Effects of habitat degradation on salmon and trout populations: Logging practices as a case study in the complexity of salmonid life cycles

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Why worry about habitat?
Factors responsible for risk in 214 stock complexes

More than one factor was responsible for risk in many cases

Nehlsen et al. 1991

Habitat
Overfishing
Biotic Factors
Understanding the degradation process may help guide efforts to reverse it.

pre-development

Restoration

Rehabilitation

Substitution

Degradation

present
Forest Practices: Activities, physical effects, and consequences for salmon

1) Physical Activities of Forest Management:
   i. Road building
   ii. Harvesting
   iii. Yarding

2) Effects of management
   i. Sediment
   ii. Temperature
   iii. Woody Debris
   iv. Flow regime

3) Consequences for Fish
   i. Survival
   ii. Growth
   iii. Movement
Physical Activities of Forest Management

A. Road building
B. Harvesting
C. Yarding (removal)
D. Fertilization
E. Herbicides/pesticides
Physical effects of forest management

- **Temperature**
  1) Clear cutting elevates local air temperature
  2) Loss of riparian shade increases solar radiation
  3) Sedimentation decreases stream depth, increasing temp variation
  4) Groundwater volume and/or temperature?
Paired stream July temperatures, Hubbard Brook, NH

Likens et al. 1970. Ecological Monographs 40
Summer temperatures (May – Sept) with and without logging, Carnation Creek B.C.

Holtby and Scrivener 1989
Generalized physical and simple biological effects of logging

- **Temperature**
  1. Summer: warmer, more day-night variation
  2. Winter: “Shorter” (in coastal zone)
  3. More rapid incubation of embryos
  4. Higher scope for growth or thermal stress
Consequences for fish of altered thermal regimes

Elevated temperatures accelerate embryo development, causing earlier emergence.

Elevated temperatures can accelerate growth if food is sufficient, resulting in larger parr and higher survival rates.
Consequences for coho salmon
Carnation Creek, B.C.

Logging was associated with earlier emergence, faster growth, and a shift to primarily age-1 coho salmon smolts.
Effects of forest management

- Woody Debris Reduction
  1) Splash dams: early practice of removing debris to transport logs
  2) Removal of downed trees
  3) Removal of live trees that would eventually fall over
  4) Debris removal: Mistaken notion that wood blocked fish passage

Splash dam
Generalized physical and simple biological effects of logging

- Woody Debris
  1. Removal from stream and loss of tree “recruitment”
  2. Fewer, smaller pools
  3. Simpler channel
  4. Less flow variation
  5. Less fine organic debris
  6. Loss of streamside vegetation also affects incident light, primary production, and the insect community
Consequences for fish of woody debris reduction

- Woody Debris
  1) Provides cover in summer
  2) In winter, structures and shapes the stream
  3) Traps fine organic material, enhancing production
More abundant and larger woody debris

Higher diversity (species and ages) and density of fishes

More and larger pools, more complex habitat

(Greater benefits for some species than others)
Loss of woody debris occurs slowly (and recovery is slow too)

Hartman et al. 1996. CJFAS 53:237-251
Generalized physical and simple biological effects of logging

• **Sediment**

1. More fine material, chiefly from roads
   
   Survival to emergence decreases:
   
   • coho decreased 29.1 to 16.4 %
   • chum decreased 22.2 to 11.5 %

2. Reduced insect density and fish growth

3. Loss of large pools for adult holding
   
   • Grand Ronde: 70% decrease
   • M.F. Salmon: 40% decrease
   • Willamette: 55-90% decrease
Increased sedimentation:
1) road surfaces, and
2) “mass wasting” (landslides)

Cederholm 1982
Sediment yield from surface erosion

South Fork, Salmon River, Idaho

Platts (1989) TAFS 118:274-283
Consequences for salmon

Egg to fry survival for chum and coho salmon in Carnation Creek.

Percent egg to fry survival

Year

Logging Freshet

coho

chum

Hartman et al. 1996. CJFAS 53(suppl. 1):237-251
Generalized physical and simple biological effects of logging

• Flow Regime
  1. Increased peak flow for a given rainfall
  2. Increased snow pack at intermediate elevations; greater “rain on snow events”
  3. Scour of gravel, intrusion of fine sediment into redds
Changes in the hydrologic cycle

1) Tree removal tends to increase variation of flow: reduced vegetation speeds delivery of water to the stream.

2) Rain-on-Snow flood events: snow evaporates from trees but accumulates in clearcuts.

Jones and Grant 1996. Water Resources Research 32:959-974
Consequences for Fish

- Hydrology
  - Overall, most salmonids die in the egg-fry period (50-90%)
High winter flows reduce the survival of salmon embryos in the gravel.
What is the overall effect?

Logging practices have complex effects on key physical features of streams (temperature, sediment, flow, and woody debris). These effects may magnify or offset each other, so what is the overall consequence for fish populations?

How do we measure the consequence, and over what time frame?
How do we assess the consequences of Forest Management’s physical effects?

• Approaches:
  1) Controlled Lab Studies: cheap, quick, convincing. Relevant?
  2) Field Studies: costly, protracted, realistic. Convincing?
Adult chum salmon
Carnation Creek
When did logging occur?

[Bar chart showing adult chum salmon counts by year from 1971 to 1995.]

Tschaplinski 2000
Adult chum salmon
Carnation Creek

Pre-logging  During logging  Post-logging

Year

Adult chum salmon

Tschaplinski 2000
Adult coho salmon
Carnation Creek

Pre-logging  During logging  Post-logging

Year

Adult coho salmon

Tschaplinski 2000
Juvenile coho salmon density
Carnation Creek

Pre-logging  During logging  Post-logging

Cohio salmon parr (thousands)

Year

Tschaplinski 2000
So, does logging decrease salmon populations?

- Problems with before – after approach:
  1. Climate variation (FW and SW)
  2. Density dependent processes
  3. Complex life cycles
Carnation Creek: Two different modeling approaches

First, assemble quantitative information on life history, population dynamics, and other aspects of the basic biology of each species.

Then, examine the climate that was observed during the period of the study, and consider how things might have been different had the climate been otherwise. This helps avoid some of the pitfalls of the “before – after” study design.

Holtby and Scrivener 1989
Carnation Creek: Two different modeling approaches

- Compare stock-recruitment after logging with that simulated based on observed climate but no logging
- RESULTS:
  - Chum escapements down 34.9%, coho down 5.9%

Holtby and Scrivener 1989
Carnation Creek: Two different modeling approaches

- Simulate the effects of a 40% clearcut (which was actually done) at different periods during the 20th century for which climate records existed. This was designed to account for the fact that the study was done in the period when the climate changed markedly.
- The thermal regime recovered in 15 years but habitat quality took about 50 years to recover.
- **RESULTS:**
  - 10 years after logging, chum escapement decreased 55-69%. Coho escapements increased slightly, then decreased slightly over 30 years.

Holtby and Scrivener 1989
Natural variation in abundance (especially of adults, and especially of anadromous species) makes the “head count” an insensitive measure of the result from a habitat-related action. However, the public wants to know: Are there more fish than there were before?

This is the ecological version of the politician’s question, “Well, are you better off now than you were 4 years ago?”

We must consider the statistical “power” to detect a change, which depends on sample size and variation.
Assessing Consequences for Fish

- Parameter Selection and Sample Sizes in Studies of Anadromous Salmonids

- “Natural variation was examined for several important parameters of anadromous salmonid populations. Survival and abundance showed low statistical sensitivity to detect change, while parameters which dealt with time and size at an important life history stage showed high sensitivity. Studies of survival and abundance may require 20-30 years of produce and 80% chance of detecting a 50% change, while studies of time and size at important life history stages should require 8 to 10 years to provide and 80% chance of detecting a 5% to 15 % change”

- Lichatowich and Cramer ODFW (1979)