

The Carnation Creek Fish-Forestry Interaction Project



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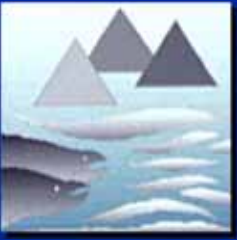
Carnation Creek Background

- ◆ Basin-scale case study of the effects of forestry practices on watershed processes and fish populations
- ◆ Now in its 40th Year
- ◆ Has generated the longest-term continuous datasets on fish-forestry interactions
- ◆ Initiated in mid 1970 by Fisheries and Oceans Canada & key industry and government partners
- ◆ Initiated because of lack of local BC information on the effects of harvesting on fish populations



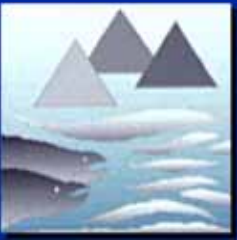
Research & Monitoring Objectives

1. What is the cumulative effect of watershed-scale harvesting beyond specific levels (e.g., 65% harvest)?
2. What is the effect on channel morphology and aquatic (e.g., salmon) habitats in both larger streams and their smaller tributaries when the riparian vegetation is removed or modified?
3. What biological changes result from these altered stream habitats?
4. How long do these physical and biological changes persist?
5. What has been the contribution of climate variability to observed physical and biological changes?
6. What are the implications of climate change for watershed processes and Pacific salmon?



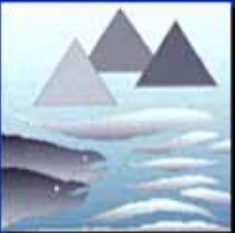
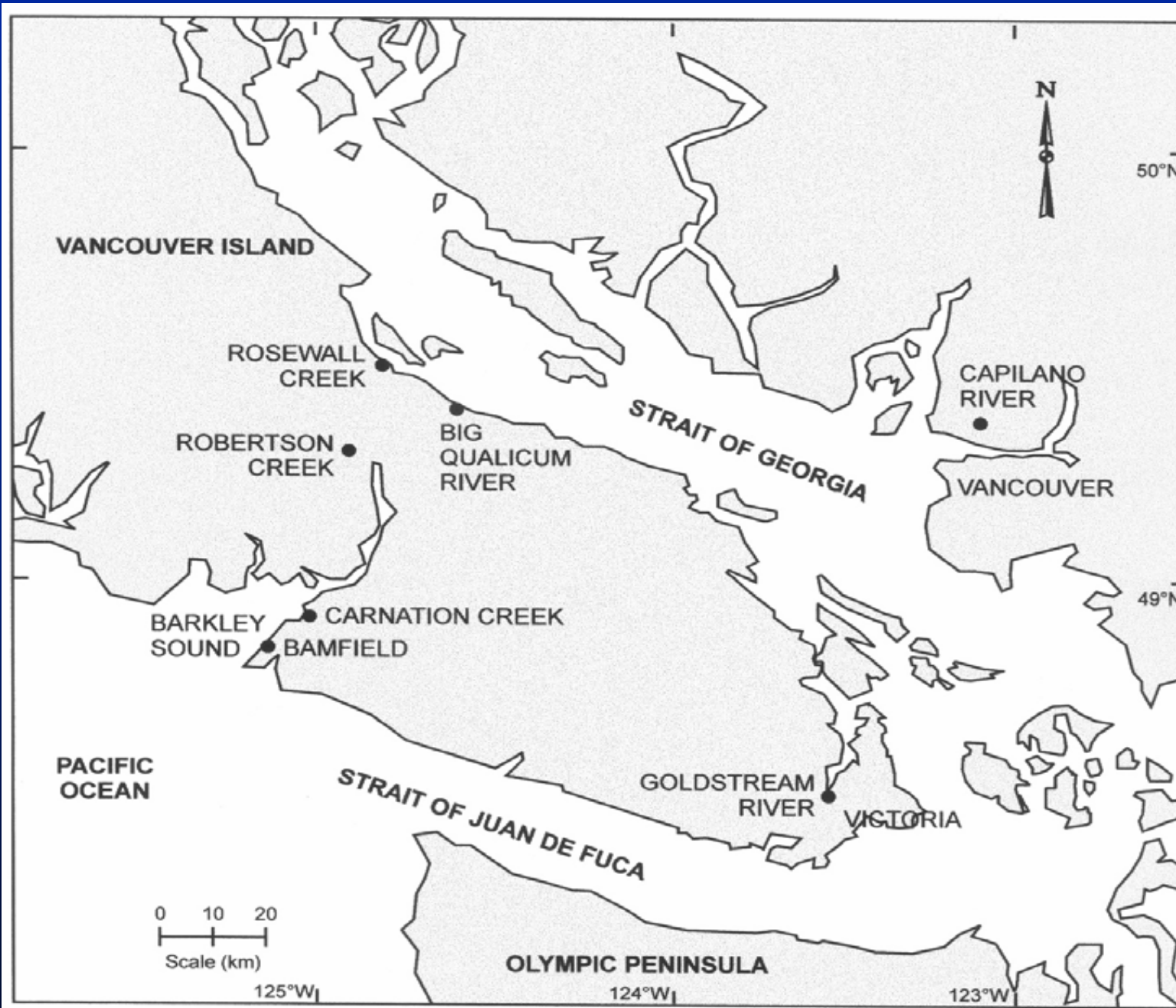
Presentation Objectives

- ◆ Illustrate changes in salmon populations in Carnation Creek over 5 Pre-Logging, 6 During-Logging, and 28 Post-Logging Years (1970 – 2009)
- ◆ Demonstrate that the effects of forest harvesting are complex
 - vary by species (coho, chum, trout)
 - vary by life stage (eggs, fry, smolts, adults)



Presentation Objectives (cont'd)

- ◆ Illustrate that salmon production from coastal streams depends on
 - **Watershed processes and land-use management**
 - **Marine processes including fishing & predation**
 - **Interactions between freshwater and marine processes**
 - **Climate variability**
- ◆ Point to the value of long-term, multi-disciplinary studies for clarifying complex interactions among land-use practices, climate variations, watershed processes, and salmon populations



Barkley Sound

Carnation Creek ca. 1977

Watershed area: 11 km²

Elevation: Sea level to 800 m

Hillslopes: 40 – 80% gradients

Creek length: 7.8 km

Anadromous salmon habitat: 3.1 km

Annual precipitation (rain-dominated): 2,900 mm at low elevation, up to 4,800 mm at high elevation

Summer low flow – $0.02 \text{ m}^3/\text{s}$
Station B streamflow weir



Autumn freshet at Station B streamflow weir
Storm discharges up to 65 m³/s





Carnation Creek Camp, late 1970s



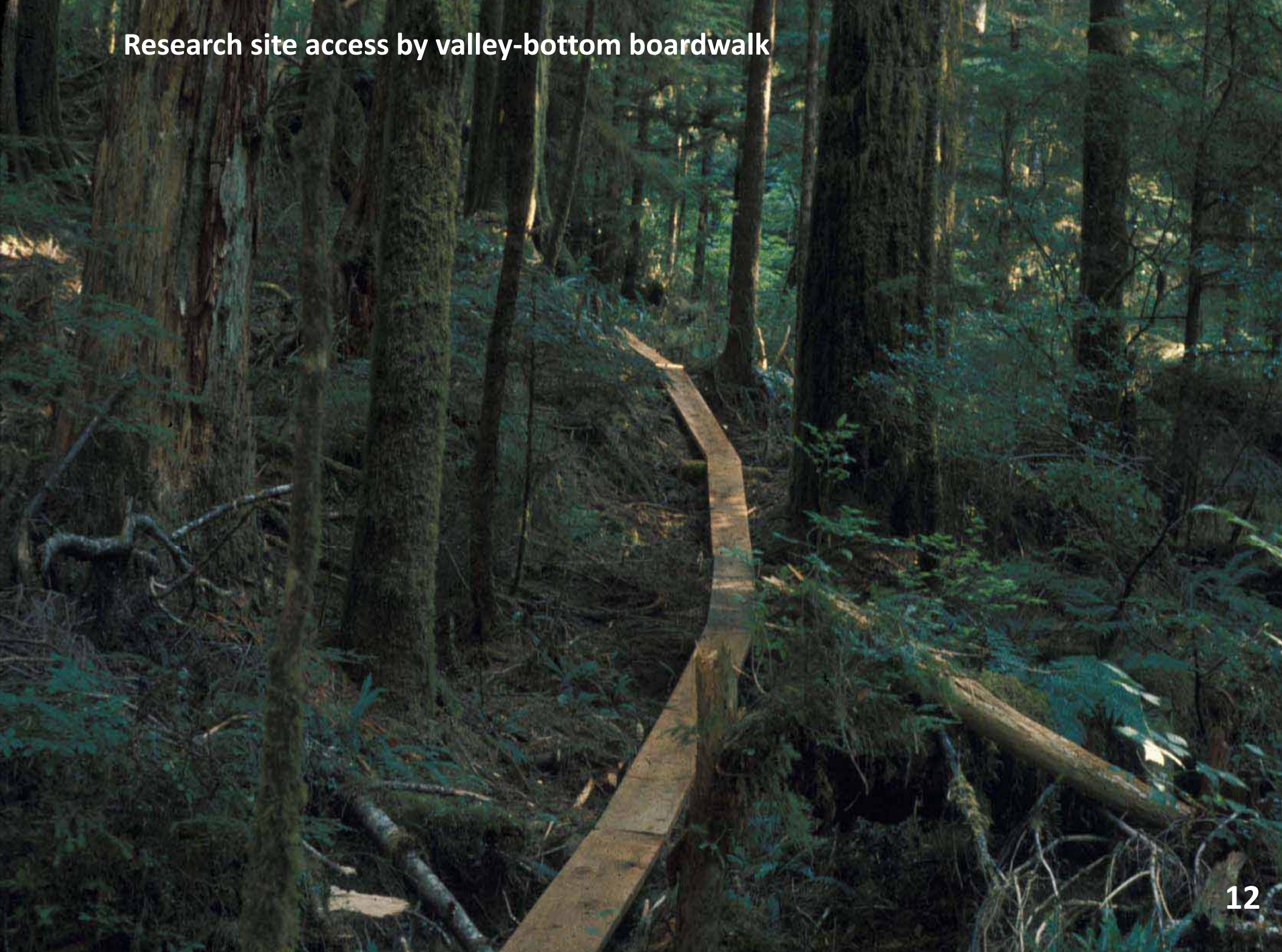
Steve Voller photo

Carnation Creek Camp, June 2010



Carnation Creek mature forest and ground
cover near new harvest opening

Research site access by valley-bottom boardwalk



Road building, 1975



Road to camp

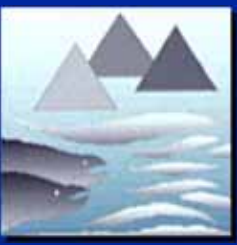


Fine sediment mobilization from road surface



Fine sediment runoff downslope from stream crossing





Harvesting initiated in winter 1975-76

- progressive clearcuts
- 3 riparian management treatments
- main harvest phase complete by 1981
 - 41% of watershed area harvested
 - Additional 25 % later under CFFG (Coastal Fishery Forestry Guidelines)



Tree felling on valley bottom





Carnation Creek 1981
Main harvest phase complete



Carnation Creek 2004

Intensive riparian harvest treatment





Cross-stream cable yarding

In-stream wood salvage



Riparian clearcut harvesting

**Two treatments: intensive (with in-stream activity), 900 m long
careful (no in-stream activity), 900 m long**





**Variable-width riparian
buffer, < 5 – 70 m wide,
1.3 km long**

Station B Main Streamflow Weir





1973

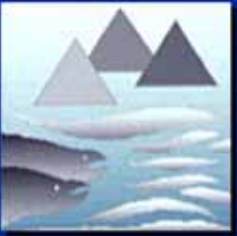
Tributary C (control sub-basin) Weir

Robin Pike photo



2008





Low elevation Climate Station A near Camp



Mt. Blenheim, high-elevation Climate Station D





Cumulative precipitation measurements the old-fashioned way, 1970s

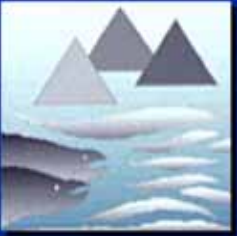
Climate station N

David Spittlehouse photo



Canopy rainfall interception, runoff, & stemflow – young forest stands





Streambed sediment samples

- frozen-core techniques
- track changes in amount & distribution of fine particles (e.g., sand)



Benthic invertebrate sampling

- streambed insects and other species
- important food source for juvenile salmon



Fish fence at head of tidal influence

- configured for monitoring seaward migrations (juvenile salmon in spring & early summer)



Fan traps





Sampling juvenile salmon

**Coho salmon fry (young of the year + Age 0);
60 mm long
Late summer**



**Coho salmon smolt – Age 1;
90 mm long**



**Steelhead (sea-going rainbow) trout smolt – Age 3;
190 mm long**



Sea-going (anadromous) Cutthroat trout – Age 2



Chum salmon spawners – Estuary pool



Marking adult salmon with disc tags



Summer assessments – resident fish population

Multi-pass electro-fishing



Summer assessments – resident fish populations

Multi-pass seining

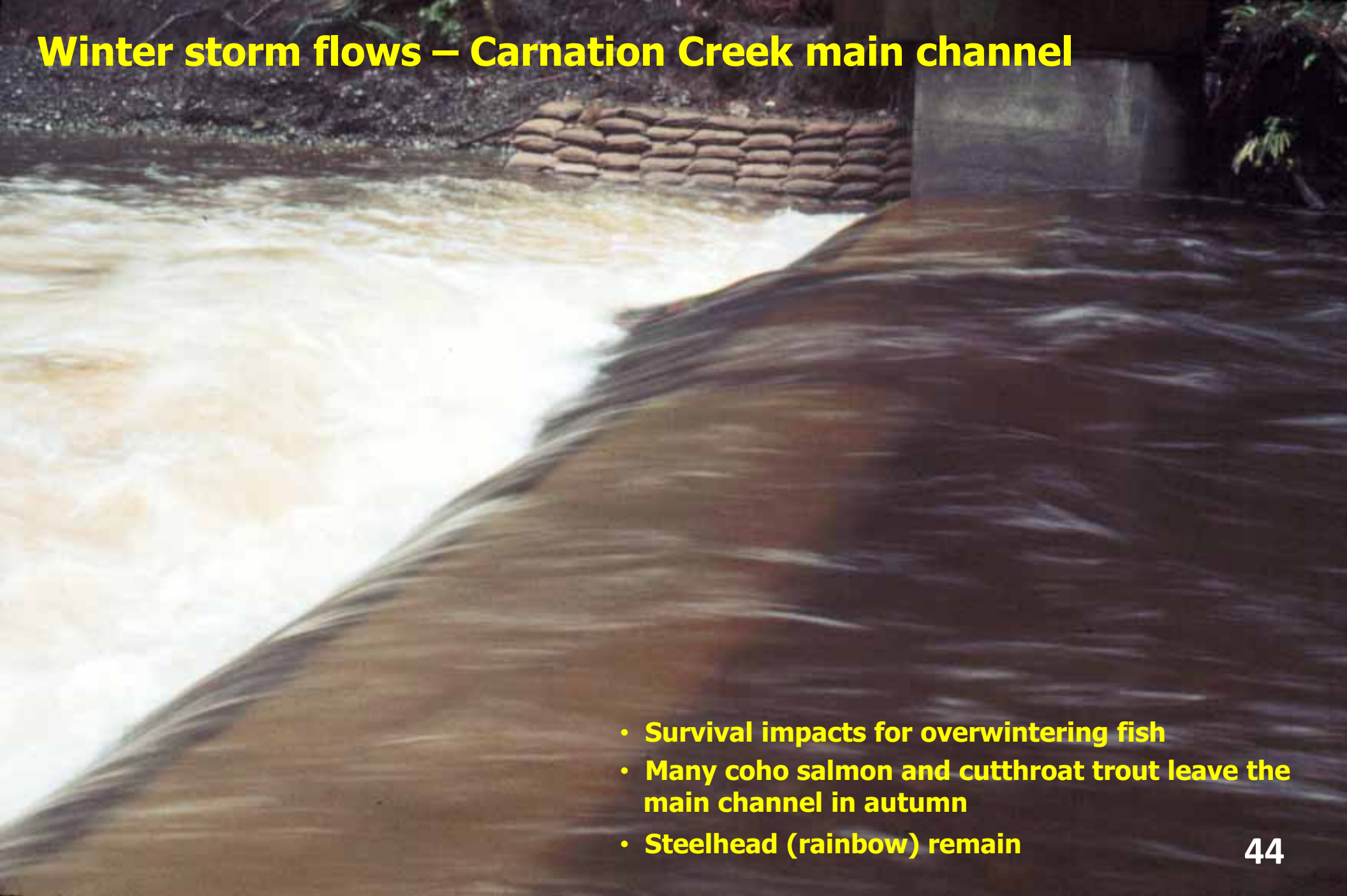


Overwinter fish population surveys

Snorkel counts



Winter storm flows – Carnation Creek main channel



- **Survival impacts for overwintering fish**
- **Many coho salmon and cutthroat trout leave the main channel in autumn**
- **Steelhead (rainbow) remain**

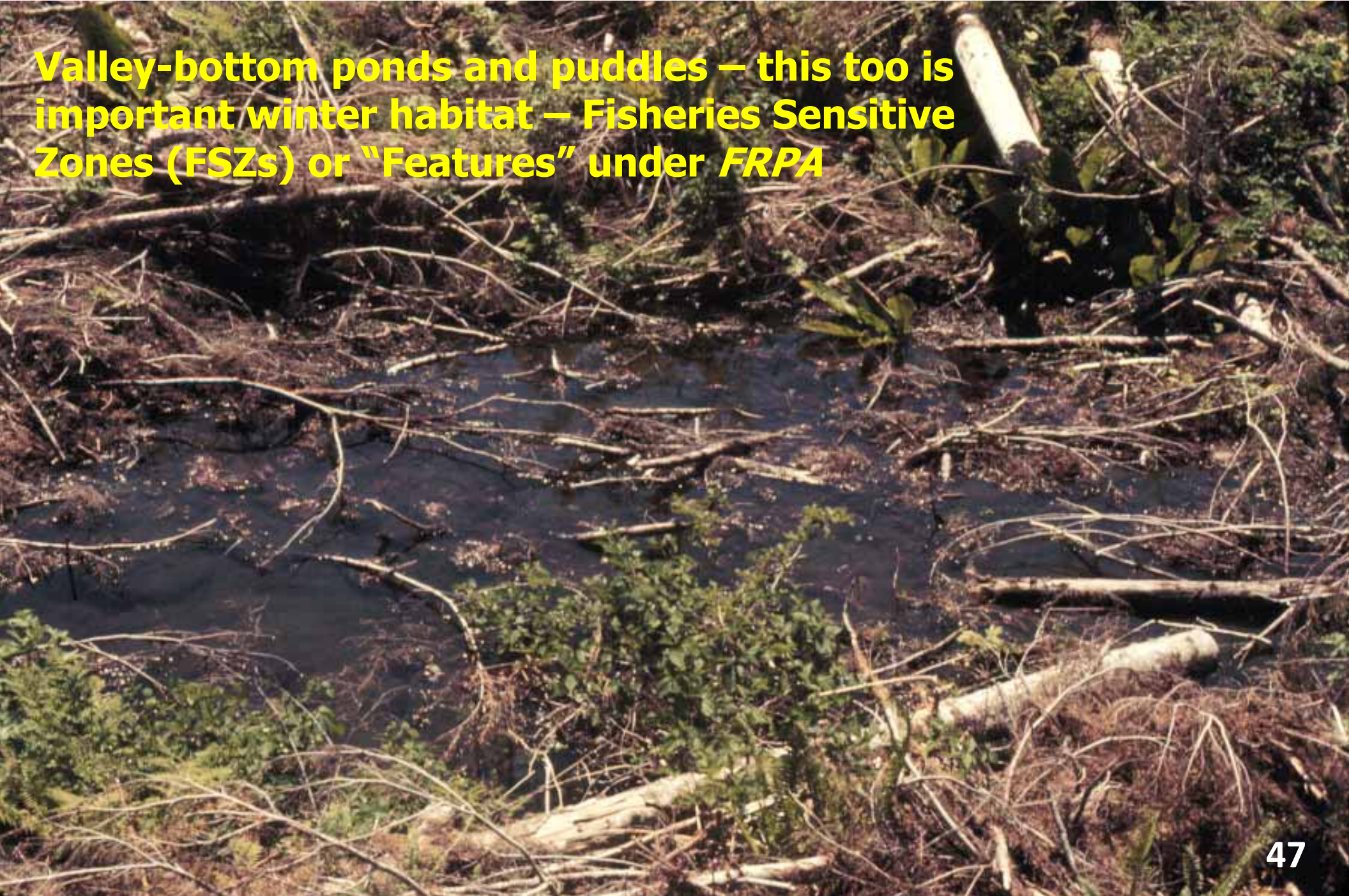


**Valley-bottom overwinter habitat
for coho salmon & cutthroat trout**

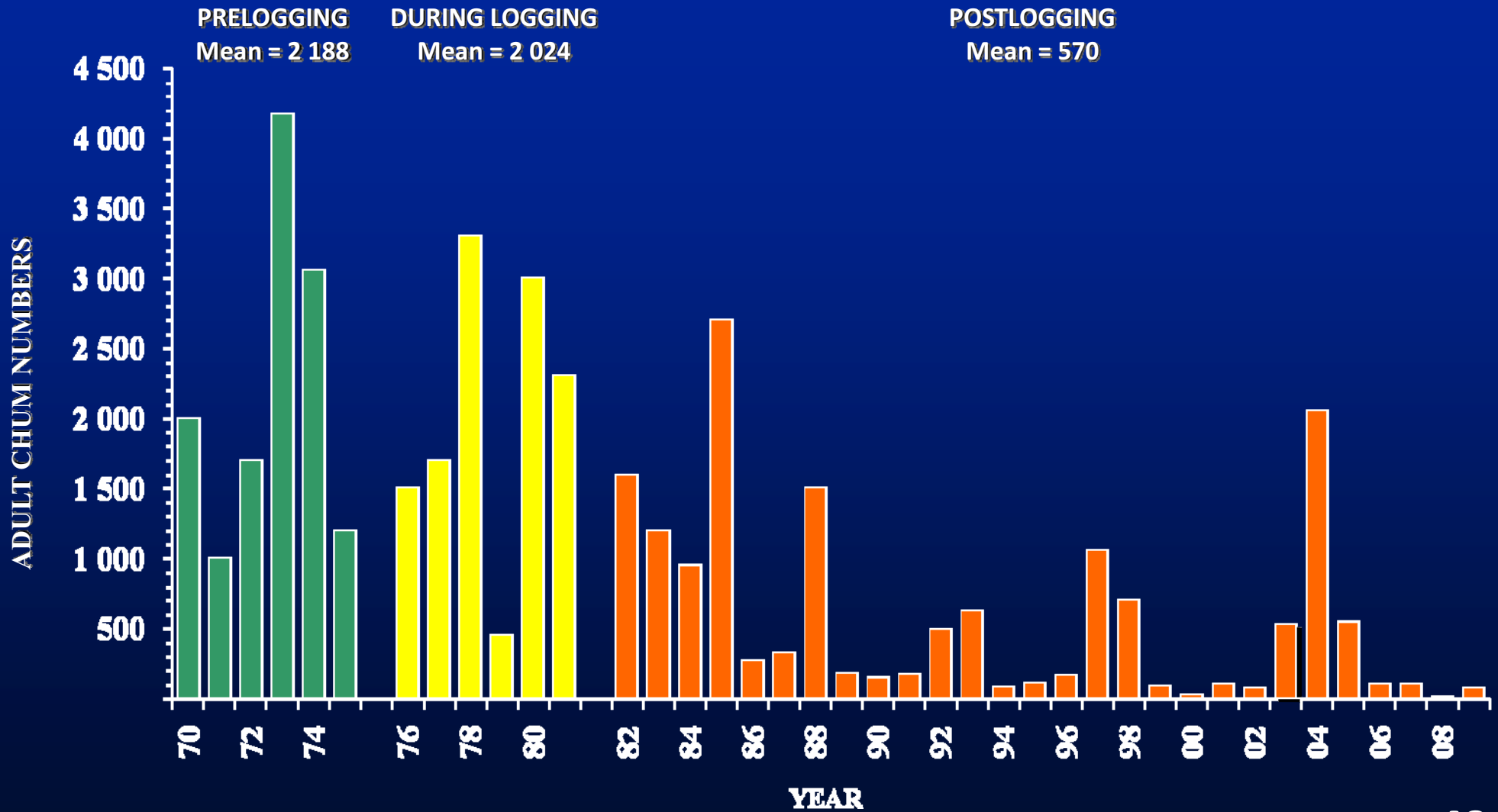
**This is fish habitat?
Winter habitat can look like this in summer**



Valley-bottom ponds and puddles – this too is important winter habitat – Fisheries Sensitive Zones (FSZs) or “Features” under *FRPA*



Adult Chum Salmon Returning to Carnation Creek, 1970 – 2009



Chum salmon

Forestry-related effects:

- 45% decline in egg survival (20% to 11%)
- Post-harvest fine sediment accumulation in spawning & egg incubation areas of streambed
- Thermal effects in stream affected marine survival: earlier egg hatch, fry emergence, seaward migration
- **Account for 25% of interannual variability in chum spawner returns**

Dominant effects: Climate-related (~equal fresh water vs. ocean)

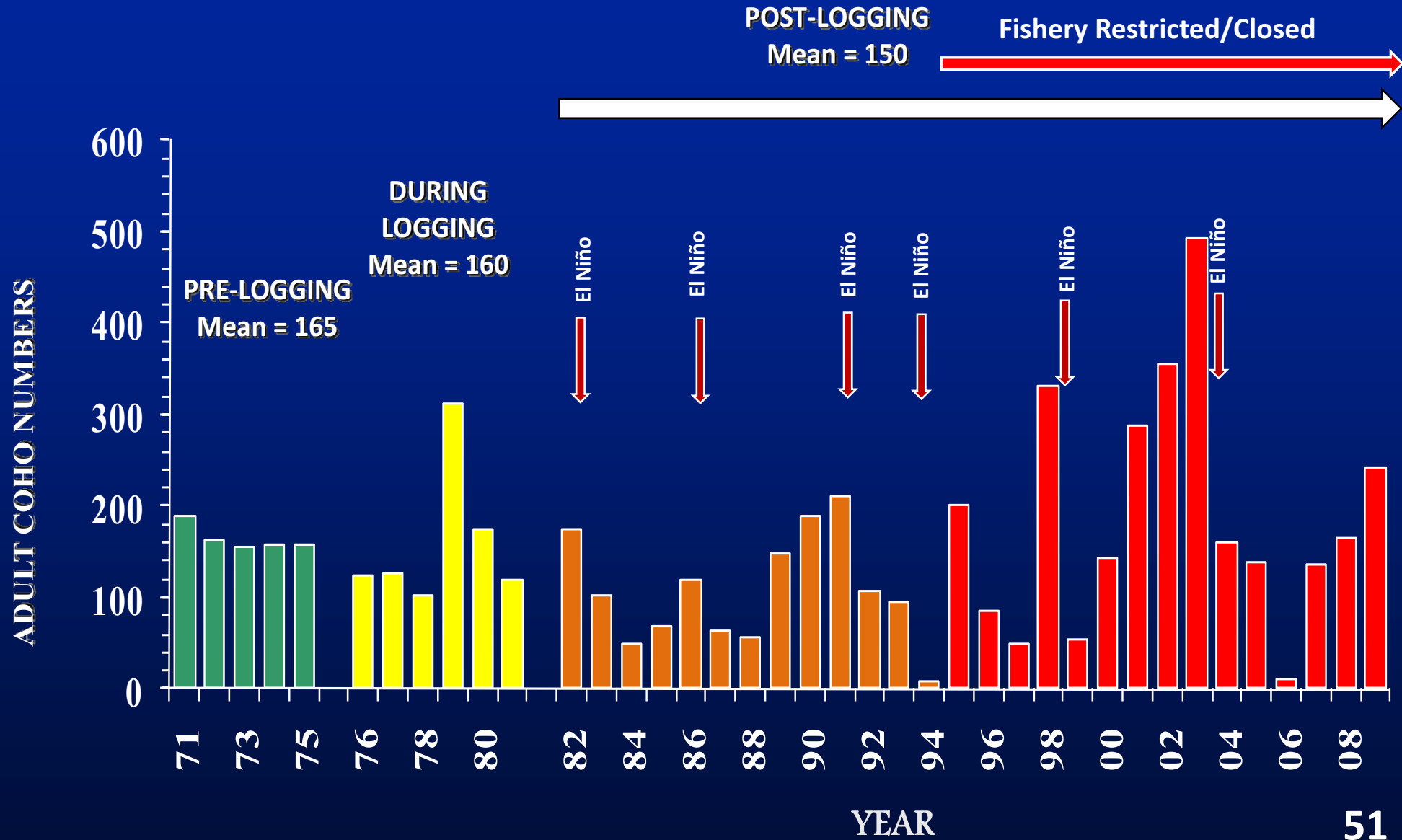
- freshwater: increased water temperatures
- ocean: lowered salinities, increased water temperatures, increased predation

Chum salmon spawning area – lower Carnation Creek & estuary



**Fish fence configured for adult salmon
migration monitoring**

Adult Coho Salmon Returning to Carnation Creek, 1971 – 2009



Coho salmon

Forestry-related effects mixed:

- Habitat alterations have reduced stream rearing capacity and juvenile population abundance
 - Thermal effects have increased growth, overwinter survival, and smolt production
- < 10% of interannual variability in coho spawner returns attributable to forestry**

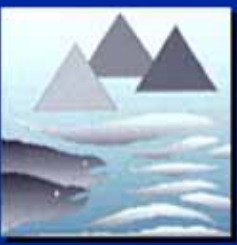


Pre-dominant effects: Climate-related with ocean changes outweighing freshwater changes

- Ocean effects:
- (1) Long-term temperature increases associated with global warming
 - (2) Periodic cycles of lowered salinities, increased water temperatures, lowered productivity, increased predation



**Diverse salmon rearing and spawning habitats:
pools, shallow riffles, & stable in-stream wood**



Prime pool habitat

- **stable undercut banks**
- **overhanging vegetation**
- **provides shade, cover & terrestrial invertebrate food source**





Post-harvest habitat changes

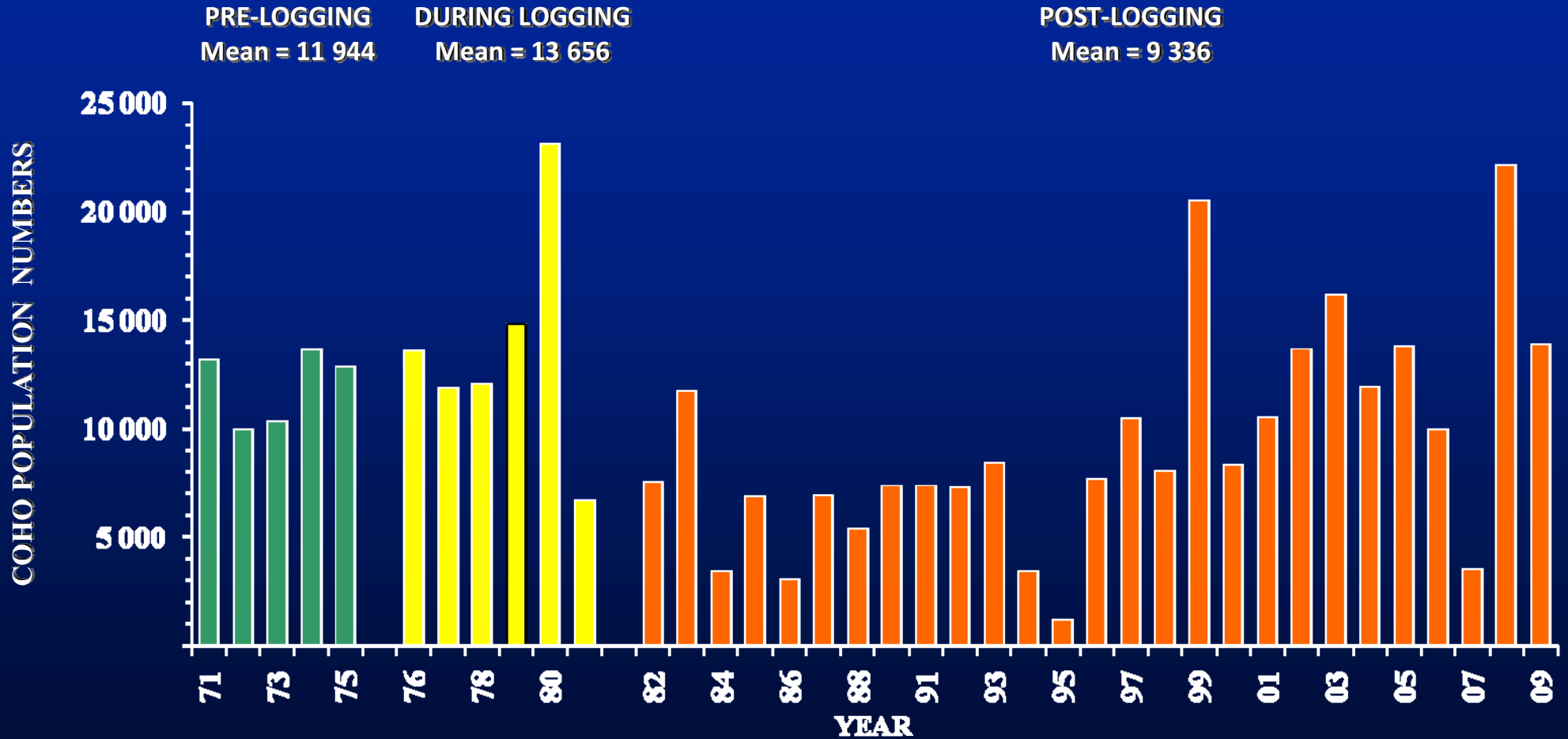
- **loss of structural diversity & in-stream functional wood**
- **accelerated bedload movements**
- **channel 2-3 X wider**
- **unstable, mid-channel bars and sediment wedges**
- **changes persist today**

Landslides, logjams, & long-term channel changes

- Channel instability; lateral erosion; bedload & woody debris movements
- Coho salmon egg survival reduced by nearly $\frac{1}{2}$ from 29% to 16%



Late-Summer Coho Populations in Carnation Creek, 1971 – 2009



Thermal Effects on Coho Salmon

- forestry and climate components
- riparian harvesting increased mean water temperatures in all seasons:
 - 0.7°C in winter
 - 3.2°C in summer

Outcomes of Winter Thermal Changes:

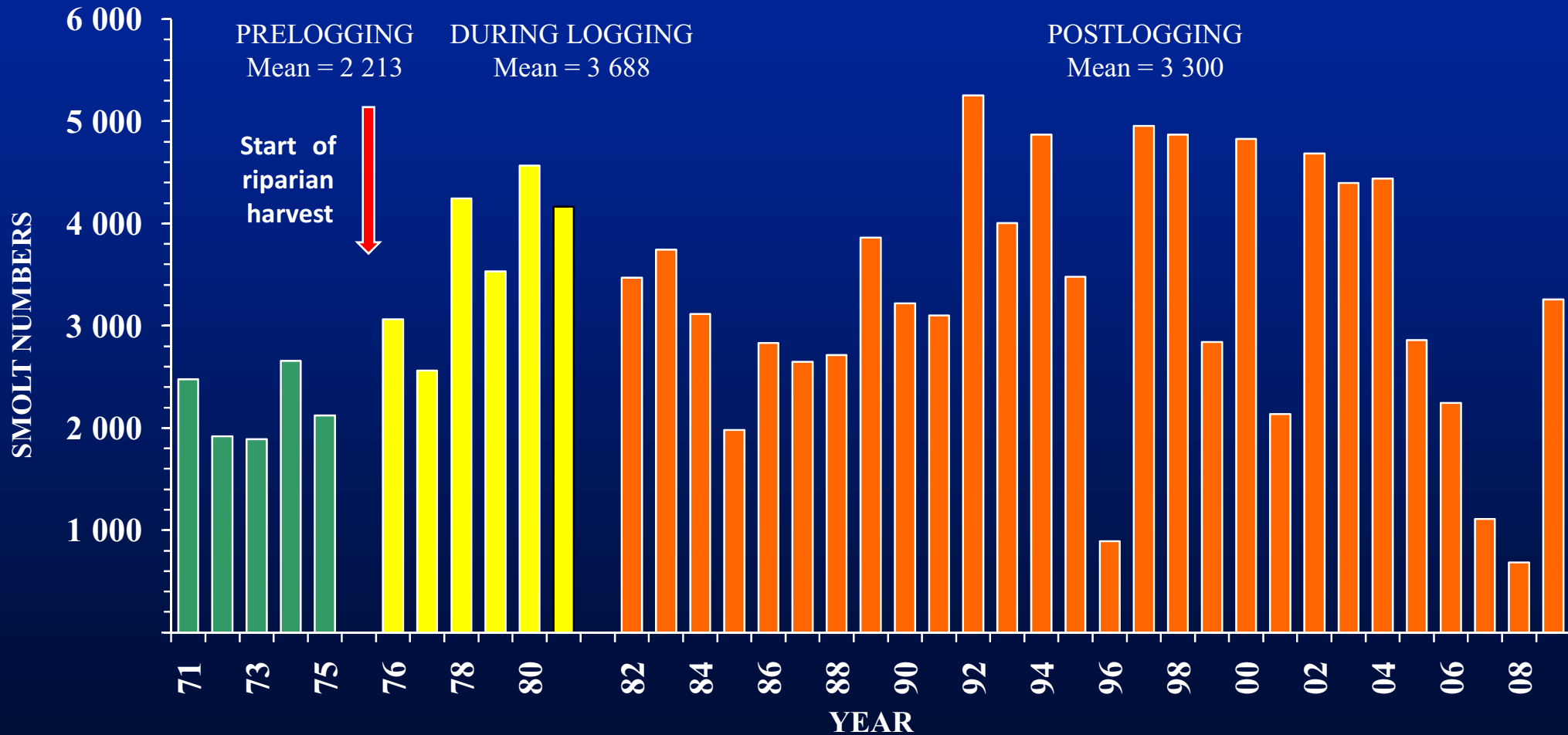
- Accelerated egg development
- Earlier fry emergence in spring (up to 6 weeks)
- Longer period of summer growth
- Larger size by autumn (11 mm longer)
- Better overwinter survival
- 1.6X increase in post-logging smolt numbers



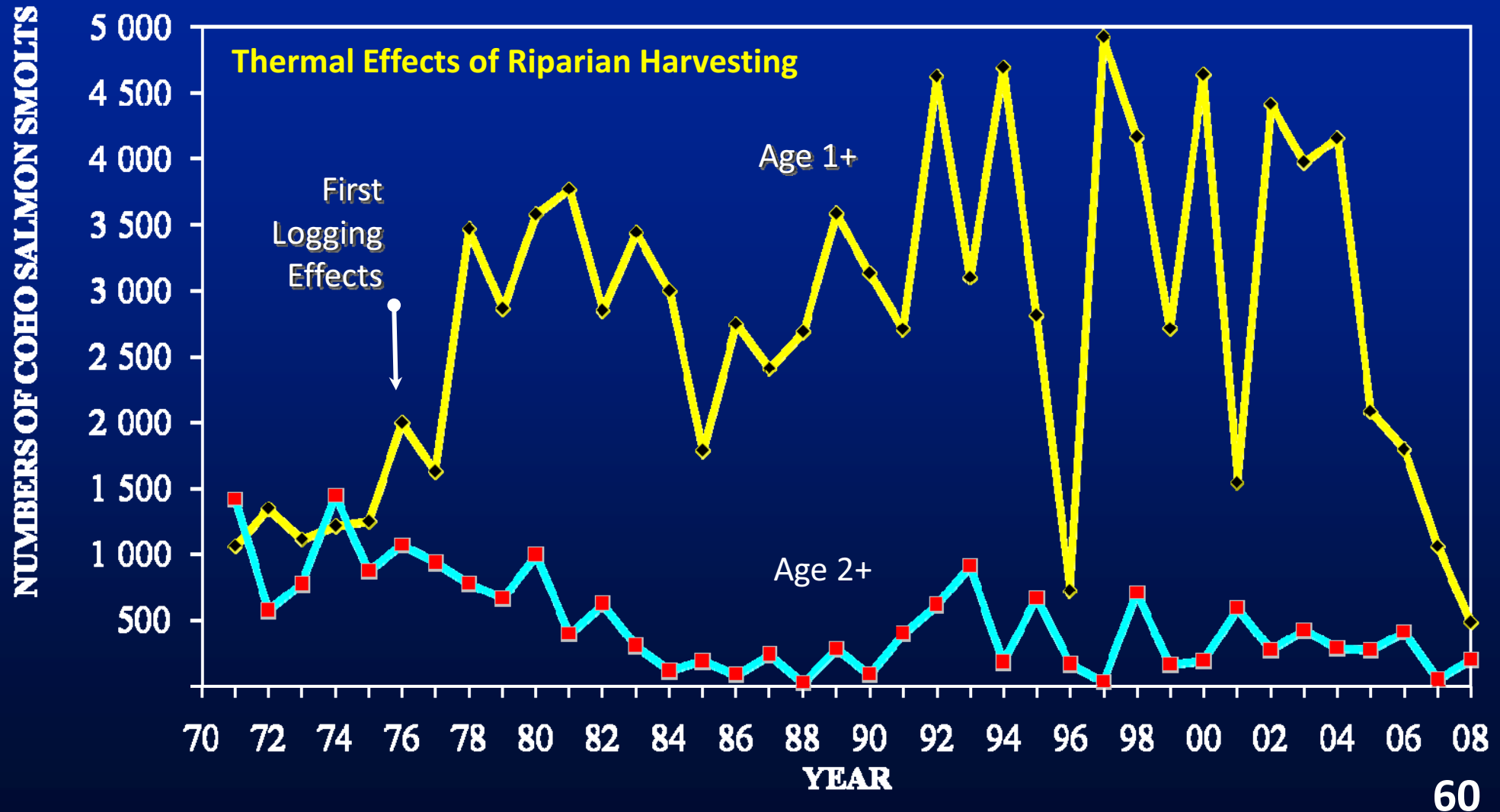
Coho salmon fry populations reduced by nearly ½ in post-logging period producing 1.6 X more smolts.

Coho Salmon Smolts Produced at Carnation Creek, 1971 – 2009

Thermal Effects



Comparing One-Year-Old vs. Two-Year-Old Coho Salmon Smolts Produced in Carnation Creek, 1971 – 2008



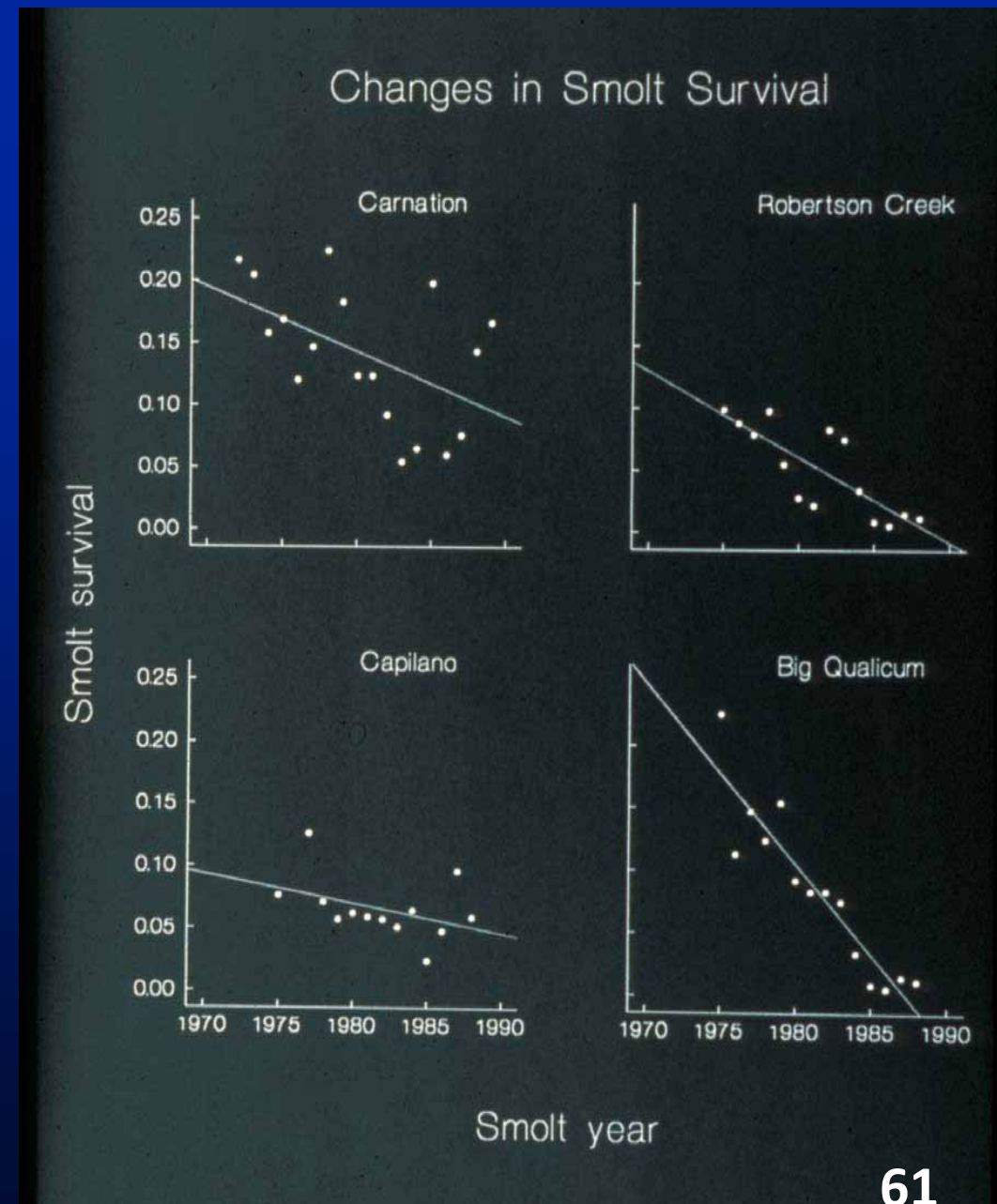


Ocean Survival Declines

- More smolts going seaward do not mean more adult spawners returning
- Decade-scale ocean survival reductions appear widespread & regional

Freshwater-marine linkages:

- shifts warmer stream temperatures mean shifts in smolt migration timing – up to 1 month earlier in spring
- survival-related implications
- migrations occurring during period of low marine productivity





Freshwater-Marine Linkages

Consequences for early migrations linked to forestry and climate

Winter marine conditions

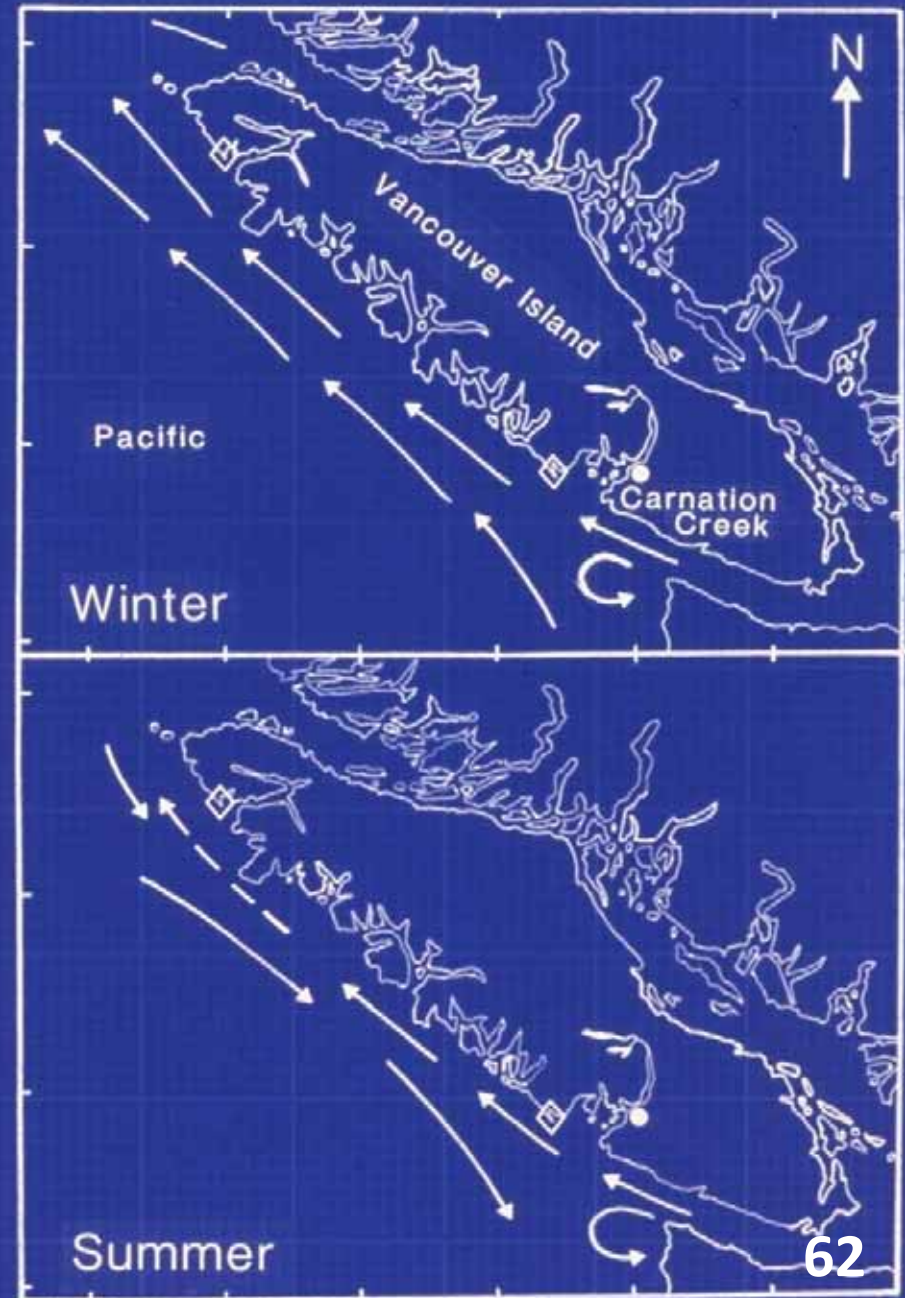
- northwest-flowing currents
- warm, low salinity, low productivity
- poor conditions for smolt survival
- long-term climate warming to emphasize these patterns?
- El Niño prolongs patterns into summer
 - moves zone of upwelling away from coast and to the north

More coho smolts entering the ocean in conditions unfavourable for survival

Summer marine conditions

- counter-current coastal flow generates upwelling
- Cold, nutrient-rich water
- high biological productivity (e.g., zooplankton)
- excellent conditions for smolt survival

Vancouver Island Coastal Currents





Future Implications for Watershed Conditions

- Second-growth forest management will predominate
- Conditions at Carnation Creek will be common in many watersheds harvested decades ago
- Streams will have residual forestry-related alterations from 1st harvest
 - Low abundance of functional in-stream wood (LWD)
 - Low levels of LWD input for several decades
 - Channel habitat quality alterations: wider, shallower, more bedload
 - Reduced capacity to support juvenile salmon
- Climate-linked shifts progressing with implications for water temperatures and salmon thermal preferences and tolerances
- Implications for riparian and watershed management for professionals in a result-based *FRPA*



Future Implications for Research & Monitoring

Future Thermal Regimes and Effects on Salmon

- Thermal regimes in Carnation Creek main channel have not recovered to pre-harvest levels 29-34 years after riparian harvesting
- Residual forestry effects: channel remains 2-3X wider – affecting shade available from 2nd growth riparian canopy
- Long-term climatic warming – differential effects on main channel and tributaries
- Can monitor changes in Carnation Creek with changes in unharvested, control Tributary C
- Monitor consequences for salmon population parameters, habitat use
- Distinguish climate-related & forest management effects



Future Implications for Research & Monitoring

Climate-related Disturbance Shifts in Rain-dominated Coastal BC Watersheds

- Increased frequency and magnitude of winter storms, peak flows, and related disturbances
 - Landslide frequency, channel disturbances, aquatic habitats
 - Impacts on fish egg survival, juvenile overwinter survival

Drier summers & more low-flow days

- Egg mortality for spring spawners (trout); habitat reduction for juveniles and resident adults for all species; thermal stress; thermal optima reached
- Impacts to small-stream communities: benthic invertebrate production & implications for fish food resources



Carnation Creek Research Team & Project Partners

BC Ministry of Forests and Range

BC Ministry of Environment

Environment Canada – Water Survey of Canada

Fisheries and Oceans Canada

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