishing tells us*

- Fish can learn unnatural cues
- Fish can use sound cues (from above water)

What does a salmon remember?

• Habitat (commuting to work)

• Natal stream

• ???

Influence of large woody debris and a bankfull flood on movement of adult resident coastal cutthroat trout (Oncorhynchus clarki) during fall and winter

Bret C. Harvey, Rodney J. Nakamoto, and Jason L. White

Abstract: To improve understanding of the significance of large woody debris to stream fishes, we examined the influence of woody debris on fall and winter movement by adult coastal cutthroat trout (Oncorhynchus clarki) using radiotelemetry. Fish captured in stream pools containing large woody debris moved less than fish captured in pools lacking large woody debris or other cover. Fish from pools lacking cover commonly moved to habitats with large boulders or brush, particularly during the day. Movements by fish over 1-day periods were strongly influenced by large woody debris or other elements providing cover. Fish initially found in habitats lacking large woody debris, large boulders, or brush cover moved the most extensively, while fish initially found in pools with large woody debris moved the least. Fish did not move extensively in response to a bankfull flood, although some moved to habitat downstream of large woody debris in tributaries or secondary channels. Habitat downstream of woody debris in the main channel was not used during the flood, apparently because of extreme turbulence. Overall, these observations provide additional evidence for the value of habitat complexity to some stream fishes and support previous observations of minimal effects of flooding on adult fish.

What a salmon senses

• (that we need to include in a population model)

What can a salmon sense?

• Vision

➢Ability to see at low light levels allows fish to feed at dusk, night, dawn...

when predators are much less able to see them

What can a salmon sense?

- Sound (example: lawnmower)
- Smell (predators, predation, siblings, natal stream...)
- Date, season, day length...
- Internal state (hunger; fat reserves, growth rate?)
- Social rank

Does a fish know the temperature?

- Physiology is affected by temperature in many ways, at different rates
- Everything is slower at lower temperatures...
	- ➢including cognition?
	- ➢so does relativity make everything seem the same??

Adaptive behaviors

- Where to feed
- When to feed
- How to feed (drift, search)
- What to attack
- What to do with energy
- When to defend space
- When to flee to escape cover
- Where to conceal when not feeding
- Schooling
- When and where to migrate
	- ➢Other rearing habitat
	- ➢To the ocean

An example adaptive behavior: Facultative anadromy

- In species like *Oncorhynchus mykiss, O. clarki, Salmo trutta*: there is variation in whether and when individuals migrate to the ocean
- Could improving stream habitat *reduce* abundance of anadromous individuals?

Three perspectives on facultative anadromy: (1) Anadromy as a genetic tendency

> • (You can look at a fish's genes and determine whether it will be anadromous or resident)

Three perspectives on facultative anadromy: (2) Anadromy as a population-level adaptation

- The populations of different rivers have life history trends adapted to local survival and growth rates
- (You can look at a population's environment and determine whether it should be dominated by anadromy or residence)

Three perspectives on facultative anadromy: (2) Anadromy as a population-level adaptation

Modeling anadromy as a population-level adaptation: Theory of Satterthwaite et al.

- Populations should be dominated by the life history that maximizes reproduction rate
- Reproduction rate for anadromy is the product of: ➢Survival rate until smolting (increases with freshwater growth, freshwater survival)

➢Survival rate for outmigration & ocean (increases with fish size at smolting)

➢Fecundity of anadromous females (constant)

Modeling anadromy as a population adaptation

• Reproduction rate for residence is the product of: ➢Survival rate to freshwater spawning (increases with freshwater survival and growth, decreases with time until spawning)

➢Fecundity at freshwater spawning (increases with fish size and freshwater growth)

Model results: Different rivers with different growth and survival rates produce different life histories

Satterthwaite et al. 2010

Three perspectives on facultative anadromy: (3) Anadromy as an individual adaptation

- (You can look at a fish's state and experience to predict whether it becomes anadromous or resident)
- Very similar to previous perspective but now we look at *individuals*, not populations

Modeling anadromy as an individual adaptation

• Individual fish make life history decisions to maximize expected future reproductive success

Facultative anadromy in salmonids: linking habitat, individual life history decisions, and population-level consequences

Steven F. Railsback, Bret C. Harvey, and Jason L. White

Abstract: Modeling and management of facultative anadromous salmonids is complicated by their ability to select anadromous or resident life histories. Conventional theory for this behavior assumes individuals select the strategy offering highest expected reproductive success but does not predict how population-level consequences such as a stream's smolt production emerge from the anadromy decision and habitat conditions. Our individual-based population model represents juvenile growth, survival, and anadromy decisions as outcomes of habitat and competition. In simulation experiments that varied stream growth and survival

Railsback, S. F., B. C. Harvey, and J. L. White. 2014. *Canadian Journal of Fisheries and Aquatic Sciences* **71:1270-1278.**

The individual anadromy decision:

- Each juvenile fish decides to become anadromous *if* and *when* its expected fitness from anadromy exceeds its expected fitness from remaining resident
- If this transition has not been made by the time the fish could mature for age 2 spawning, the fish remains resident
- *In a population of unique individuals competing in complex habitat*

The anadromy decision: Expected fitness from anadromy

• Expected reproductive output at next return from ocean = Expected survival to smolting (depends on predation and growth to avoid starvation)

X

Expected survival of downstream migration and the ocean (increases with length)

X

Fecundity of anadromous adults (constant)

The anadromy decision: Expected fitness from residence

• Expected reproductive output at age 2 spawning = Expected survival to age 2 spawning (depends on predation and growth to avoid starvation)

X

Fecundity at age 2 (increases with size & growth)

The anadromy decision

Contoured value: The benefit to expected fitness of becoming anadromous

The anadromy decision

Will stream restoration make more residents instead of more steelhead??

Simulation experiment: Could stream restoration result in fewer anadromous fish?

• Simulate many combinations of stream growth and survival:

➢Food availability 50 – 300% of calibrated value

➢Survival of predation 98 – 102% of calibrated daily probability

• Count the number of simulated fish that: ➢Stayed as residents ➢Migrated downstream to smolt

Could stream restoration result in fewer anadromous fish?

• Number of residents:

Could stream restoration result in fewer anadromous fish?

• Number of smolts:

Conclusions of this experiment:

- Restoration that improves survival and growth is predicted to produce more of *both* resident and anadromous fish ➢Higher freshwater survival causes fewer fish to choose anadromy, but more of them survive to smolt
- Individual variation in growth and risk is sufficient to make both life histories adaptive within the same population, over wide ranges of overall growth and survival
- To understand population consequences, it is not sufficient to look only at an "optimal" individual

What it is to be a juvenile salmon: Summary

Summary: to be a juvenile salmon is to be...

• Afraid

• Hungry*

• but not sad!

www.humboldt.edu/ecomodel

Individual-Based Ecological Modeling at Cal Poly Humboldt

The Humboldt Mathematics Department has a long tradition of collaborating with faculty in Wildlife, Fisherjes, and other departments to produce and use ecological models, and especially individual-based models (IBMs; also known as agent-based models). This tradition goes back to the pioneering work of Roland Lamberson and colleagues on a variety of bird and mammal models in the early 1990s. Steve Railsback and Bret Harvey joined the team in the late 1990s, focusing (but not exclusively) on inSTREAM and inSALMO, our river management models of salmonid fish. We collaborate closely with other individual-based modeling centers around the world (see Who We Are). In 2005, Volker Grimm and Steve Railsback published Individual-based Modeling and Ecology, the first monograph on IBMs. They also wrote the first textbook for agent/individualbased modeling, which is now in its second edition. Steve Railsback and Bret Harvey have now published Modeling Populations of Adoptive Individuals, a monograph on IBMs that include adaptive tradeoff decisions, in Princeton University Press's Monographs in Population Biology series. According to Google Scholar, our publications have been cited over 15,000 times.

Math Department faculty teach modeling classes and collaborate with faculty in Wildlife, Fisheries, and other departments, and co-supervise graduate students who include modeling in their research. More information is at the Mathematics Department web site, and example student projects are here.

Research Goals

Developing a conceptual and theoretical basis for individual-based ecology. Differential calculus provides the conceptual basis for classical ecological models, but IBMs have lacked such a basis. We help develop and promote standard concepts for thinking about and designing IBMs.

Applying IBMs to conservation and management issues. We developed several generations of stream salmonid IBM to address such management questions as:

What's new

Recent classes: Intro to IBMs, Intro to InSTREAM and **InSALMO**