Think Like a Fish:

Designs for Fish Passage and Habitat

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Fish Passage

The benefits of good habitat are many times cancelled by barriers to fish passage that prevent access to that habitat

Fish Movement

- Important behavior that allows fish to respond to environmental conditions so that they increase growth, survival and reproductive success

- We have focused mainly on large spawning migrations and wrongly assumed stream resident fish moved very little (restricted movement paradigm – Gowan et al. 1994)

- Such paradigm fails to fully explain stream resident fish movement patterns (Smithson and Johnston 1999)

Fish Movement

- Resident cutthroat trout were thought to spend their entire lives in 20 to 50 m long reaches

- Rainbow, cutthroat and bull trout have been observed to move from 8 to 40 kms throughout year



Fish Movement

- Studies in California by Decker and Erman (1992) confirmed that the entire fish assemblage is mobile

Fish Movement

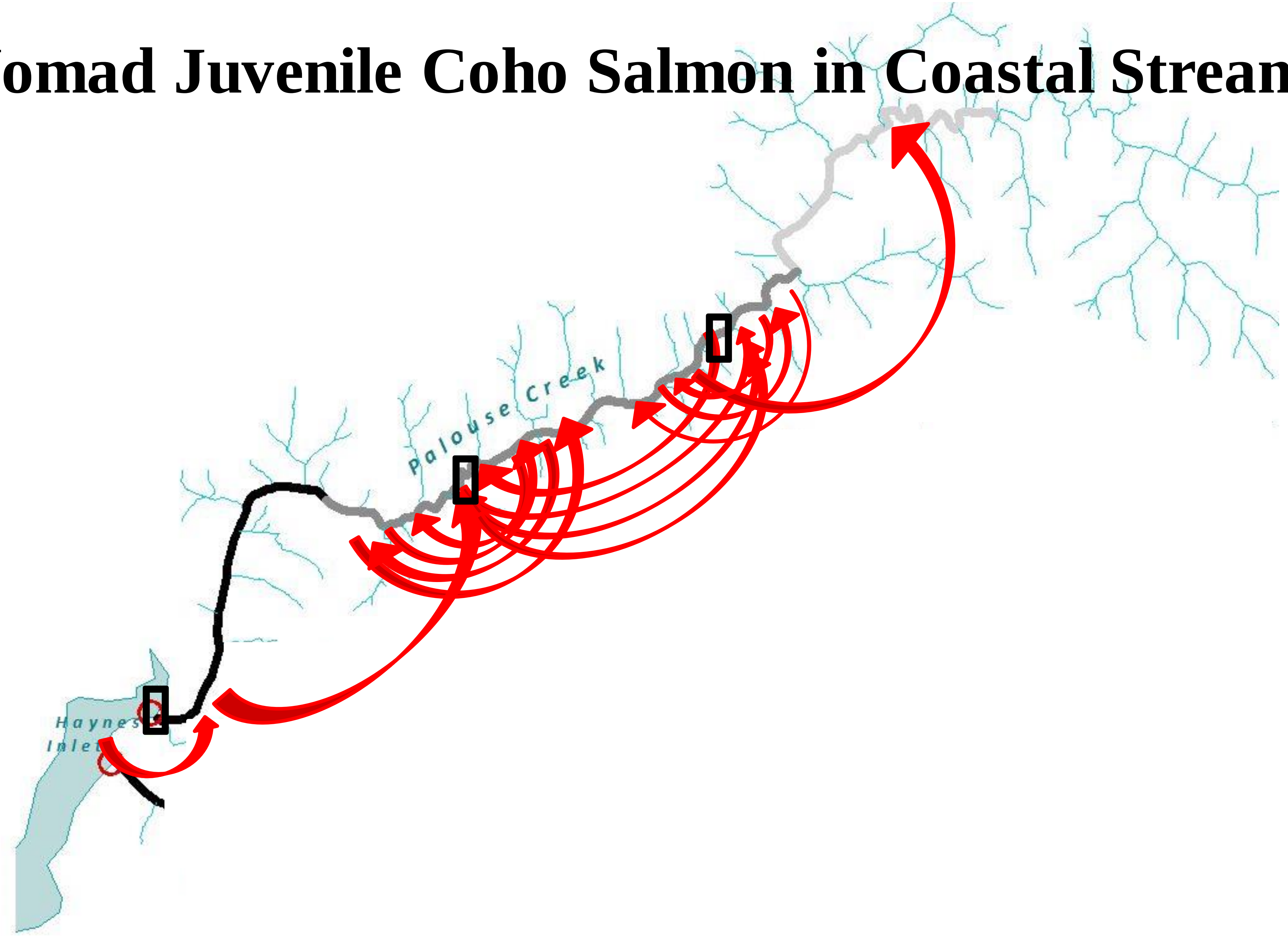
- Culverts represent bi-directional barriers to fish movement under a wide range of flow conditions throughout year (Warren and Pardew 1998)




Fish Movement

- Passive and active fry dispersal with flow and social interactions
- Subsequent movements relate to shifts in habitat use as fish grow and they need more food, avoid competition and predation
- Movements by juvenile salmonids are common, and a high proportion of juvenile fish move upstream (Kahler et al. 2001)
- Depending on habitat types and seasons movers may grow faster than residents

Nomad Juvenile Coho Salmon in Coastal Streams



Fish Movement

- Different life history stages have different needs and use different habitats
- Use of different habitats improves survival odds
- Stream fishes often spawn as flood waters start to rise
- Eggs are deposited in upstream and lateral habitats where predation pressure and risk of displacement is lower than elsewhere
- Different life history stages use different stream locations this reduces population vulnerability to localized disturbances
- Because different life history stages are completed in different locations the ability for fish to move is critical to population viability

Fish Passage

Both anadromous and resident fish are negatively affected by barriers to migration such as:

- Suspended culverts
- Dams
- Dry stream reaches

“Houston” we have a problem!

- We need drainage for roads
- But these can block movement of fish and other aquatic organisms

Photo by Meegan M. Reid, KITSAP SUN

J. Dunham, 2015

Design Passage with Critter Needs in Mind

- "Freedom of movement"
  - Movement through the crossing is the same as movement in a comparable reach of stream
  - Structure "permeable" to different species, life stages, modes of movement, etc.


Photo by Meegan M. Reid, KITSAP SUN

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Risks of Movement Restriction

- **Population impacts**
  - ↓ Demographic support
    - Can check out any time you like, but you can never return
  - ↓ Migratory life history diversity
    - Everything depends on one place, one life history
    - "Obligate" migratory species extirpated
  - ↓ Recolonization
    - No re-population after sub-population extinction
  - ↓ Population size
    - Risk of stochastic extirpation, inbreeding

We Did Replace It, But Is It Working?

In Oregon and Washington BLM and Forest lands

- **>130,000 miles of roads**
- **>5,000 culverts that block fish migration**
- **Cost of restoration: >$*375,000,000***
- **Time frame: *Decades***
- ***Don't know if it will work***

Photo: Clayton Nalder

Two Scales of Evaluation

Project level:

Individual movement at specific sites

Programmatic level:

Distribution and abundance across landscapes

USGS J. Dunham, 2015

Project Level

- Can fish move through a crossing?

- How does probability of crossing compare to a natural reference?


Photo by Meegan M. Reid, KITSAP SUN

Project Level Approach Logistic Limitations

- Not enough **fish** to study
- Not enough **stream crossings** to study
- **Limited** movement…and so on (see below)

STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station **October 2011**

Practical guidelines for monitoring movement of aquatic organisms at stream-road crossings

by Jason Dunham, Robert Hoffman, Iván Arismendi

Maintaining passage of aquatic organisms through modification or replacement of barriers (e.g., culverts) at stream-road crossings represents one of the Nation's largest investments in restoring aquatic ecosystems. Current federal guidelines specify stream

Schwartz et al. 2007). These methods allow for individual identification and detailed analyses of individual movement, but can be expensive and technically challenging to implement.

In practice resources are usually more

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The PRIMARY AIM is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.

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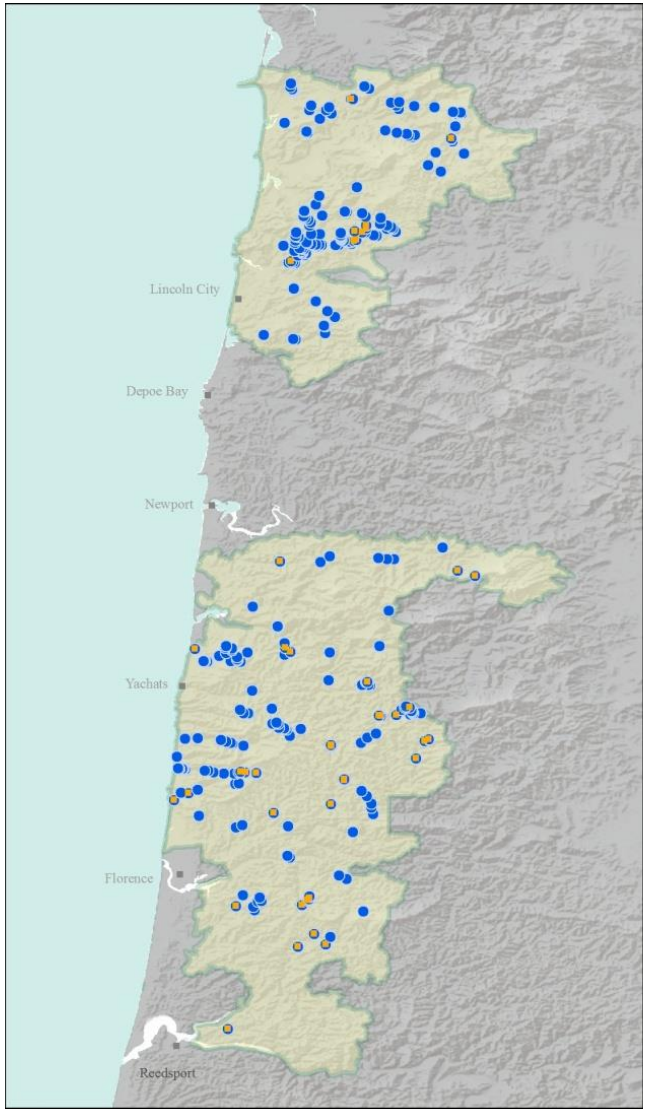
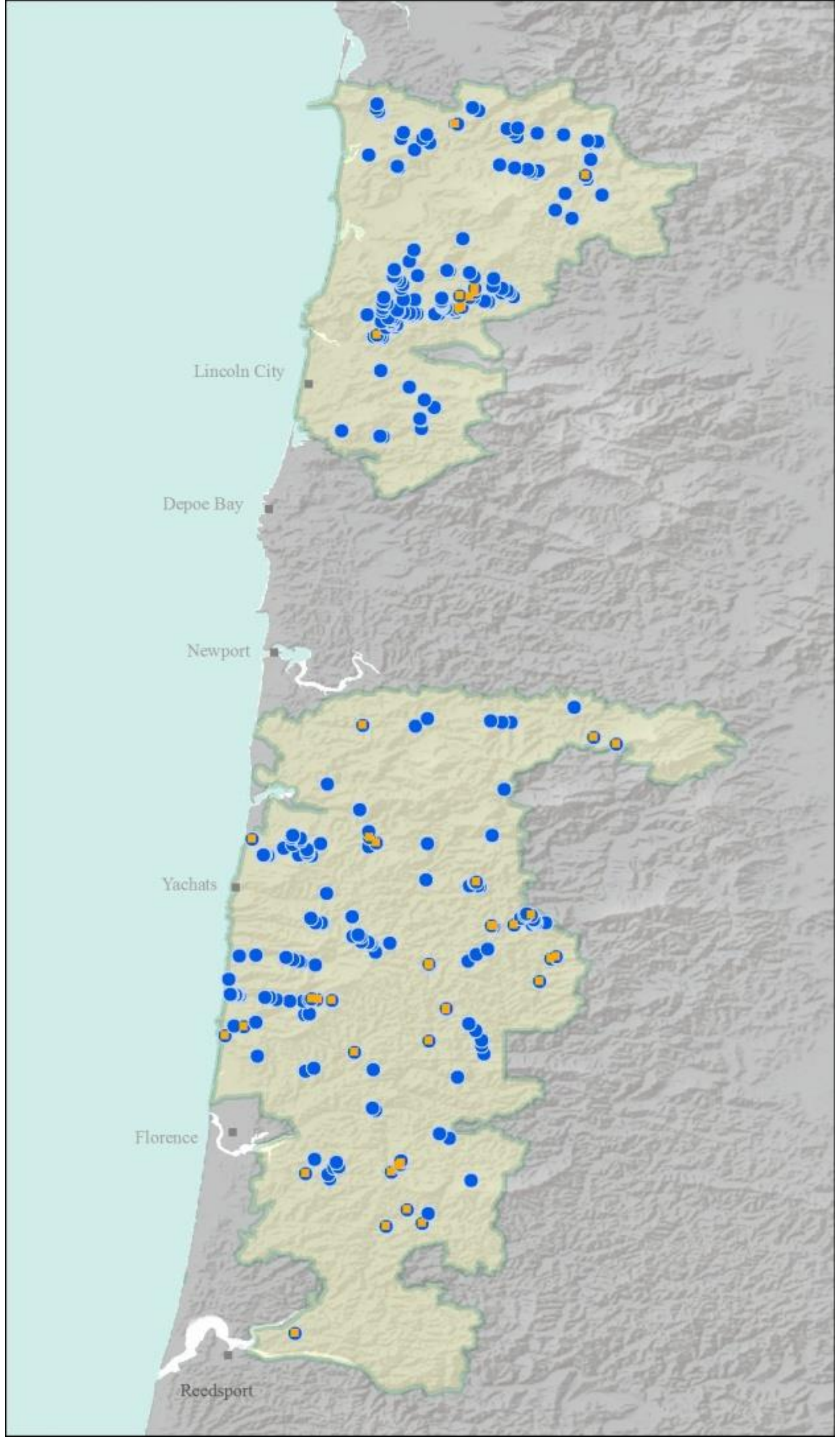
Project Level Approach: *Inferential limitations*



How do individual crossings relate to fish populations across landscapes?

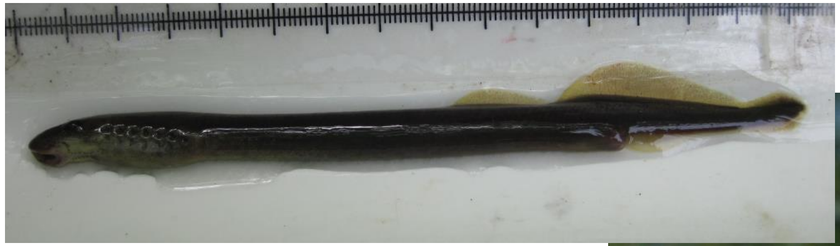
Programmatic Level Approach

- Are replaced culverts passing fish as well as natural streams do?
- What is the broader benefit to fish distribution and abundance?

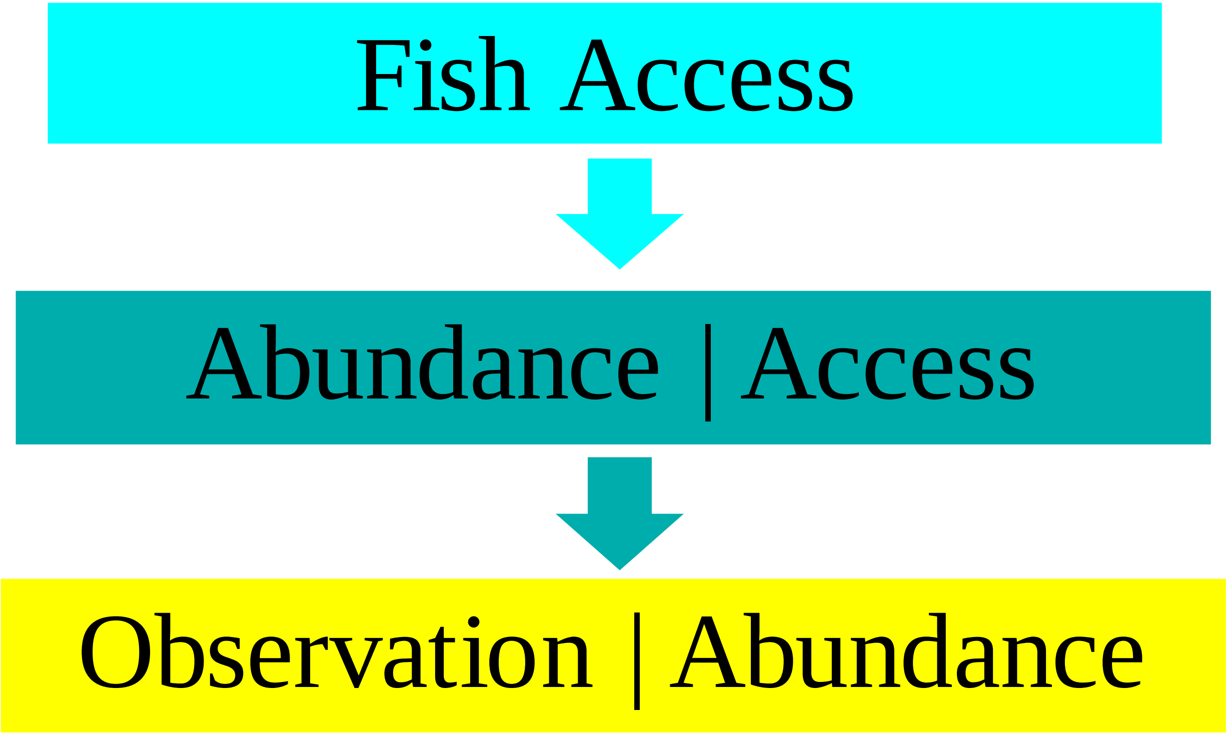


Programmatic Level Approach Challenges

- Different configurations for culverts
- Different local conditions (gradient, discharge, etc.) among culverts
- Variable species pools
- Imperfect detection, capture probabilities



3-Level Probability Model



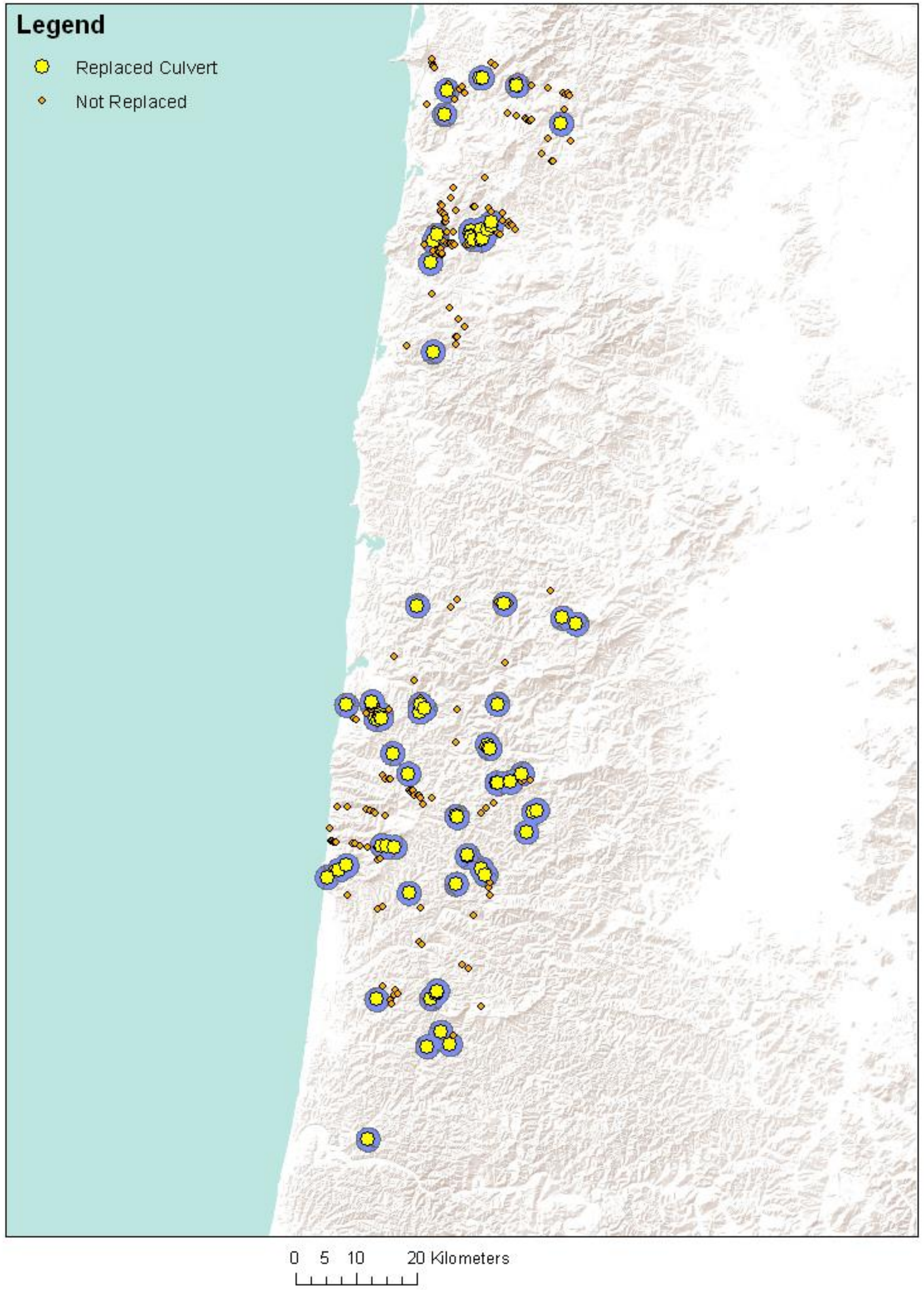
Connectivity and conditional models of access and abundance of species in stream networks
NATHAN D. CHELGREN AND JASON B. DUNHAM
Ecological Applications, 25(5), 2015, pp. 1357–1372

Sampling Design

•Population of interest = population of culverts replaced to stream simulation standards.

•Focus on studying networks surrounding replaced culverts.

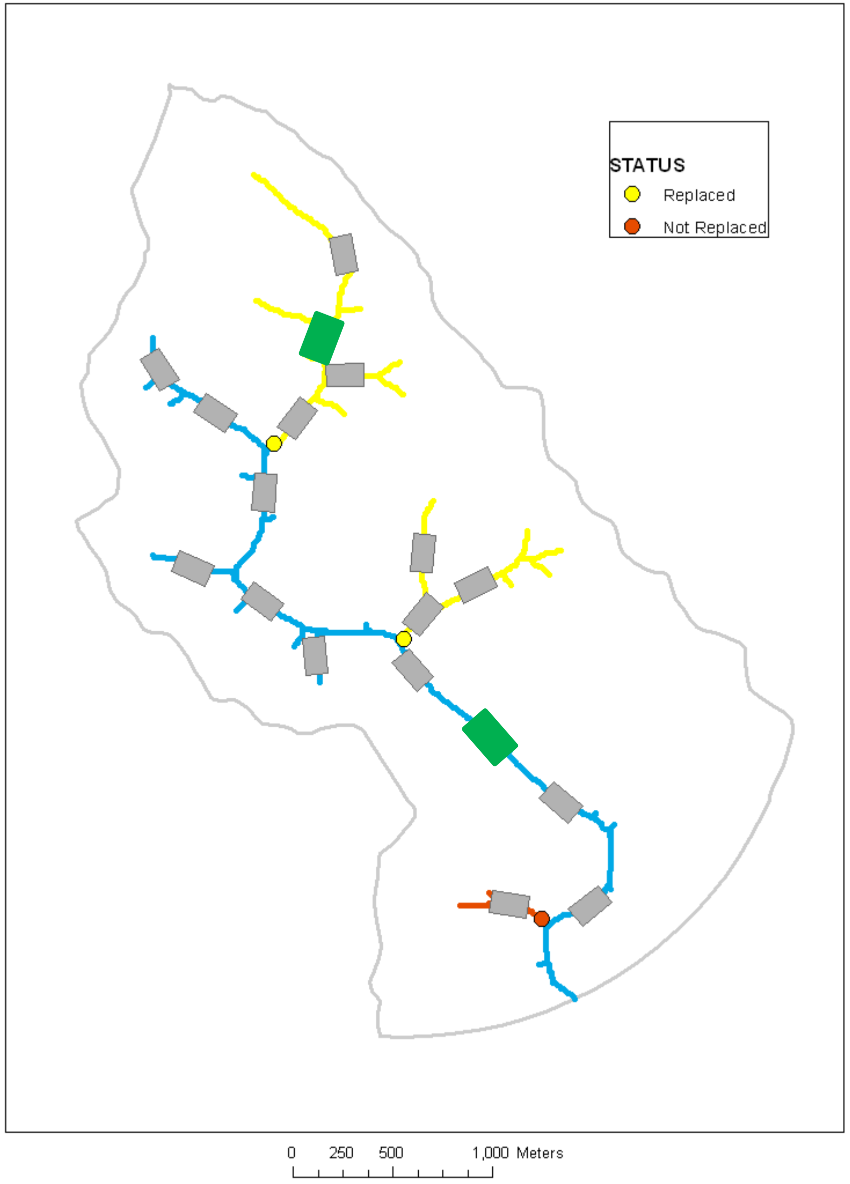
•Networks delineated by ~2 km segments adjacent to replaced culverts.



Capture probability estimates

- Randomly sampled the sub-networks by single pass electrofishing in 30-m plots (spatially balanced sample - gray).

- Used multiple passes randomly on some of the 30-m plots (green) to estimate capture probability.



J. Dunham, 2015

Lesson 1

- Fish capture probabilities are **low** overall
- Numbers of fish lower in smaller streams
- Detectability decreases as channel increases in width
- If culverts reduce actual numbers of fish, we may overestimate their influence on species due to low detectability

Lesson 2

- New designs work
- Probability of access is similar between replaced culverts and natural stream channels
- Applies across all species
- Main “barrier” for species access was channel gradient in networks
- Replaced culverts opened 187 km of channel to fish but less that 10% of that (12.39 km) could be colonized by fish

Lesson 3

- Although new crossings allow fish access, the upstream benefits are limited
  - NOTE – This may NOT apply to your situation!
  - AND there are other reasons to fix culverts
- Resident fish likely present before/after
  - BUT may temporarily experience inbreeding during isolation (Wofford et al. 2005 showed the more barriers the more inbreeding)

2006 floods on Mount Hood National Forest (photo courtesy of Dan Shively)

Lesson 3

- Lack of pre-restoration information may contribute to lower estimated benefits
  - Investment in prior information *is* actually cost effective – We cannot afford *not* to know

- Lower gradient lands off SIU are key to fish

Ecological Applications, 17(1), 2007, pp. 66–80

DISTRIBUTION OF SALMON-HABITAT POTENTIAL RELATIVE TO LANDSCAPE CHARACTERISTICS AND IMPLICATIONS FOR CONSERVATION

KELLY M. BURNETT,[1,4] GORDON H. REEVES,[1] DANIEL J. MILLER,[2] SHARON CLARKE,[3,5] KEN VANCE-BORLAND,[3] AND KELLY CHRISTIANSEN[1]

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The Good News

- We now have means of evaluating an entire program of passage restoration
- Data before and after can help to better estimate benefits….and priorities
- Sampling protocols easily used by field crews

Recommended Readings

1680

NRC Research Press

ARTICLE

Genetic monitoring of trout movement after culvert remediation: family matters[1]

Helen M. Neville and Douglas P. Peterson

1667

NRC Research Press

ARTICLE

Simulation and empirical analysis of novel sibship-based genetic determination of fish passage[1]

Andrew R. Whiteley, Jason A. Coombs, Benjamin H. Letcher, and Keith H. Nislow

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science for a changing world

Prepared for USDA Forest Service, San Dimas Technology & Development Center, San Dimas, CA 91773; Interagency Agreement No. 09-IA-11138150-041

Aquatic Organism Passage at Road-Stream Crossings— Synthesis and Guidelines for Effectiveness Monitoring

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Maintaining passage of aquatic organisms through modification or replacement of barriers (e.g., culverts) at stream-road crossings represents one of the Nation's largest investments in restoring aquatic ecosystems. Current federal guidelines specify stream simulation as the standard for passage restoration (Stream Simulation Working Group 2008). From a biological perspective the intent is to design crossings that allow for natural movements of native aquatic organisms, including species that depend on water for movement such as fish, amphibians, and aquatic invertebrates. The extent to which design standards, such as stream simulation, allow for natural movement of aquatic organisms remains a major question of interest.

The most direct way to evaluate aquatic organism passage is to monitor movements of individuals through crossings. Recent advances in tagging and telemetry (e.g., radio and acoustic telemetry, passive integrated Schwartz et al. 2007). These methods allow for individual identification and detailed analyses of individual movement, but can be expensive and technically challenging to implement.

In practice resources are usually more limited, and tracking of "batch" marked or tagged individuals may be a more feasible approach to evaluating individual movement. Examples include marks such as fin clips (fig. 1; Burford et al. 2009) and tags (e.g., external tags or injected dyes or polymers; Ficke and Myrick 2009; Guy et al. 1996). With this approach "batches" of generically marked or tagged individuals are released at a given location and subsequently recaptured or re-sighted to infer movement (fig. 1). Whereas methods of marking or tagging are often the initial focus of such studies, their design and implementation often have a greater influence on study outcomes. With this in mind, our objective here is to briefly review study designs that can be used with batch marking or tagging

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Ideas and opinions expressed are not necessarily Forest Service policy. Citations, reviews, and use of trade names do not constitute endorsement by the USDA Forest Service.

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USDA United States Department of Agriculture

Forest Service

Rocky Mountain Research Station

General Technical Report RMRS-GTR-174

September 2006

Strategies for Conserving Native Salmonid Populations at Risk From Nonnative Fish Invasions:

Tradeoffs in Using Barriers to Upstream Movement

Kurt D. Fausch
Bruce E. Rieman
Michael K. Young
Jason B. Dunham