Chinook & Steelhead Habitat Requirements

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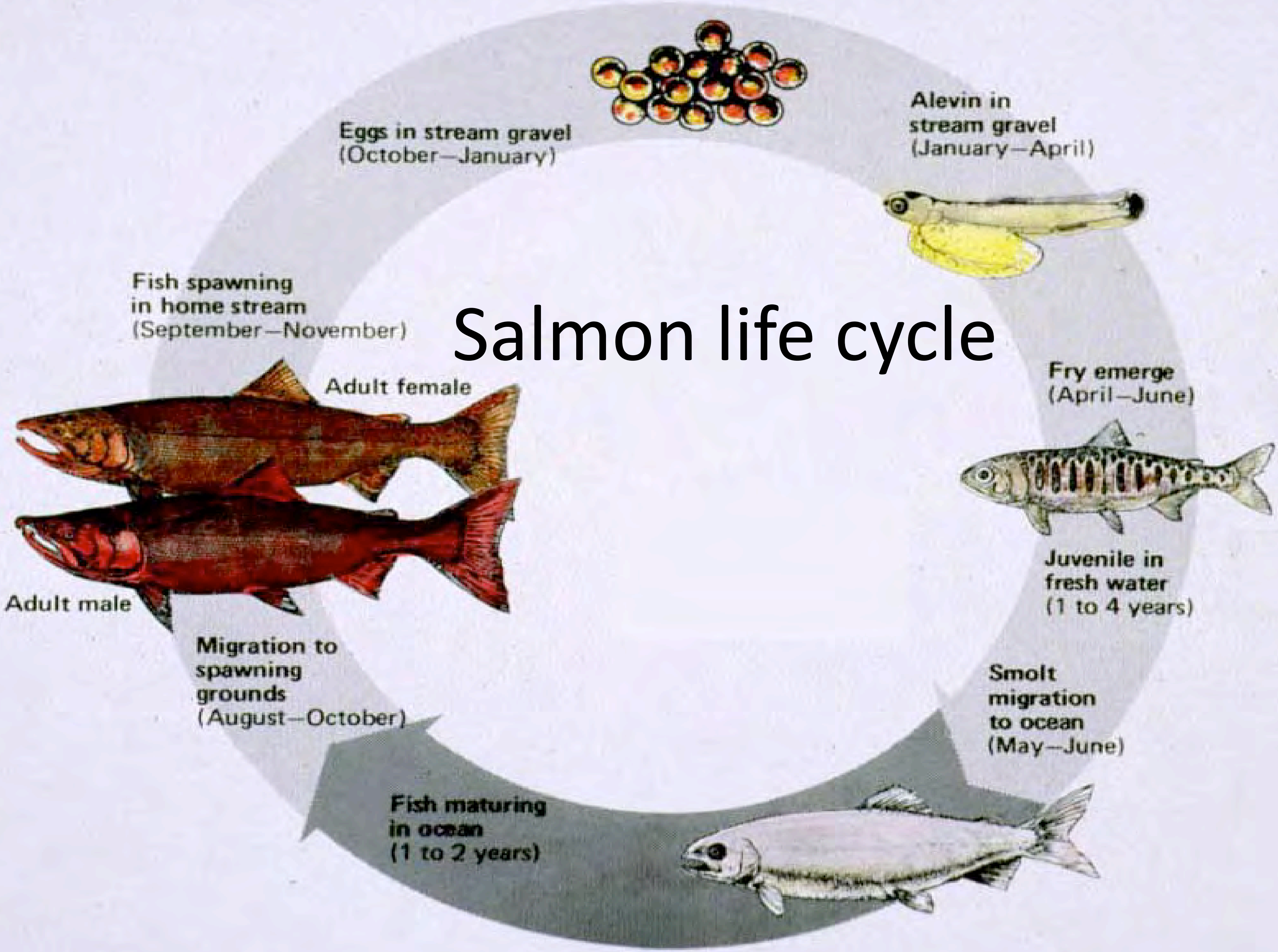
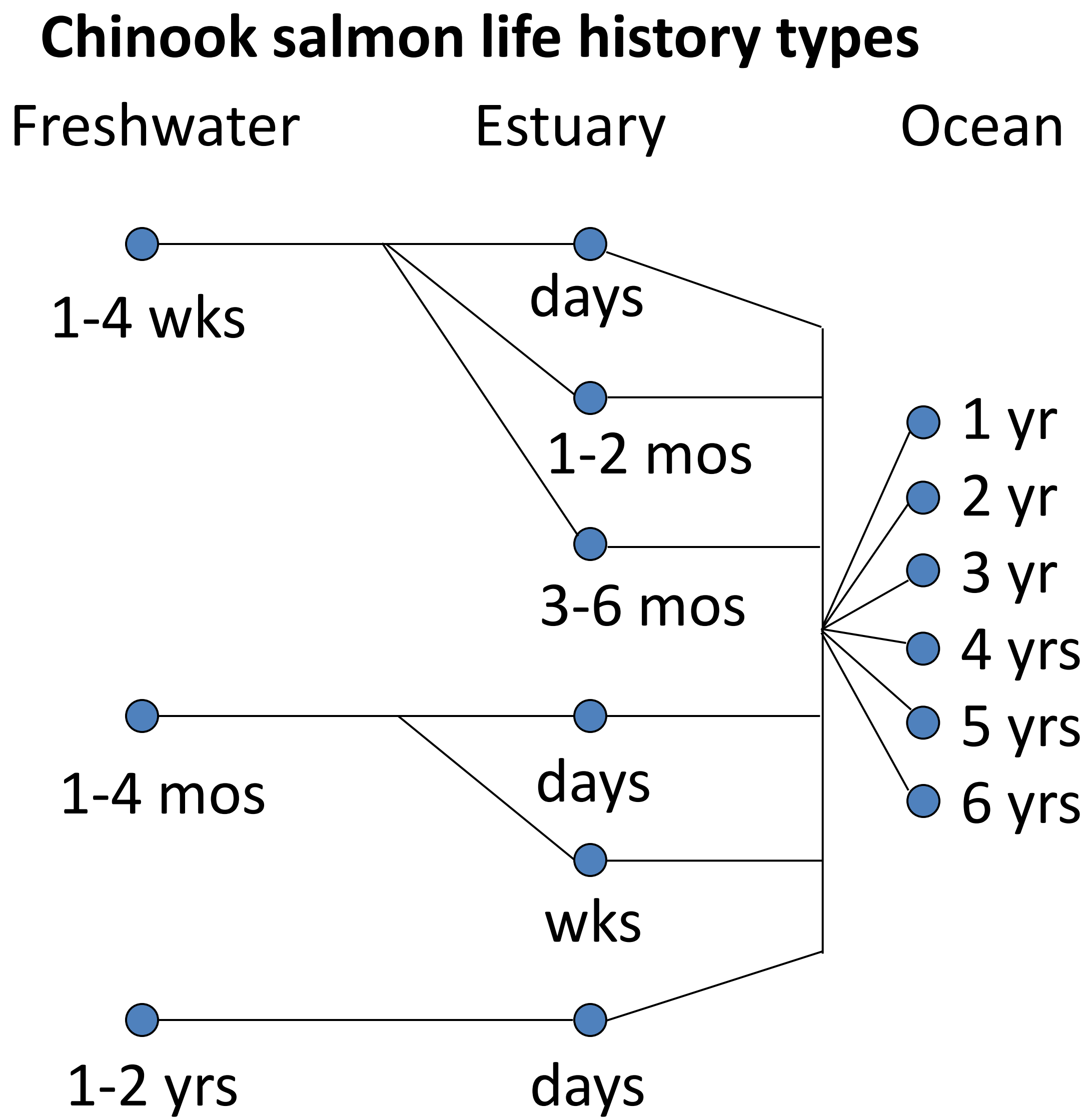
Salmon life cycle

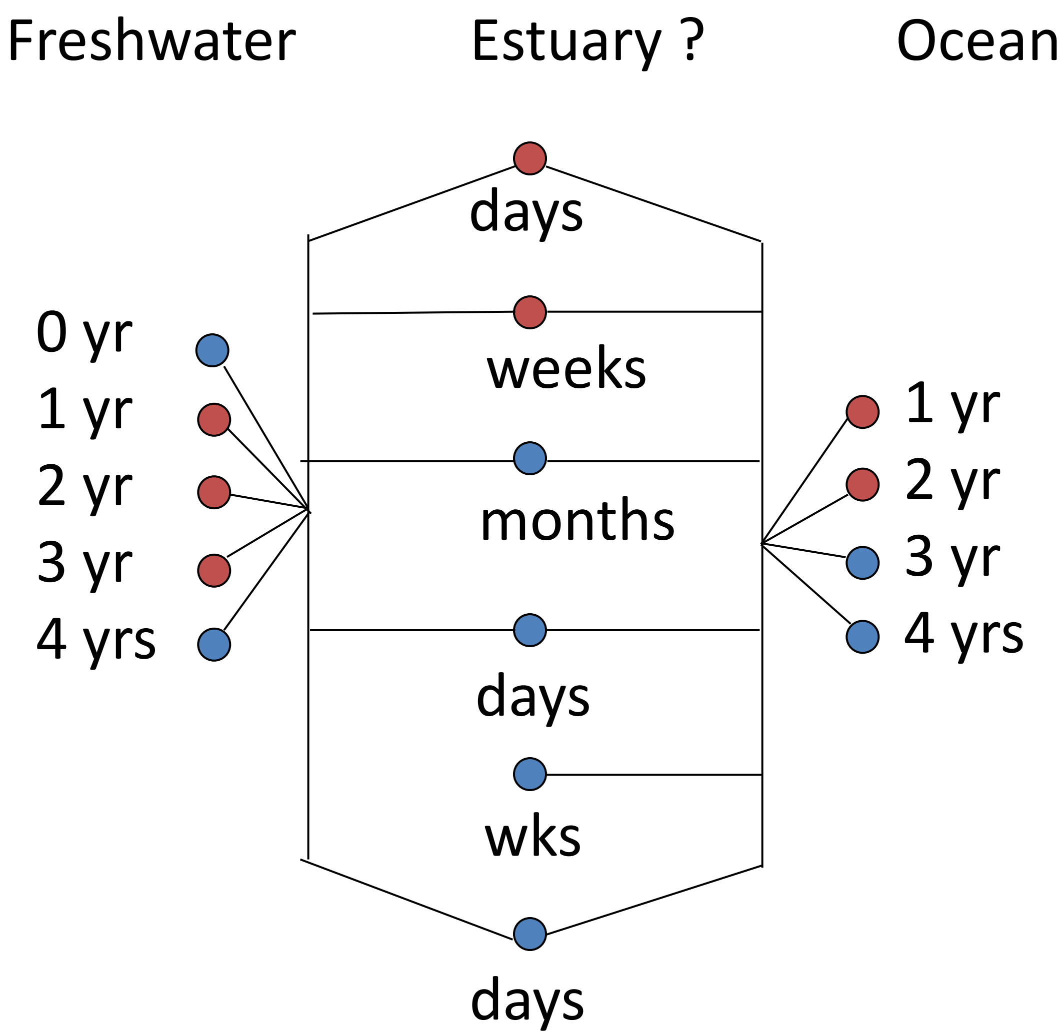


Chinook Life history diversity

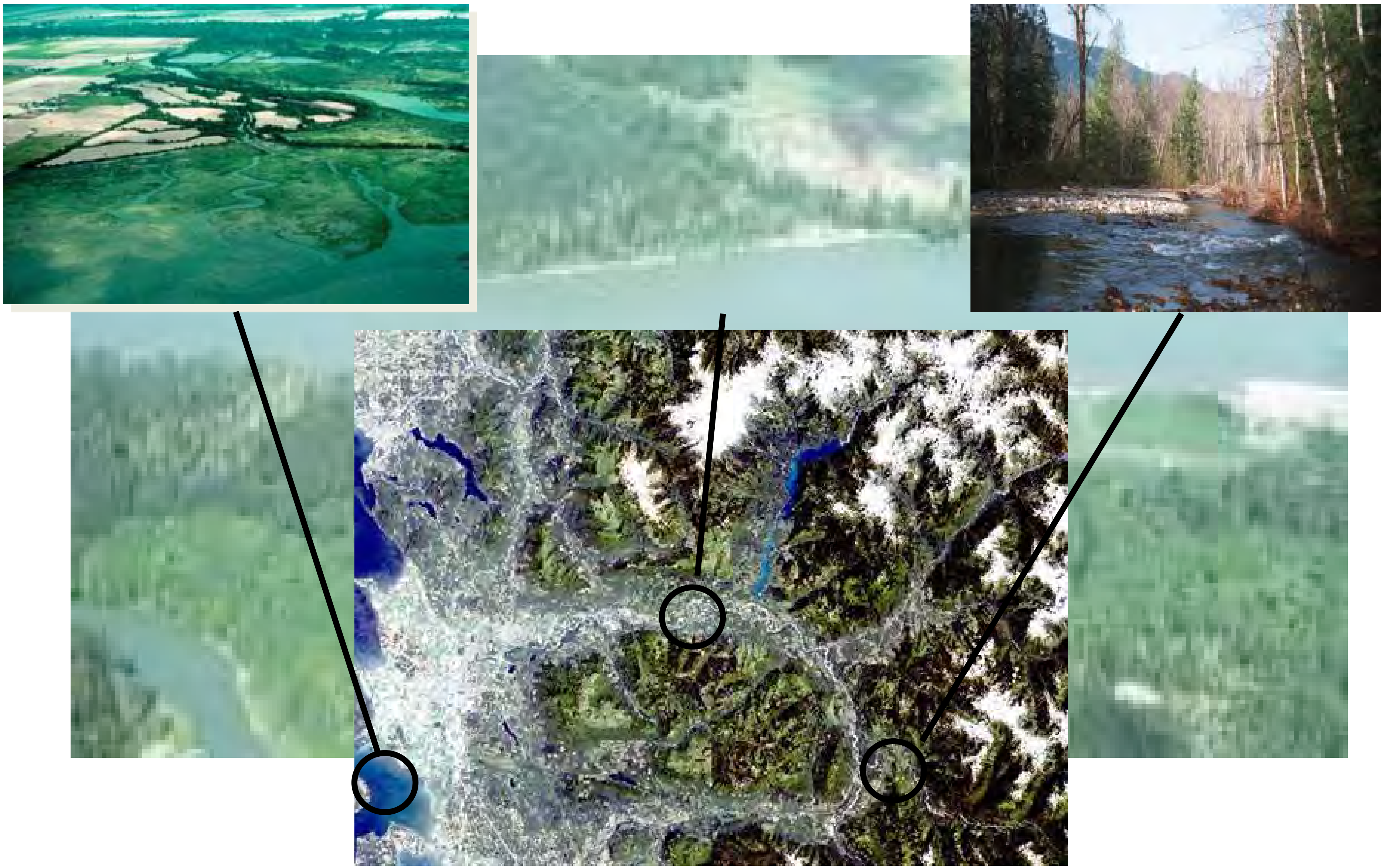


After C. Greene (unpublished) & Wissmar and Simenstad 1998

Steelhead Life history diversity



Landscape Scale Habitat Requirements



II. Micro and Meso-Habitat Requirements

Adult Holding Habitat

Spawning Habitat

Incubation Habitat

Fry Habitat

Summer Parr Habitat

Winter Parr Habitat

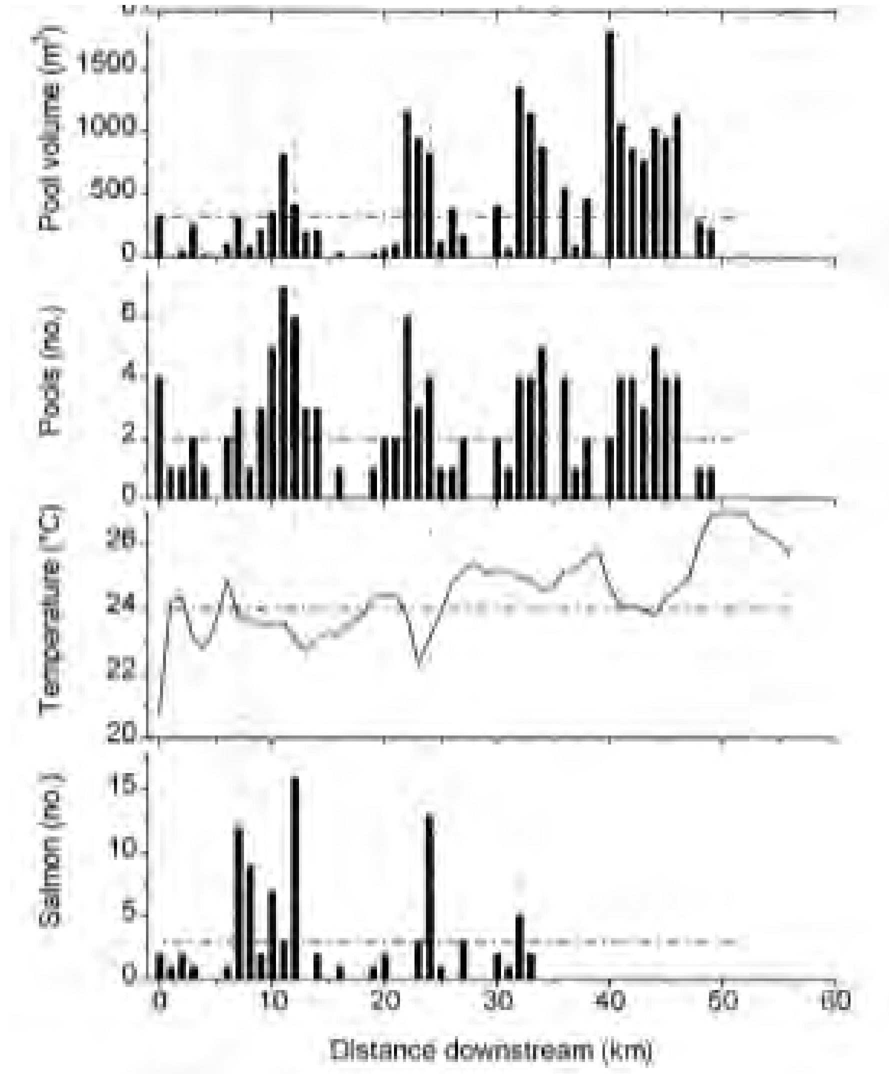
Smolt Migration Corridor

Roger Peters photo

T. Hillman photo

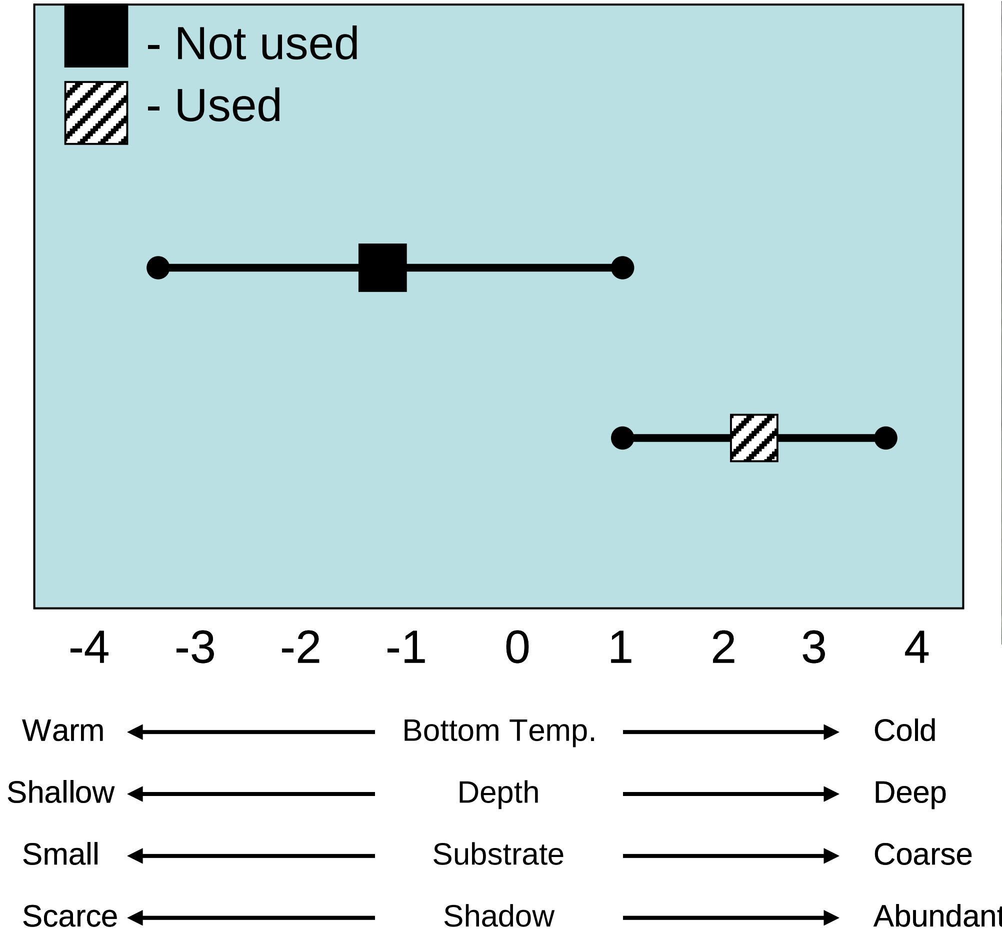
Adult Holding – Chinook

- Adequate
  - Depth
  - Cover
  - Temperature
    - Cool H20 refuge areas
  - Proximity of pools to spawning areas



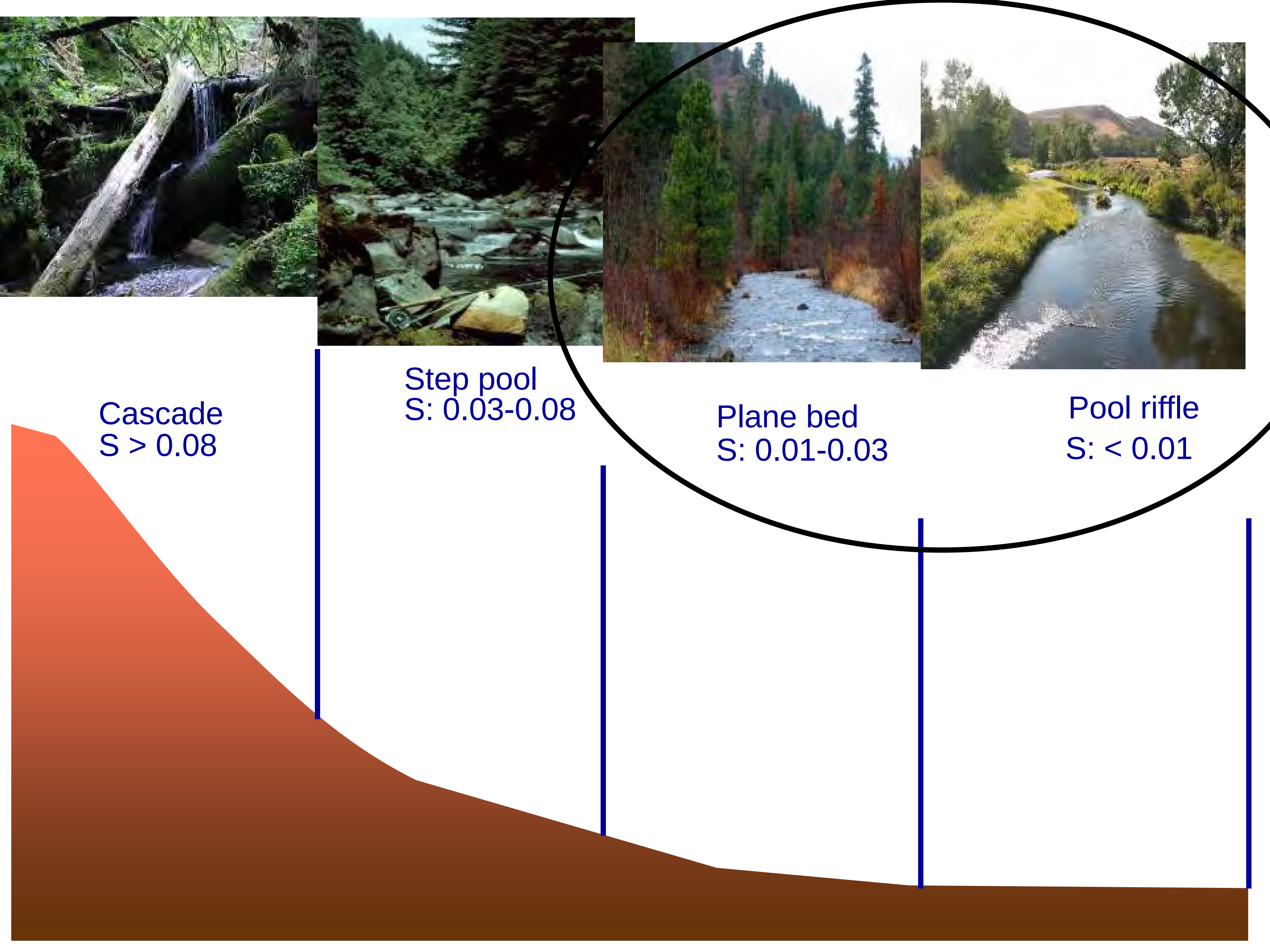
Torgersen et al. 1999

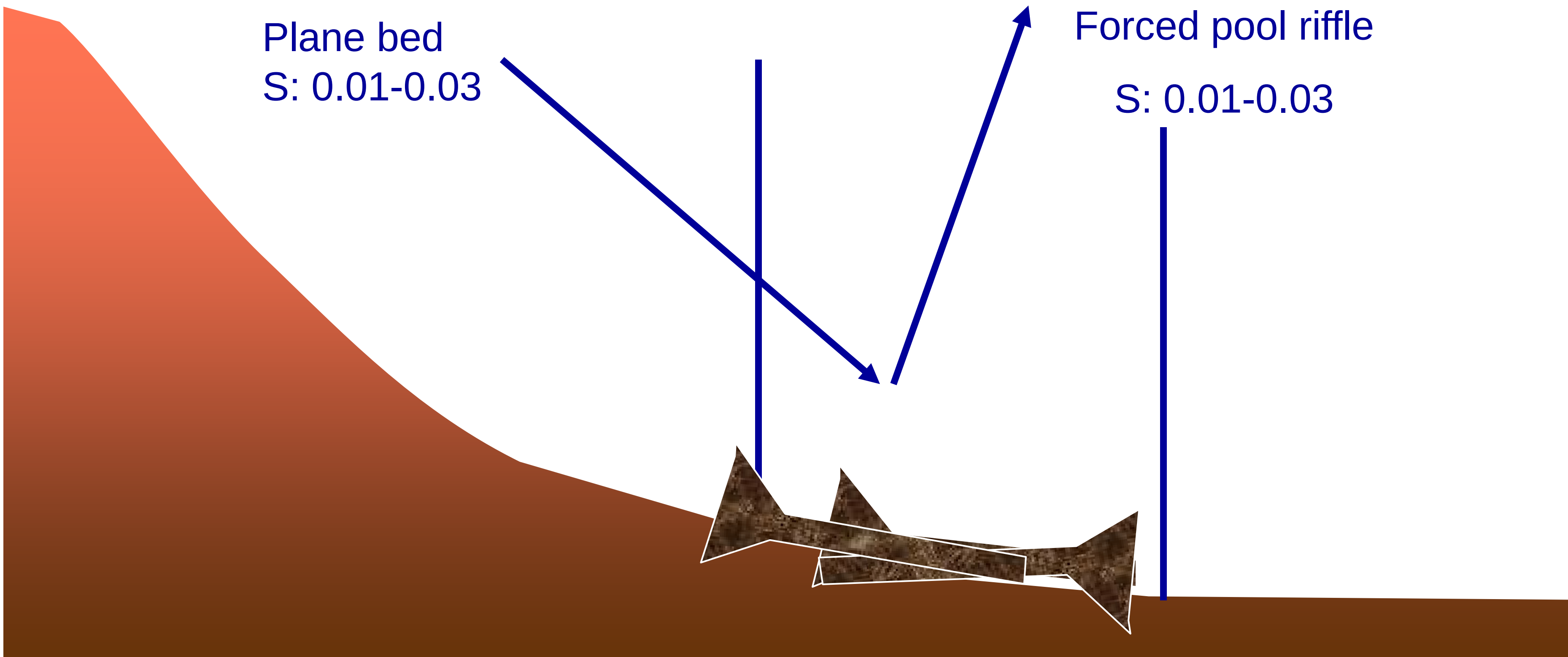
Adult holding habitat requirements



Baigun, C.R.M. 2003,
Nakamoto et al. 1994

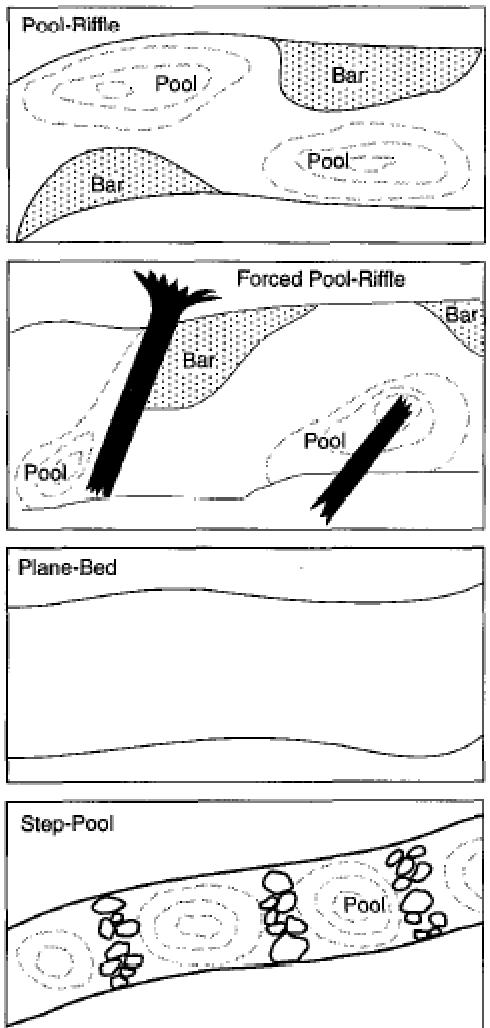
- Summer steelhead
  - Colder water
  - Deeper pools
  - More cover
  - Larger substrate

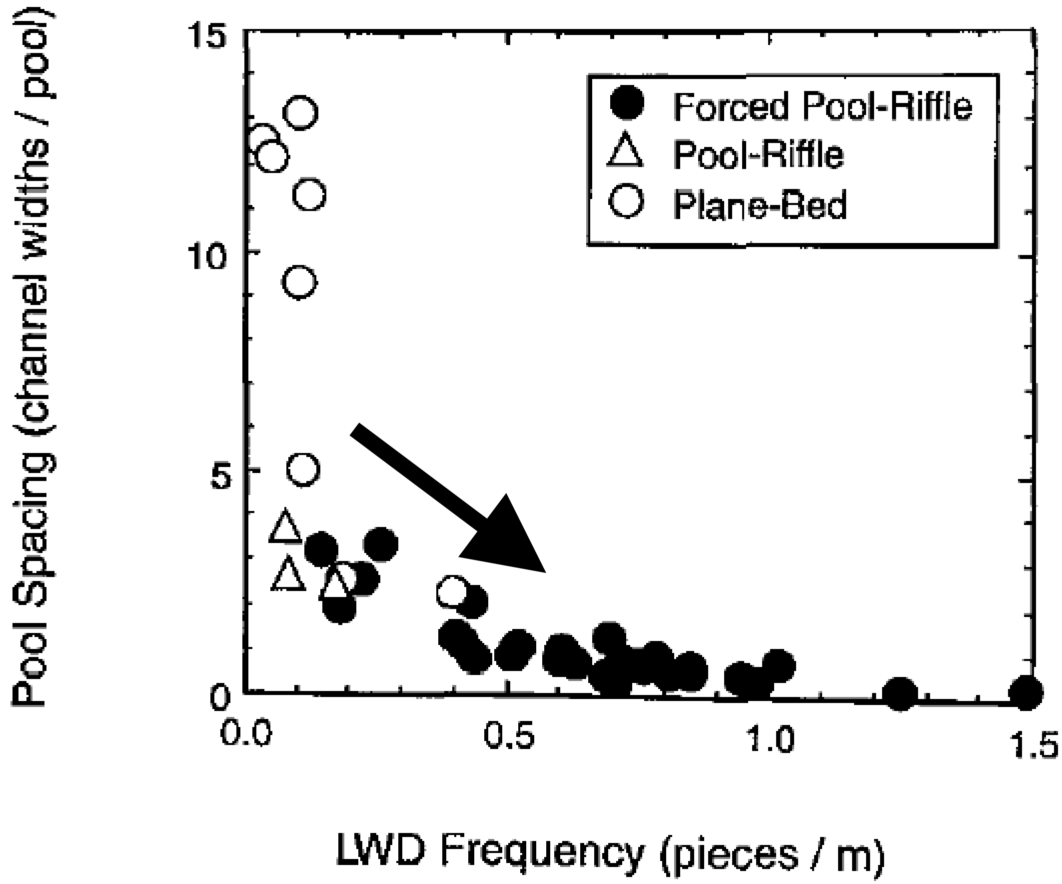

Cascade
S > 0.08
Step pool
S: 0.03-0.08
Plane bed
S: 0.01-0.03
Pool riffle
S: < 0.01


Plane bed
S: 0.01-0.03
Forced pool riffle
S: 0.01-0.03

Adult holding & what it means to restoration

Increased LWD frequency = increased density of pools

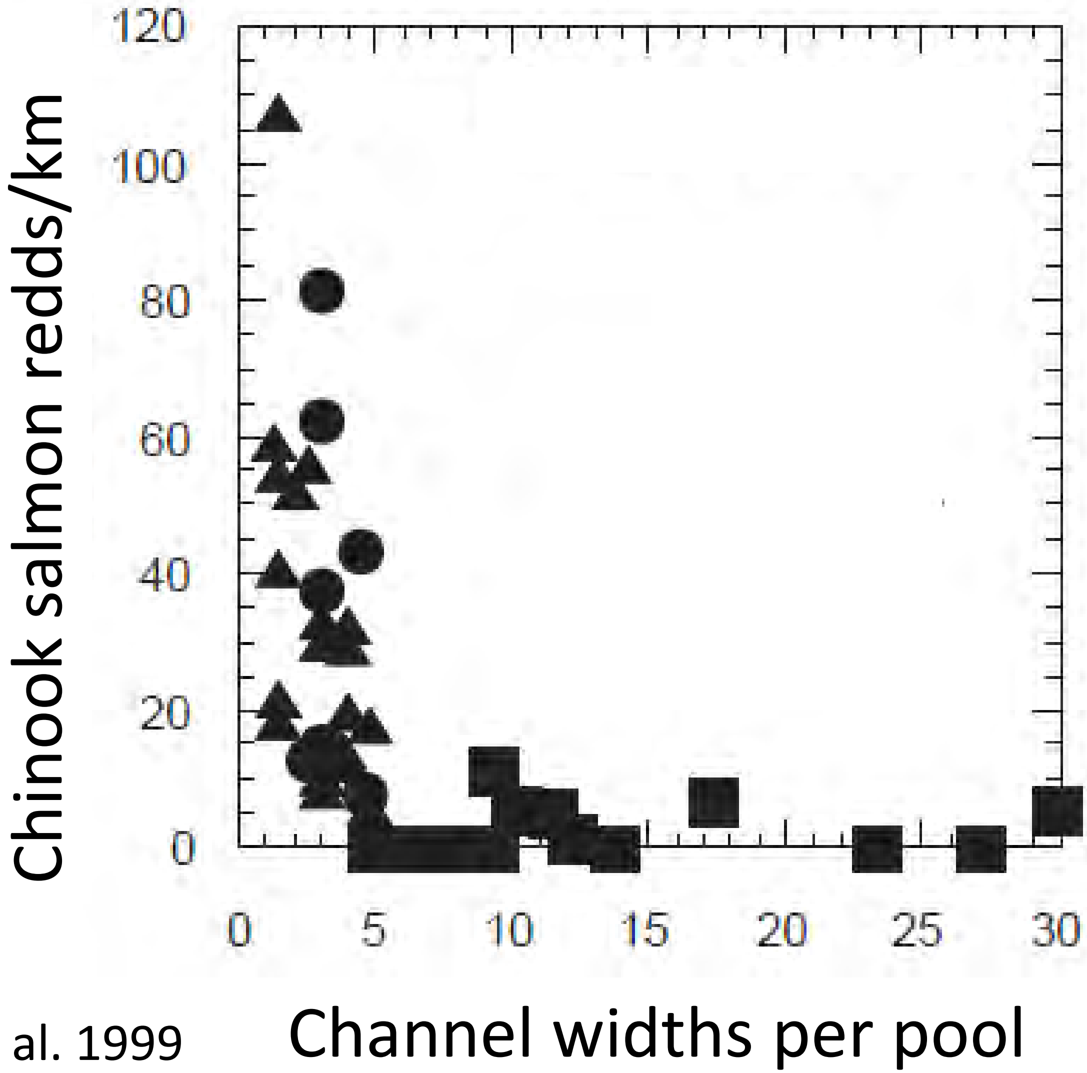




Montgomery et al. 1995

Adult holding habitat & what it means to restoration

Increased pool density = increased redd density



Montgomery et al. 1999

~30 times as Chinook salmon redds in Forced Pool-Riffle Channels

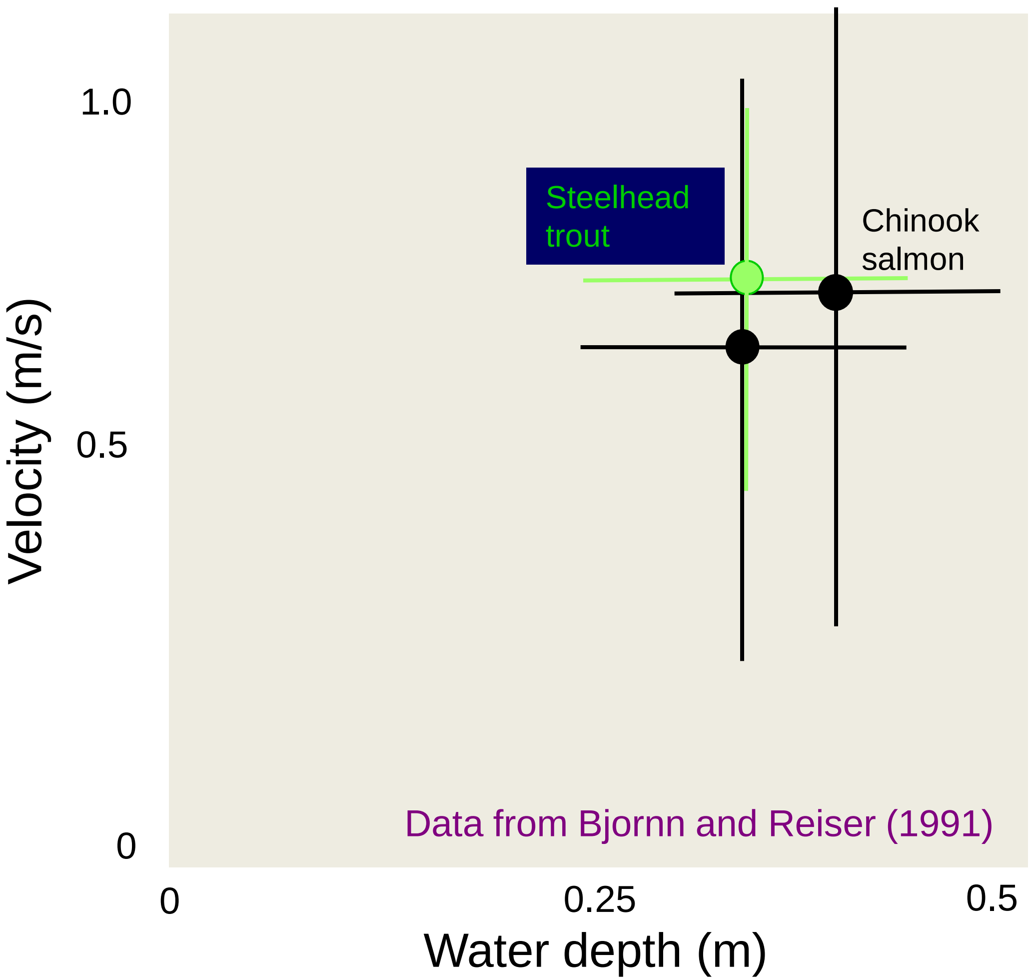
Forced-Pool Riffle Channel

Plane Bed Channel

Adult Spawning Habitat

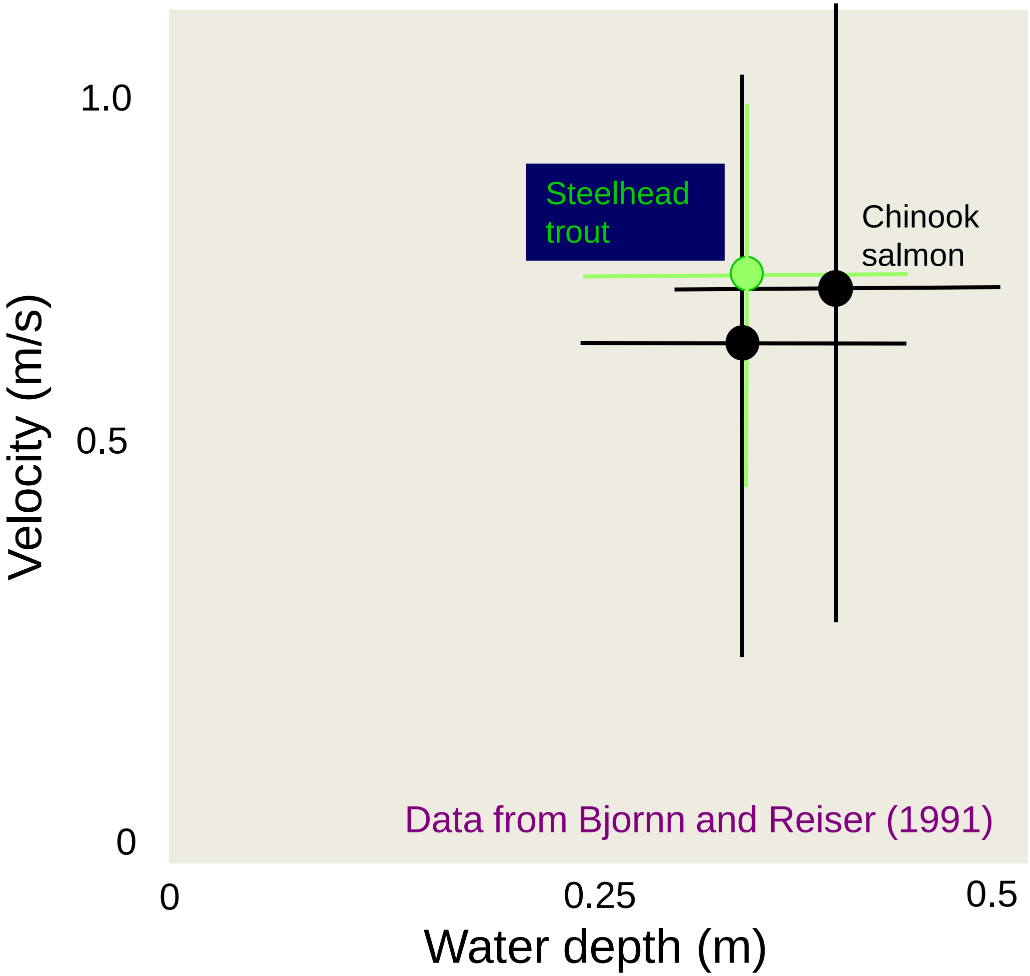
Chinook Spawning Habitat

- Depth > 24 cm
- Velocity 30-91 (cm/s)
- Substrate 1.3-10.2cm
  - Fines < 20%
- Temp ~ 5 to 14^{o}C



Steelhead Spawning Habitat

- Depth > 24 cm
- Velocity 40-91 (cm/s)
- Substrate 0.6-10.2cm
  - Fines < 20%
- Temp ~ 4 to 10°C



Adult Spawning

- Considerations for restoration project selection
  - Pools, cover and holding areas close to spawning areas (increase LWD, Riparian cover)
  - Adequate cool water refuges (deep pools)
    - Increase LWD, riparian cover,
    - Reduce excess sediment filling pools

J. McMillan photos

Incubation Habitat

Chinook

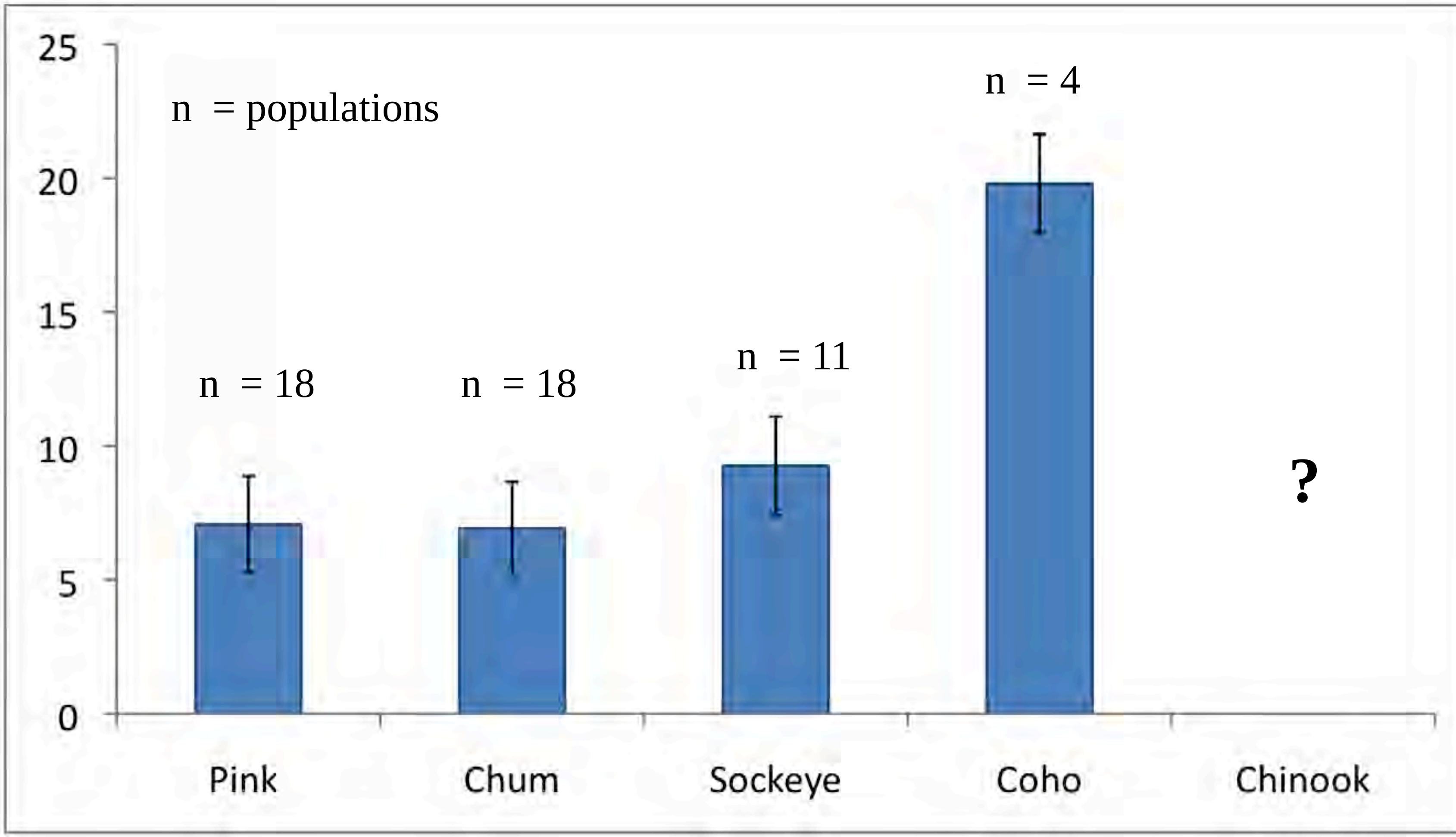
- Temperature 5 to 13 (but as low as 0.6) (Bell 1990; Bjornn & Riser 1991)
- Fines/infiltration < 20%
  - Jensen et al. 2009
- Limited scour/high flows
- DO – saturation (> 7mg/l)
  - Low DO groundwater?
  - % Organics?

Steelhead

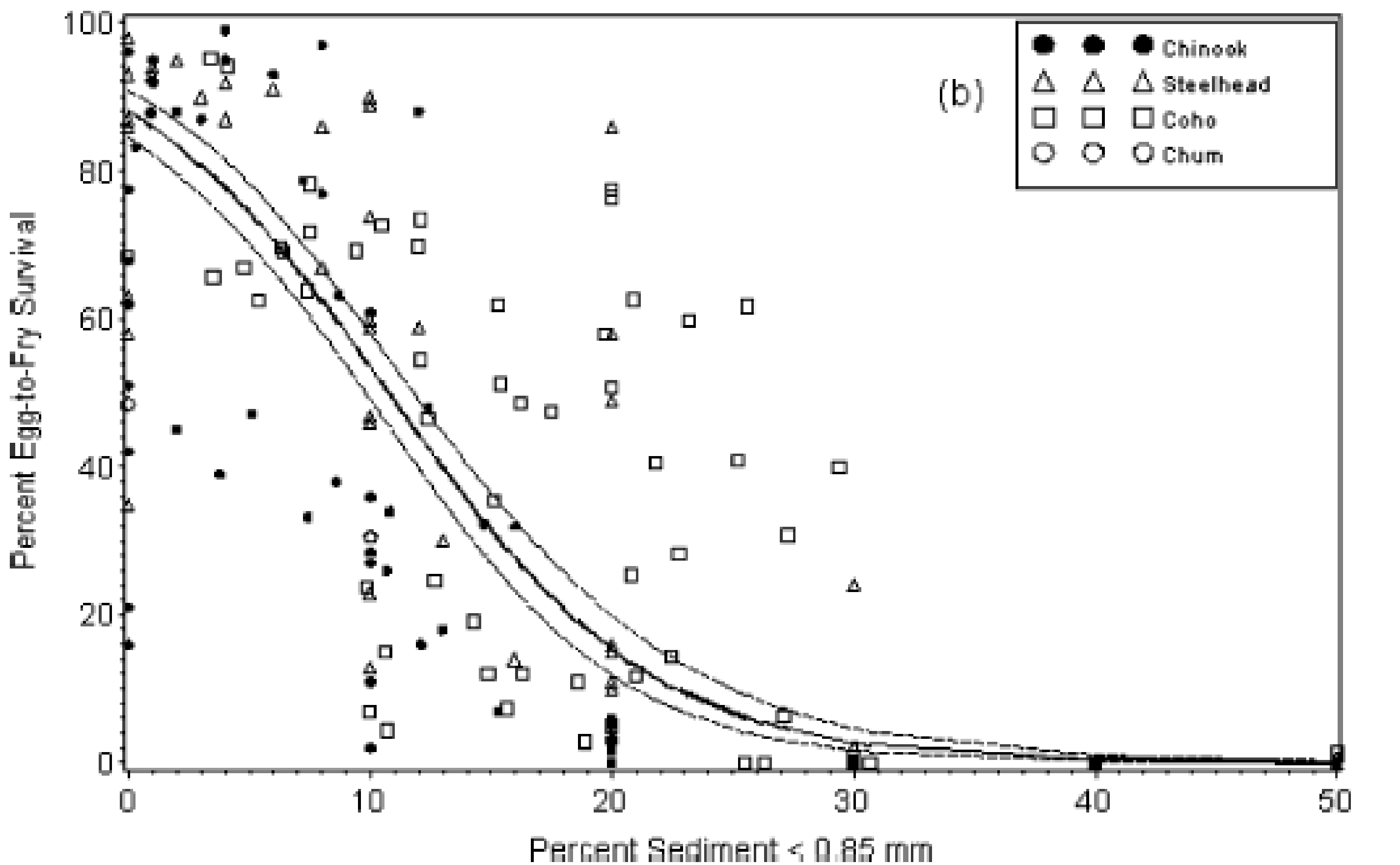
- Temperature ~4 to 13
- (Bell 1990)
- Fines/Infiltration < 20%
  - Jensen et al. 2009
- Limited scour/high flows
- DO – saturation (> 7 mg/l)
  - Low DO groundwater?
  - % Organics?

Estimates of Salmonid Egg-to-Fry

Bradford 1995



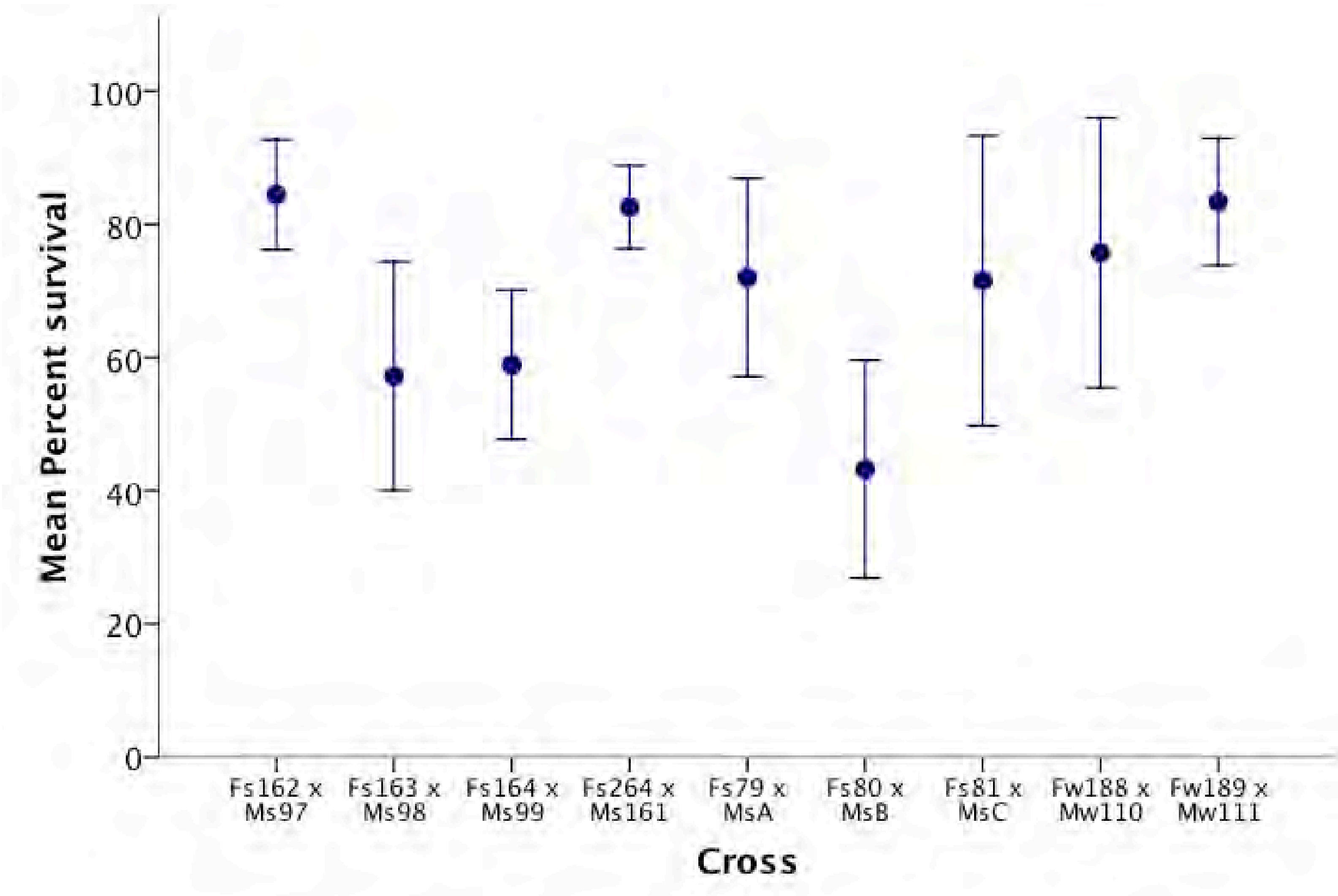
Egg to Fry Survival



Jensen et al. 2009

Adult Fitness Important

Yakima River Chinook Survival by Male-Female Cross



Johnson, Roni & Pess In press.

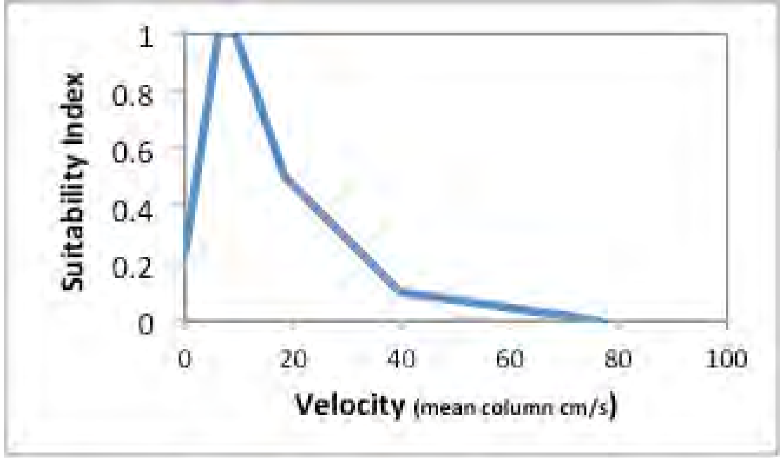
Incubation Habitat

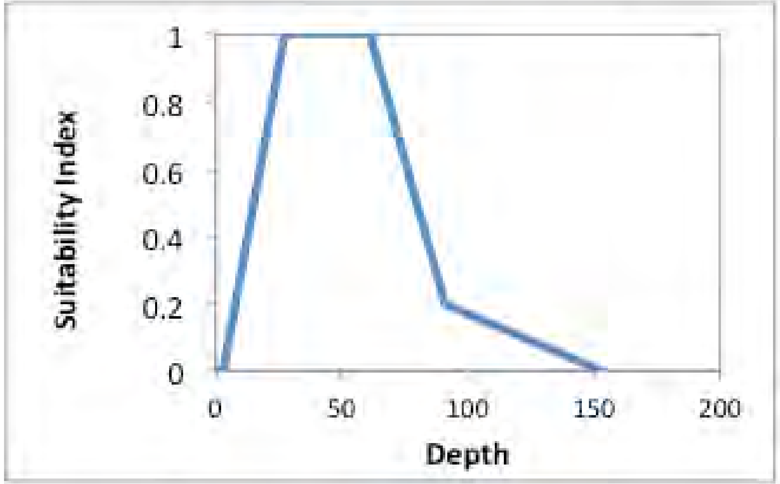
- Possible considerations for project selection
  - Reduce road, grazing, upland impacts, bank erosion (fines, temp, DO, scour)
  - Restore riparian areas (fines, scour, temp)
  - Remove channel confinement (scour)

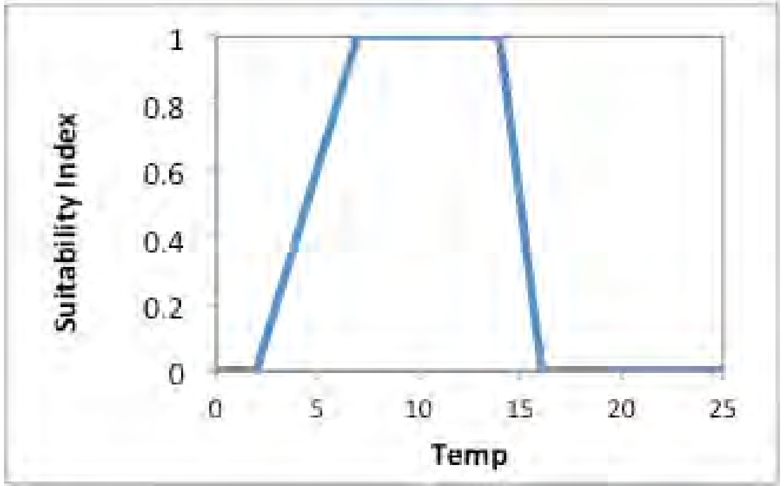
Fry Habitat Requirements

Chinook fry

- Low velocities
- Shallow water

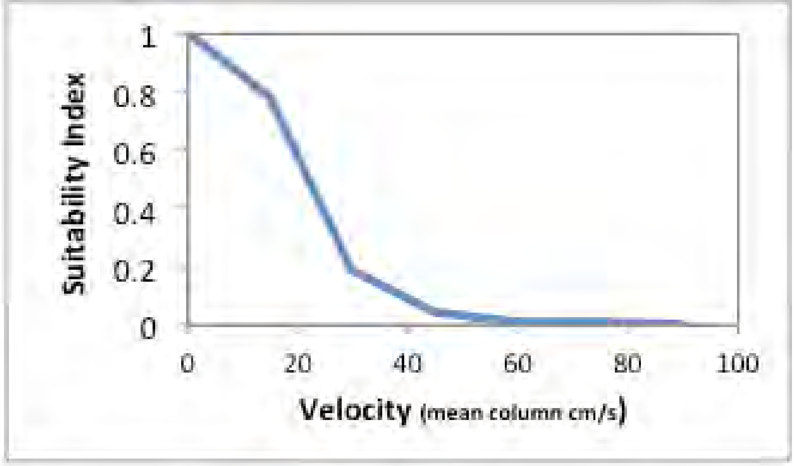


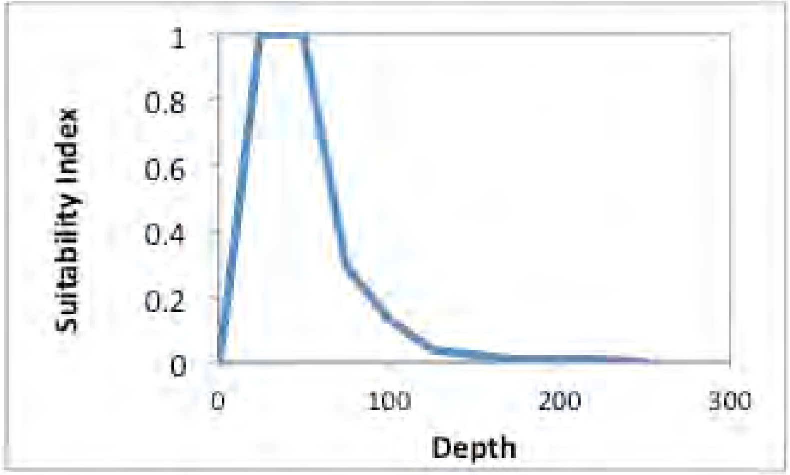


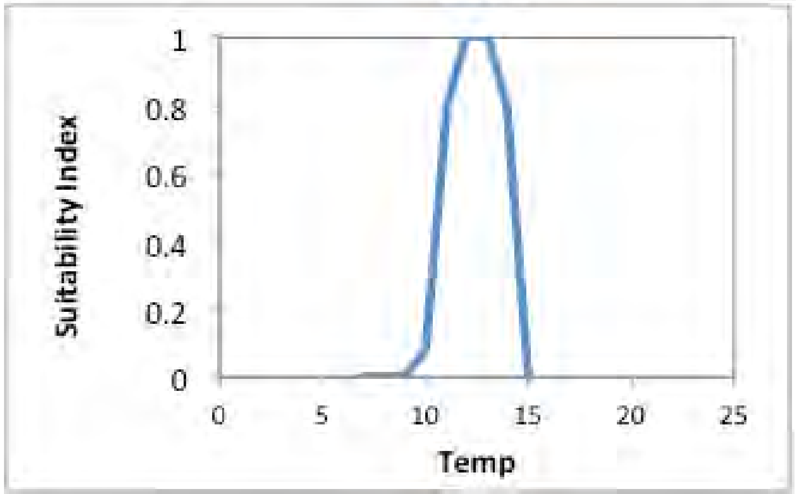


Steelhead fry

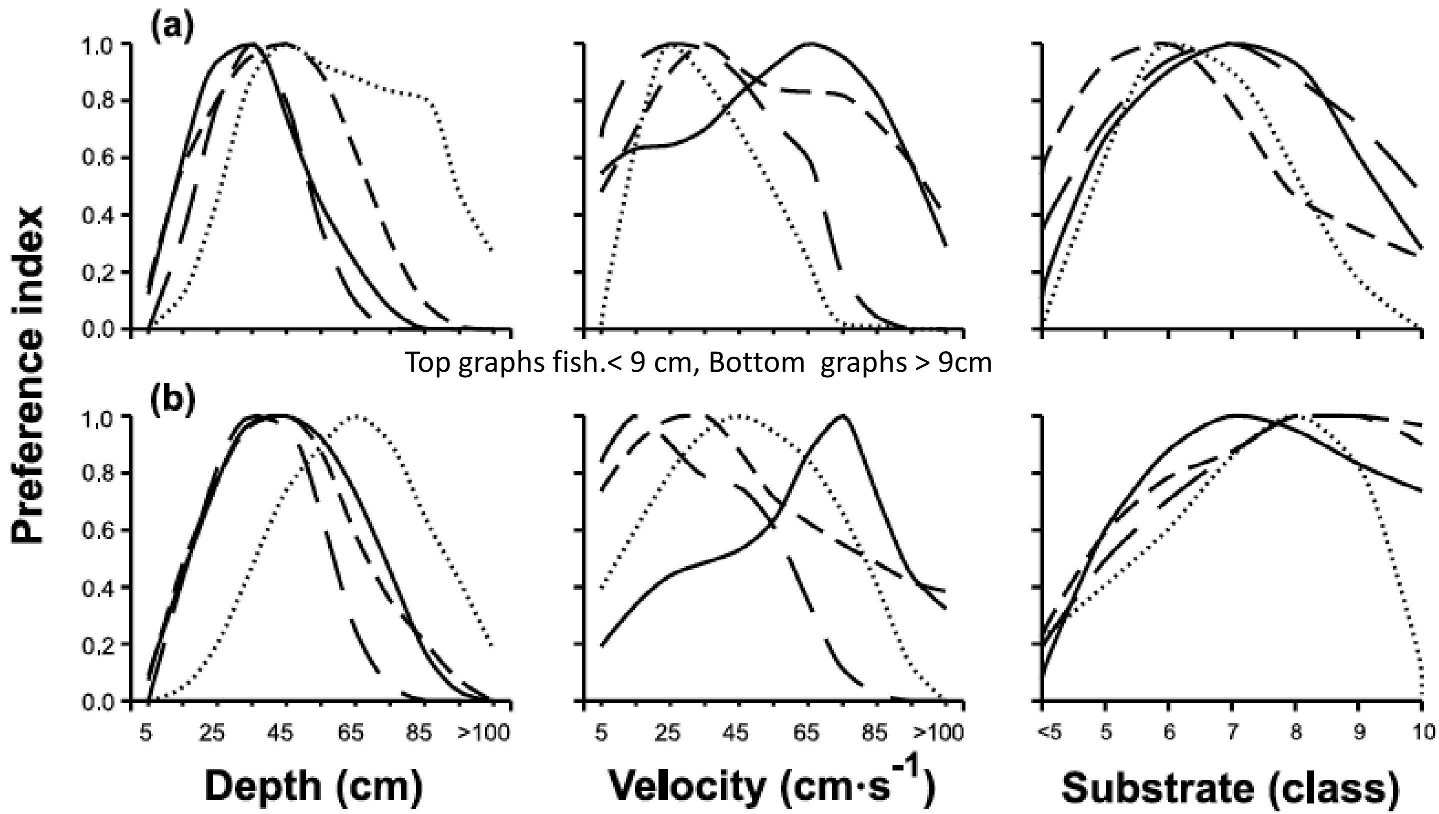
- Low velocities
- Shallow water







Note About Habitat Suitability Curves

- General based on literature – varies based on ecoregion, watershed or even tributary
- 

(—, Koitajoki; — —, Pyhäjoki; – –, Simojoki; ....., Tenojoki)

Source Maki-Petays et al. 2012

Chinook and Steelhead Fry Habitat

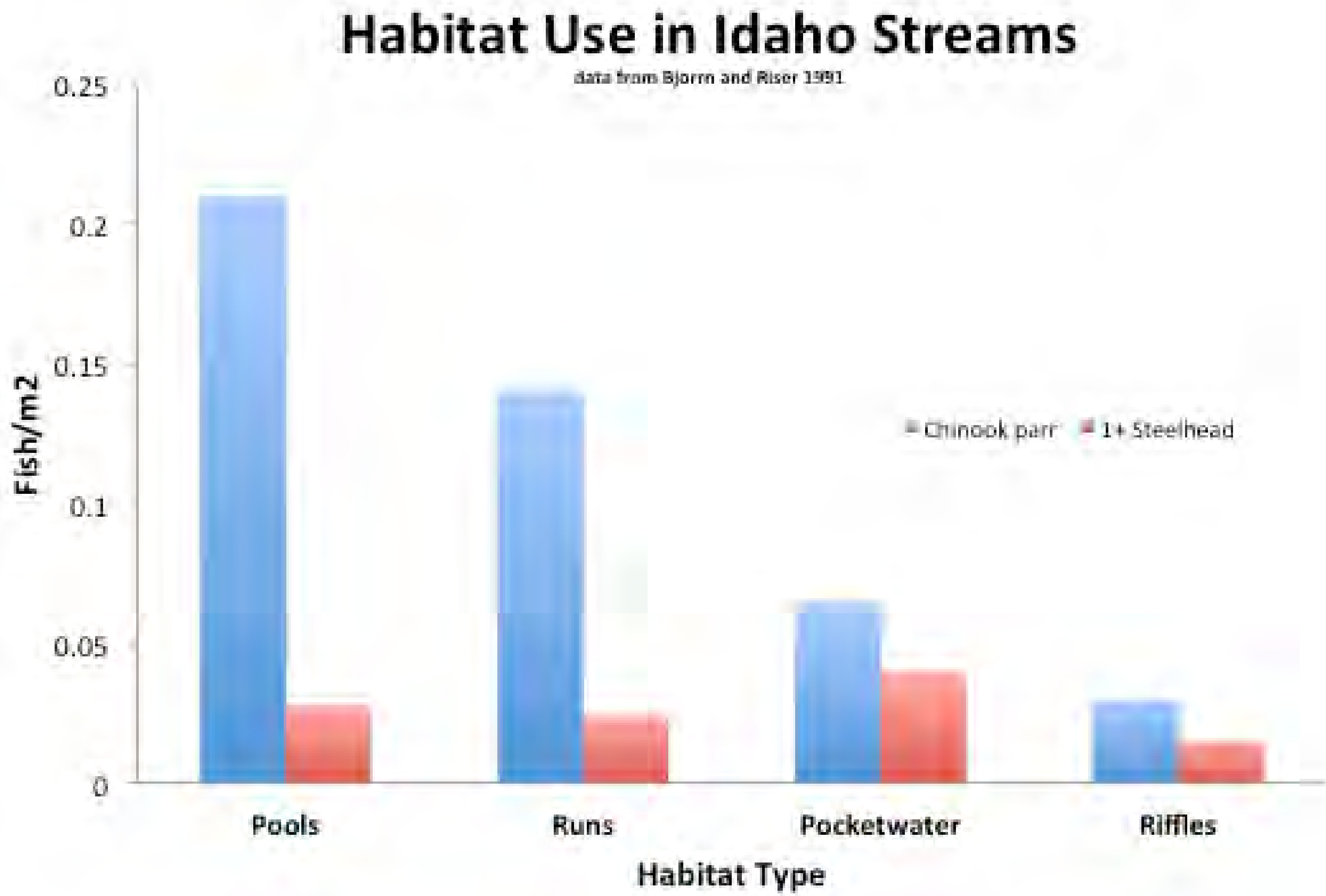
Daytime Habitat

- Post-emergent Chinook and steelhead cluster at stream margins in slow (0-10 cm/s) and shallow water (<60 cm).
- Chinook fry typically station over fine substrates with abundant vegetation cover (brush, grasses, and woody debris).
- Steelhead fry typically station over cobble and small boulder substrates.

Nighttime Habitat

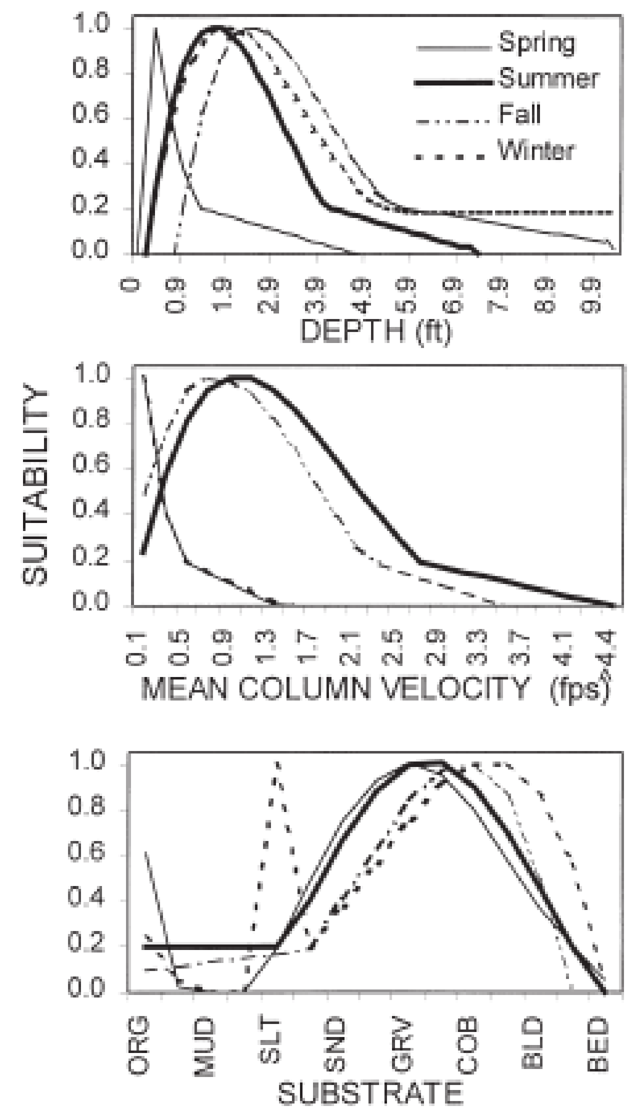
- Nighttime habitat selected by Chinook and steelhead fry is similar to their daytime habitat.
- Both species select shallow, quiet (<1 cm/s) water at night.
- Although both Chinook and steelhead fry select similar microhabitat, they are spatially segregated because of different emergent dates.

Summer rearing



Summer rearing

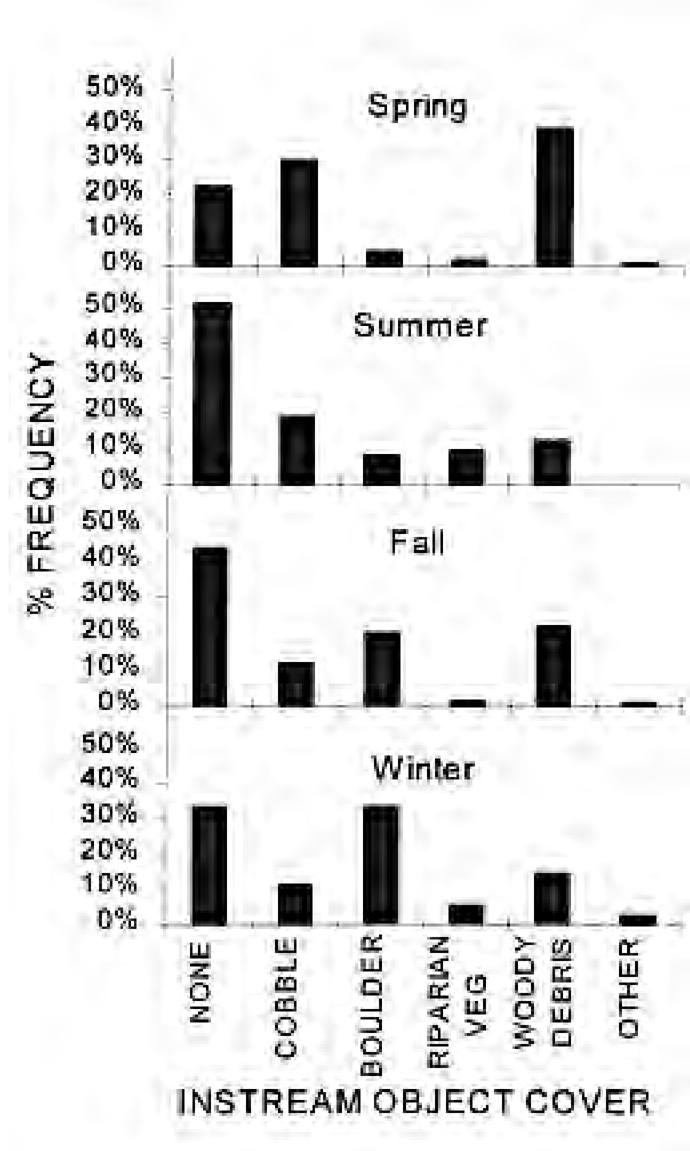
- Chinook
  - Temp ~ 12-14C
  - Vel 0-25 cm/s
  - 15-60 cm
- Steelhead
  - 10-13 C
  - 4 – 40 cm/s
  - 15 to 70 cm
- Changes with
  - Fish size
  - Season



Seasonal habitat preferences for Yakima River Chinook - Allen 2000

Summer rearing – Seasonal Change in Cover

- Chinook
  - Temp ~ 12-14C
  - Vel 0-25 cm/s
  - 15-60 cm
- Steelhead
  - 10-13 C
  - 4 – 40 cm/s
  - 15 to 70 cm
- Changes with
  - Fish size
  - Season



Seasonal use of cover for Yakima River Chinook - Allen 2000

Chinook and Steelhead Summer Parr Habitat Selection

Daytime Habitat

- As Chinook grow, they use faster (2-44 cm/s) and deeper (25-300 cm) water, and select brush, woody debris, or cobble/boulder cover.
- As steelhead grow, they use faster (2-34 cm/s) and deeper (19-190 cm) water, and use cobbles and boulders for cover.

Nighttime Habitat

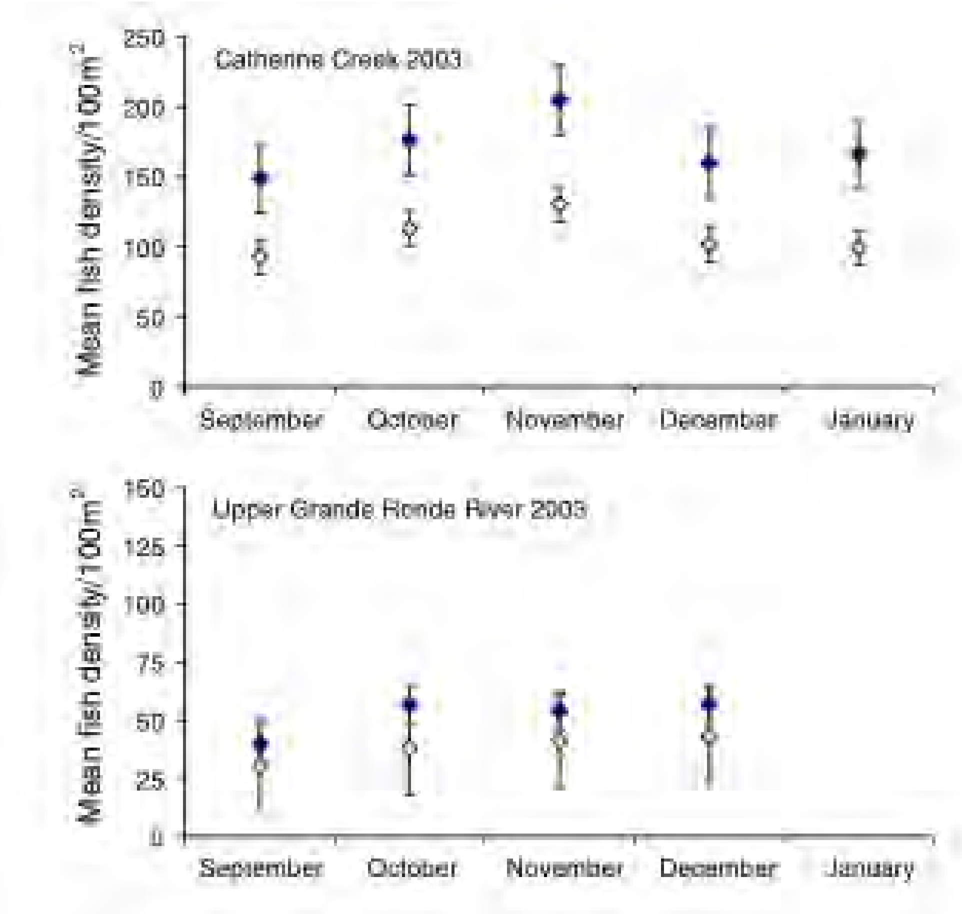
- At night, both Chinook and steelhead move into shallow, quite (<1 cm/s) areas and rest on or in the substrate.
- Both species use areas with fine sediments, bedrock, or coarse substrate.
- Larger fish use deeper (40-90 cm) water than smaller fish (15-60 cm)

Summer rearing

- Day and Night Habitat Requirements
  - High temps fish hide/seek cover during day
  - Concealment, cover, substrate become even more important
- Changes in habitat requirements with growth.

Winter Rearing

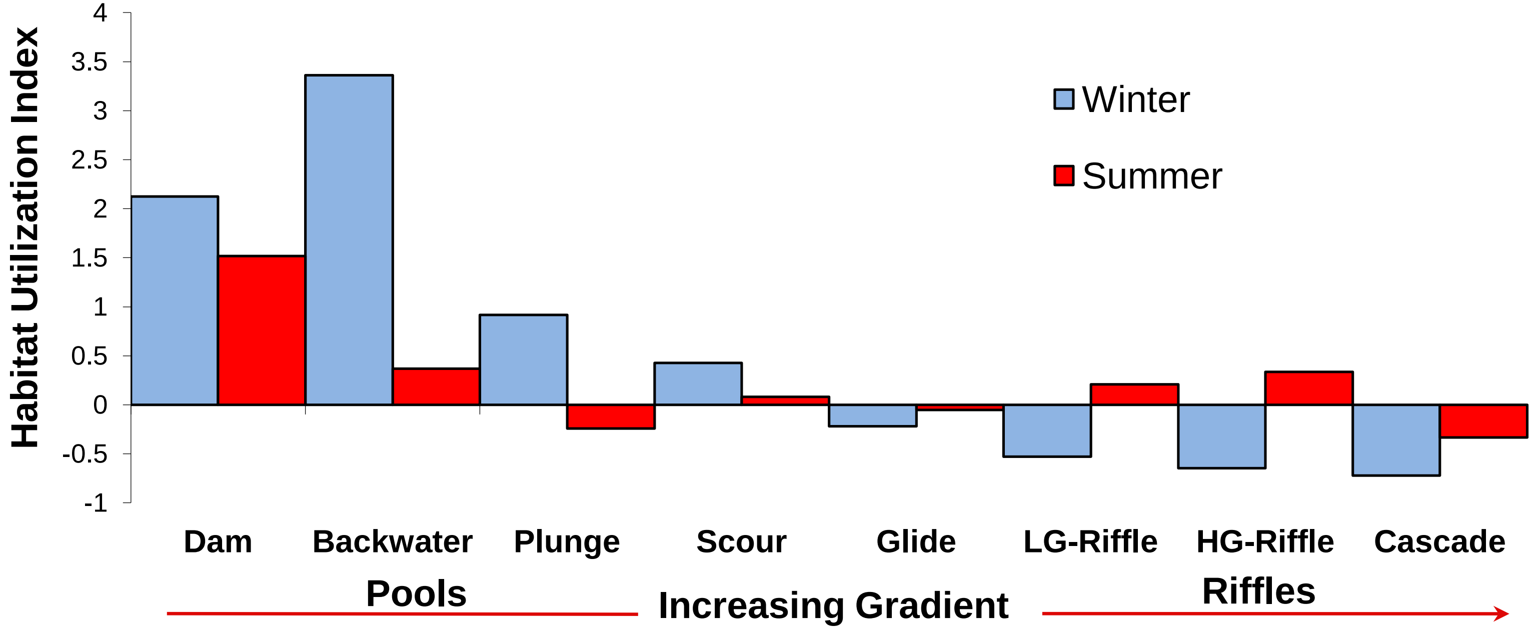
- Chinook
  - slower water
  - side channels/off-chann areas
  - Cobble/concealment habitat
- Steelhead
  - Cover/ concealment habitat
  - Day vs night habitat use



Mean juvenile spring Chinook densities in pools with high (blue diamonds) and low (open diamonds) winter concealment habitat scores. Source Van Dyke et al. 2009 (Grande Ronde River)

Winter Rearing – Steelhead 1+

preferences change with season



Source Roni 2003 – data from 28 streams in Washington and Oregon

Chinook and Steelhead Winter Parr Habitat Selection

Daytime Habitat

- During periods when temperatures are less than 10°C, both Chinook and steelhead parr remain concealed in cover (woody debris or coarse substrate).

Nighttime Habitat

- Both species emerge from cover at night and reside near the stream bed over sand, bedrock, or boulders in depths that range from 50-200 cm.
- Both species use velocities less than 2 cm/s at night.

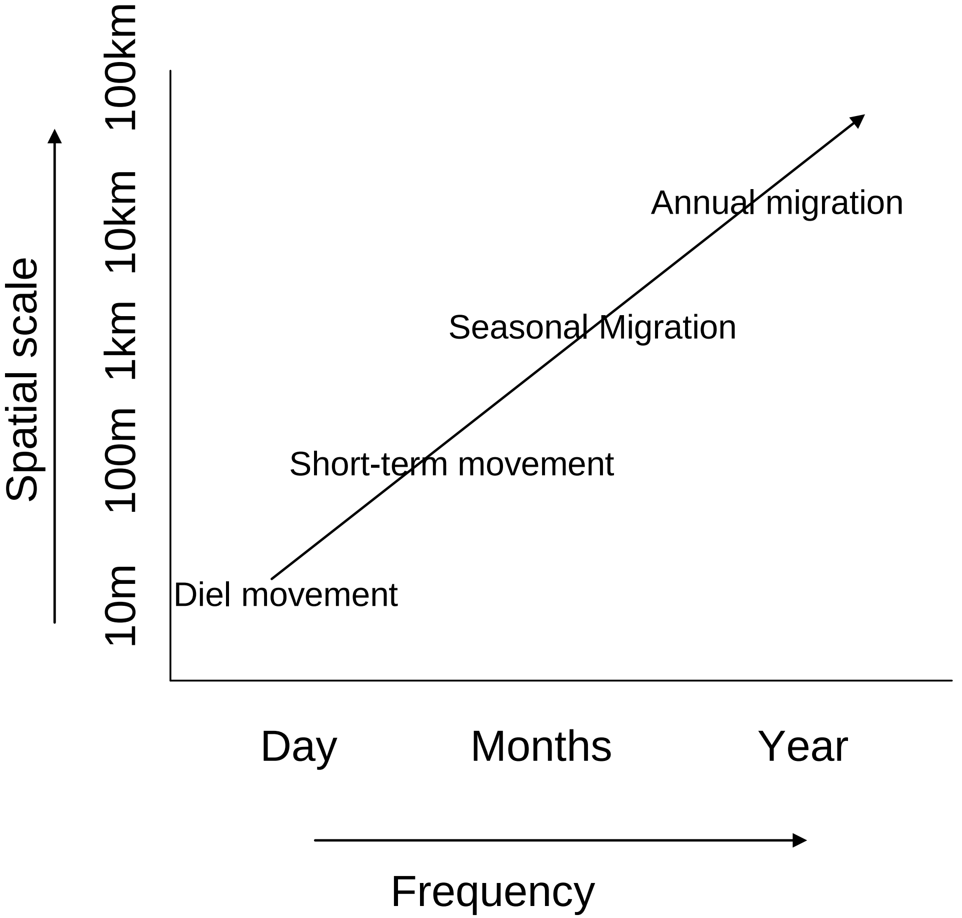
Summer & Winter Rearing

- What it means to restoration
  - Restoration that improves/maintains
    - Temperature
    - Pools
    - Cover
    - Substrate size/embeddedness
    - Cool water refuge areas (off-channel or ground water)

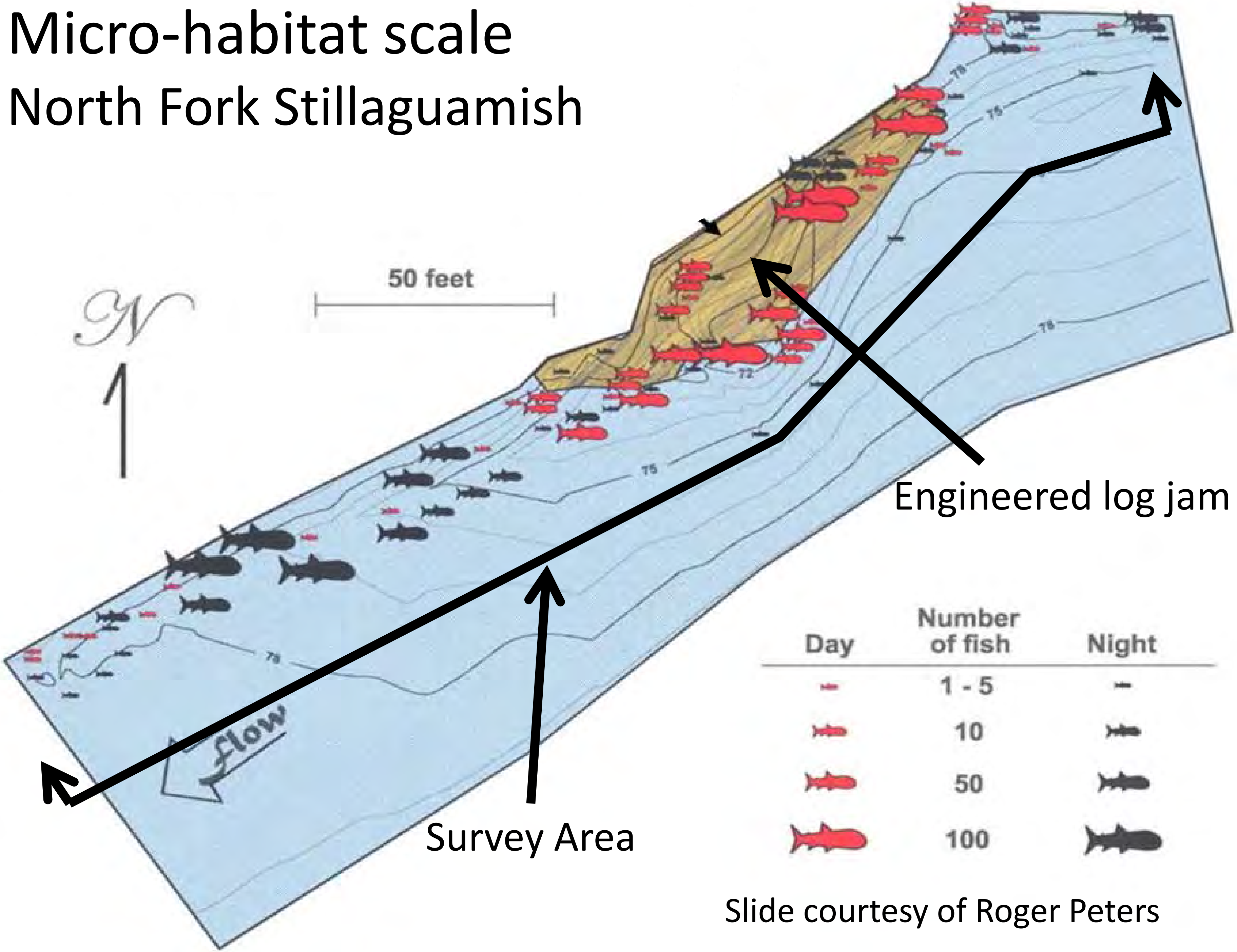


Movement & Migration

- Important to consider movement and migration
  - Within reach
    - Often limited in summer and winter
  - Among reaches and habitat
    - Often large seasonal movements fall and spring



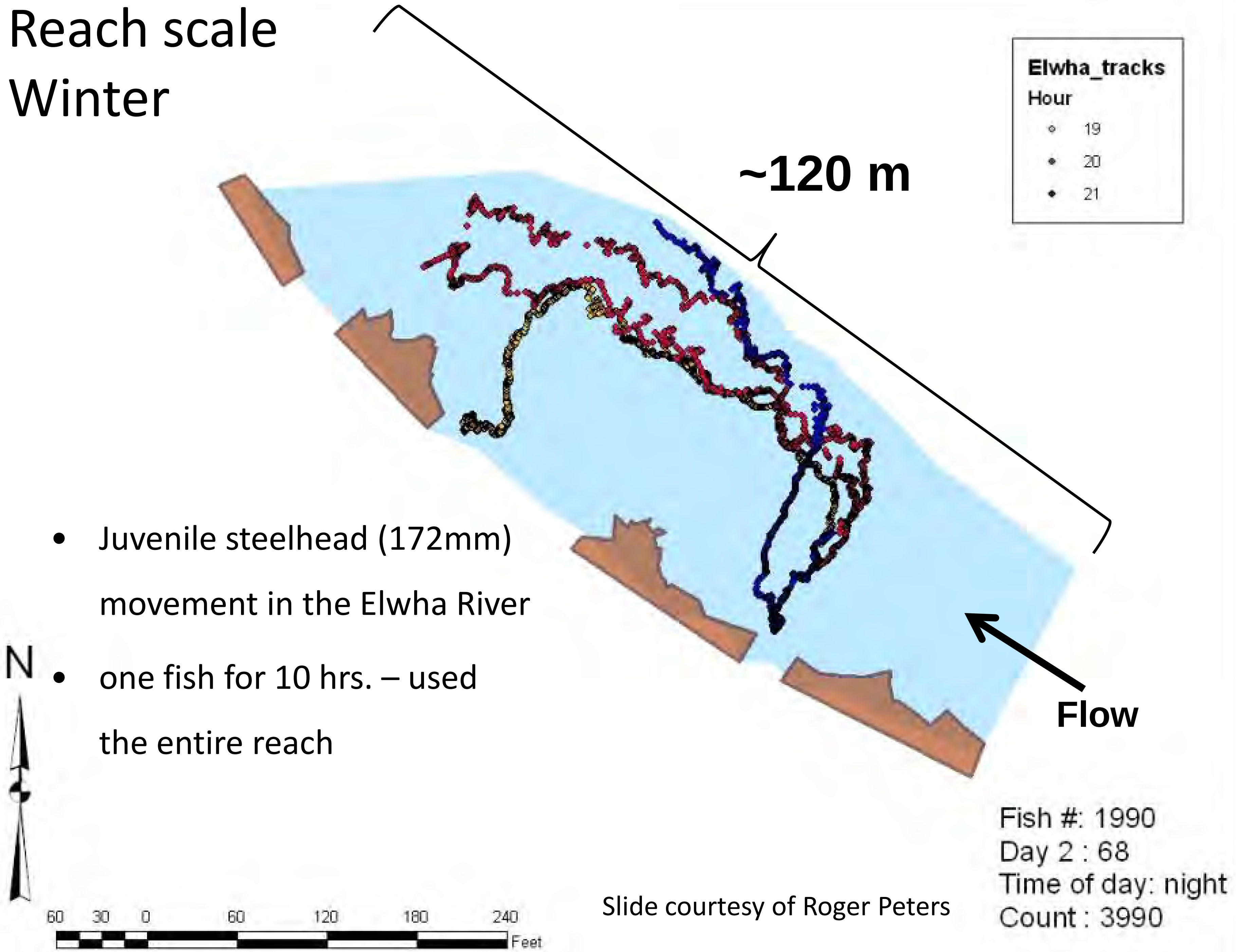
Micro-habitat scale
North Fork Stillaguamish



Slide courtesy of Roger Peters

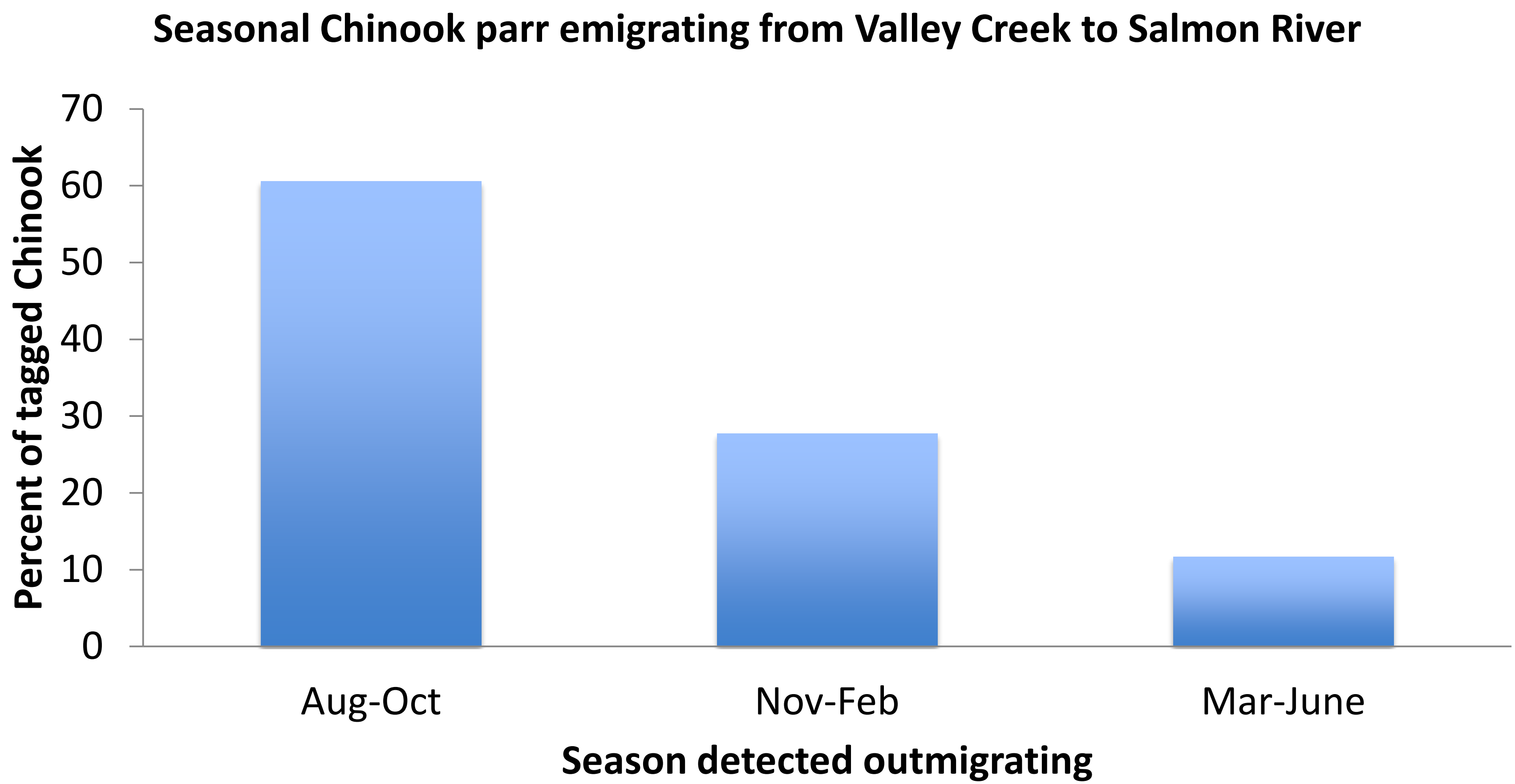
Reach scale
Winter

- Juvenile steelhead (172mm) movement in the Elwha River
- one fish for 10 hrs. – used the entire reach



Slide courtesy of Roger Peters

Watershed Scale Movement

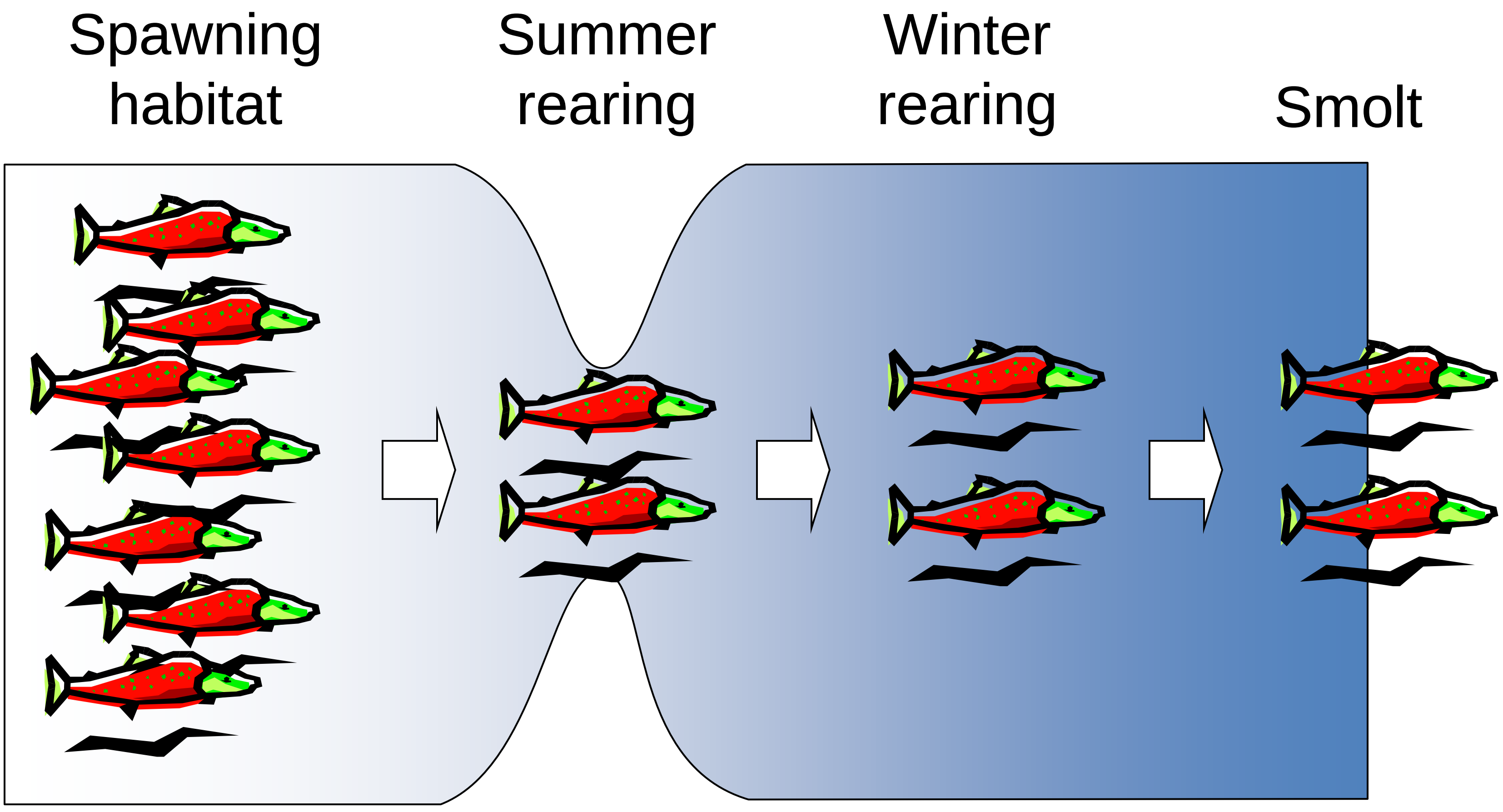


Source: Achord et al. 2012

Smolt Migration

- Adequate Flow
- Suitable Temperature
- No barriers/diversions
- Predators

Limiting Factors



What is limiting factors analysis?

- Compares the relative carrying capacity of different habitat types in a freshwater system.
- Identifies “possible factors limiting production” in freshwater
- Valid across specific spatial scales such as the sub-basin and watershed.

What is limiting factors analysis?
Analysis steps

1. Classify habitat types

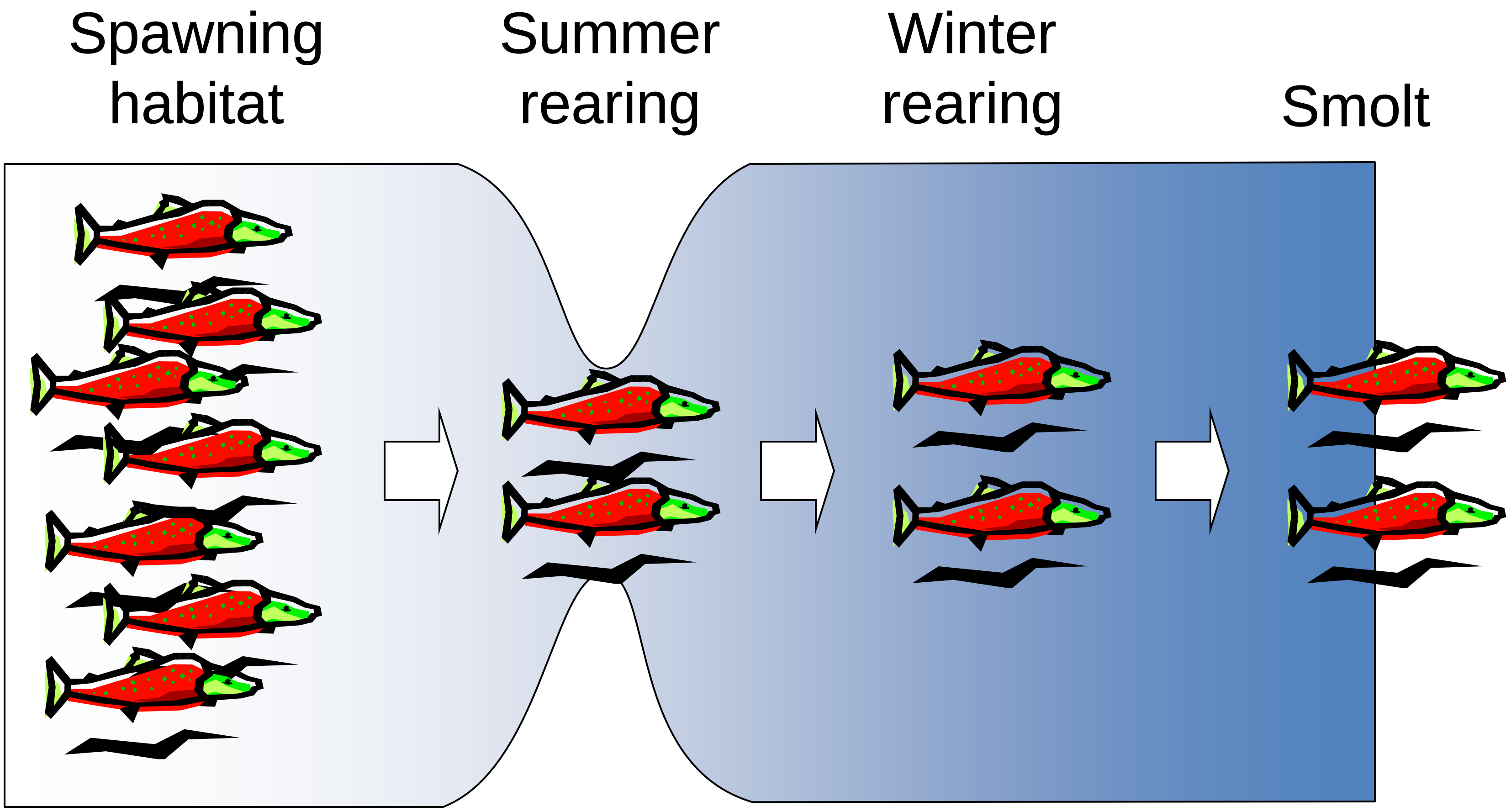
2. Identify fish use by habitat type

3. Devise methods of estimating change for each habitat type
   - Disconnected, lost, degraded, or restored habitats

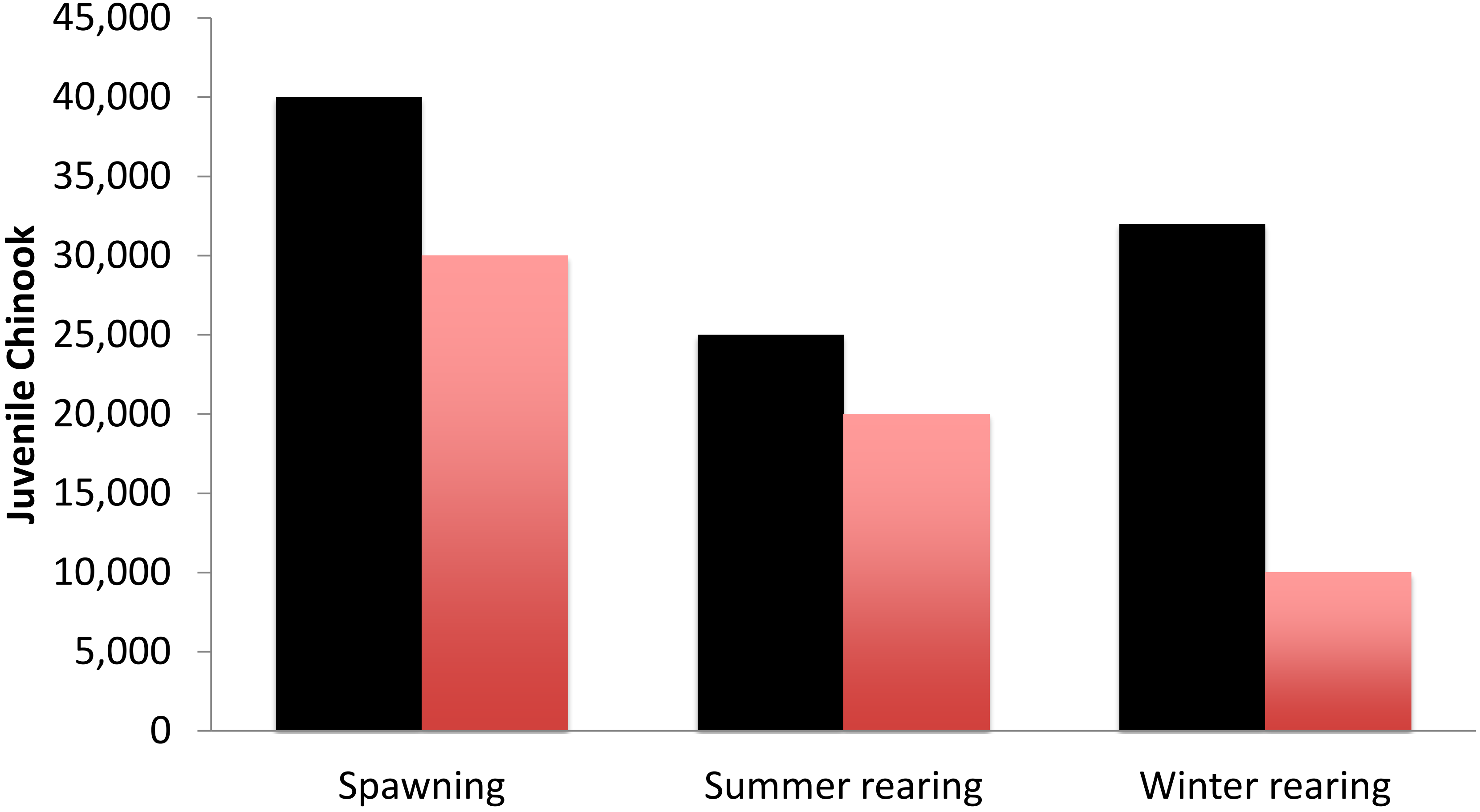
4. Assess habitat change – historic v. current, current v. restored

5. Estimate relative effects of each loss on production

Habitats or habitat quality associated with a specific life stage or season may limit potential



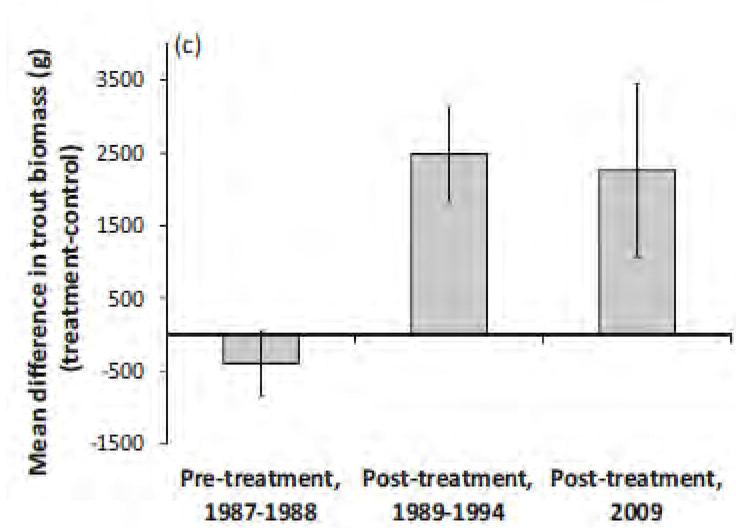
What Habitat is Limiting?

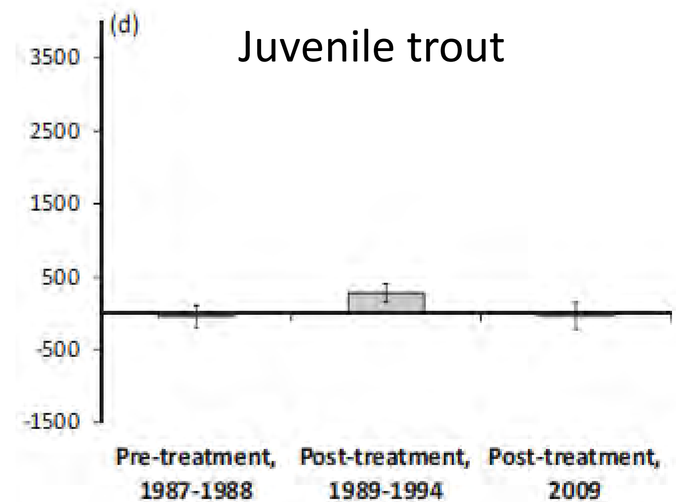


Target the right life stage & focus on limiting factors

- Trout populations 20 years after wood placement
  - Adult trout abundance
    - increased rapidly after structures were installed
    - remained 53% higher in treatment sections 21 years later.
  - Juvenile trout abundance
    - No change detected
    - Fry recruitment is strongly influenced by effects of annual snowmelt runoff.

Adult trout

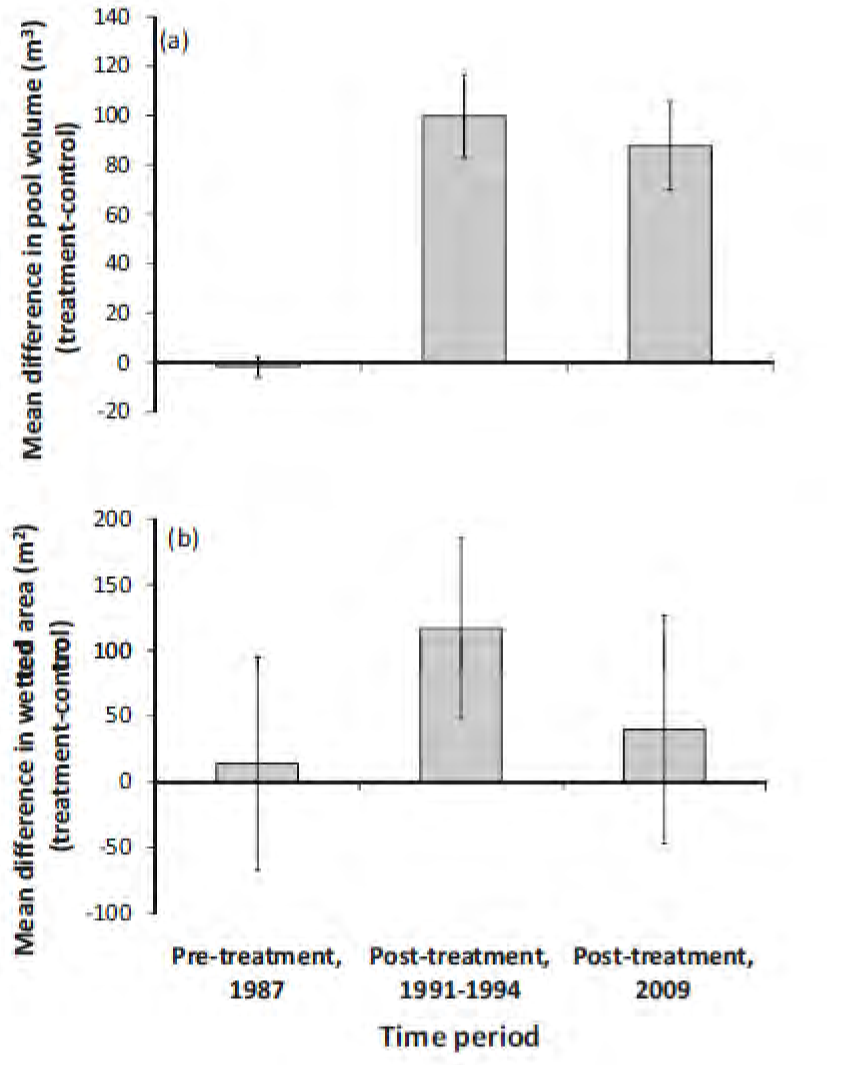




White et al. 2011

Target the right life stage & focus on limiting factors

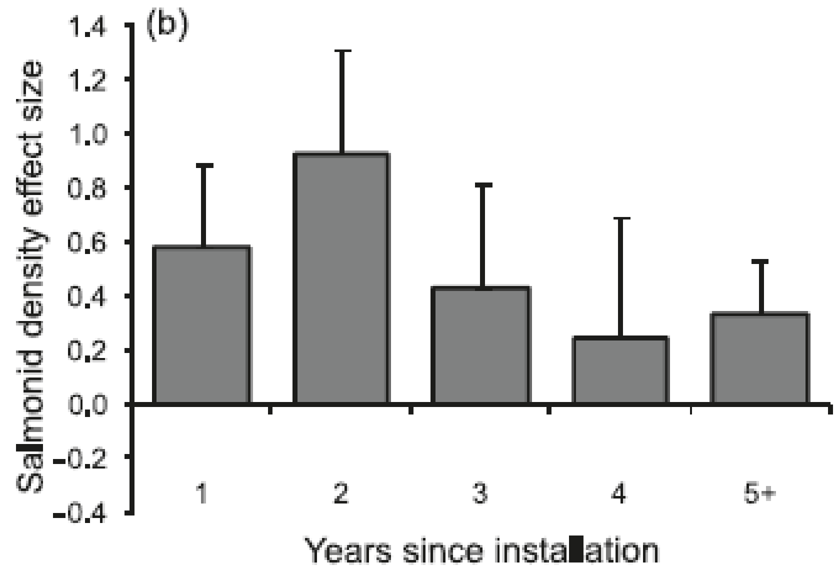
- Trout populations 20 years after wood placement
  - The increase in pool volume & wetted area has maintained over time.



White et al. 2011, Roni et al. 2002

Discuss the longevity of restoration over time, what does it mean to the resource?

- Structures & fish abundance meta-analysis
  - Salmonid densities decrease after two years.
  - However, most studies do not go beyond 1 year monitoring.



Whiteway et al. 2010

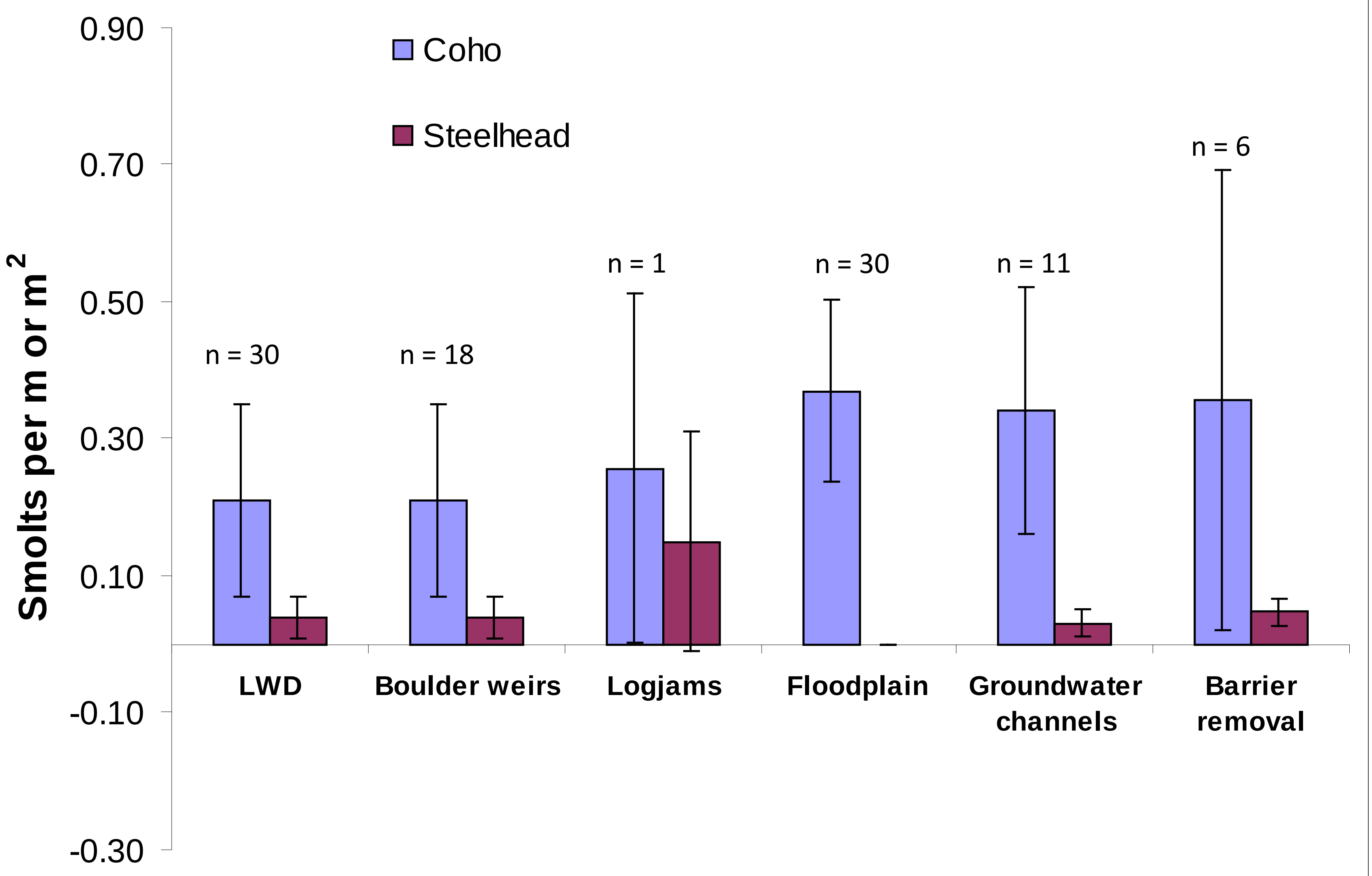
Estimating Habitat Benefits

Develop scenarios to compare current v. restored

Salmon Habitat	Restoration type
Streams/Rivers	
small – accessible	Wood placement
small - inaccessible	Barrier removal
medium	Boulder weir placements
large	Logjam construction
Floodplain habitat	
lost side channels	Develop groundwater channels
lost sloughs	Floodplain reconnection

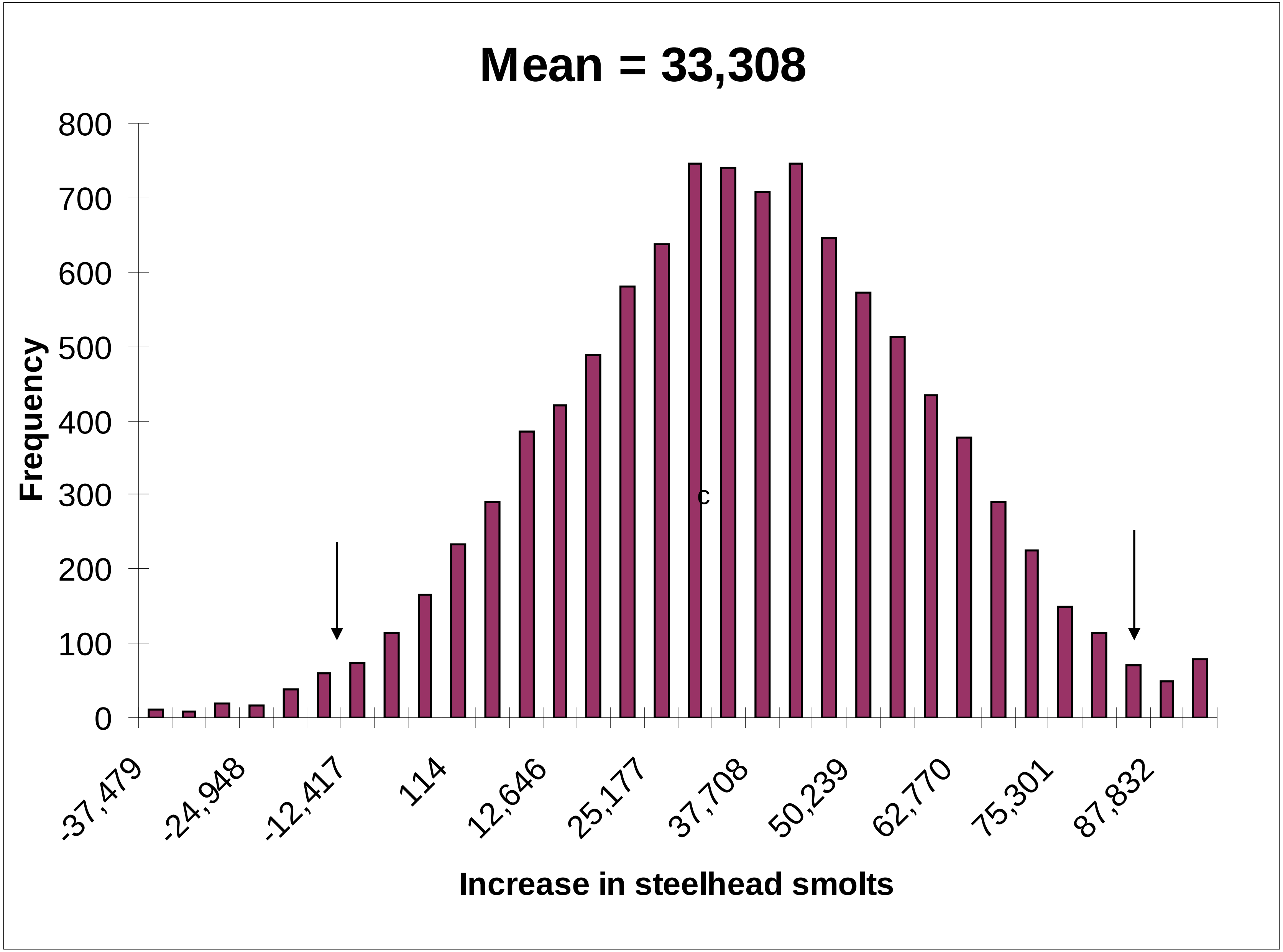
*Small = <15m bfw, medium = <25m bfw, large = >25m bfw

Mean increase in smolts due to restoration actions

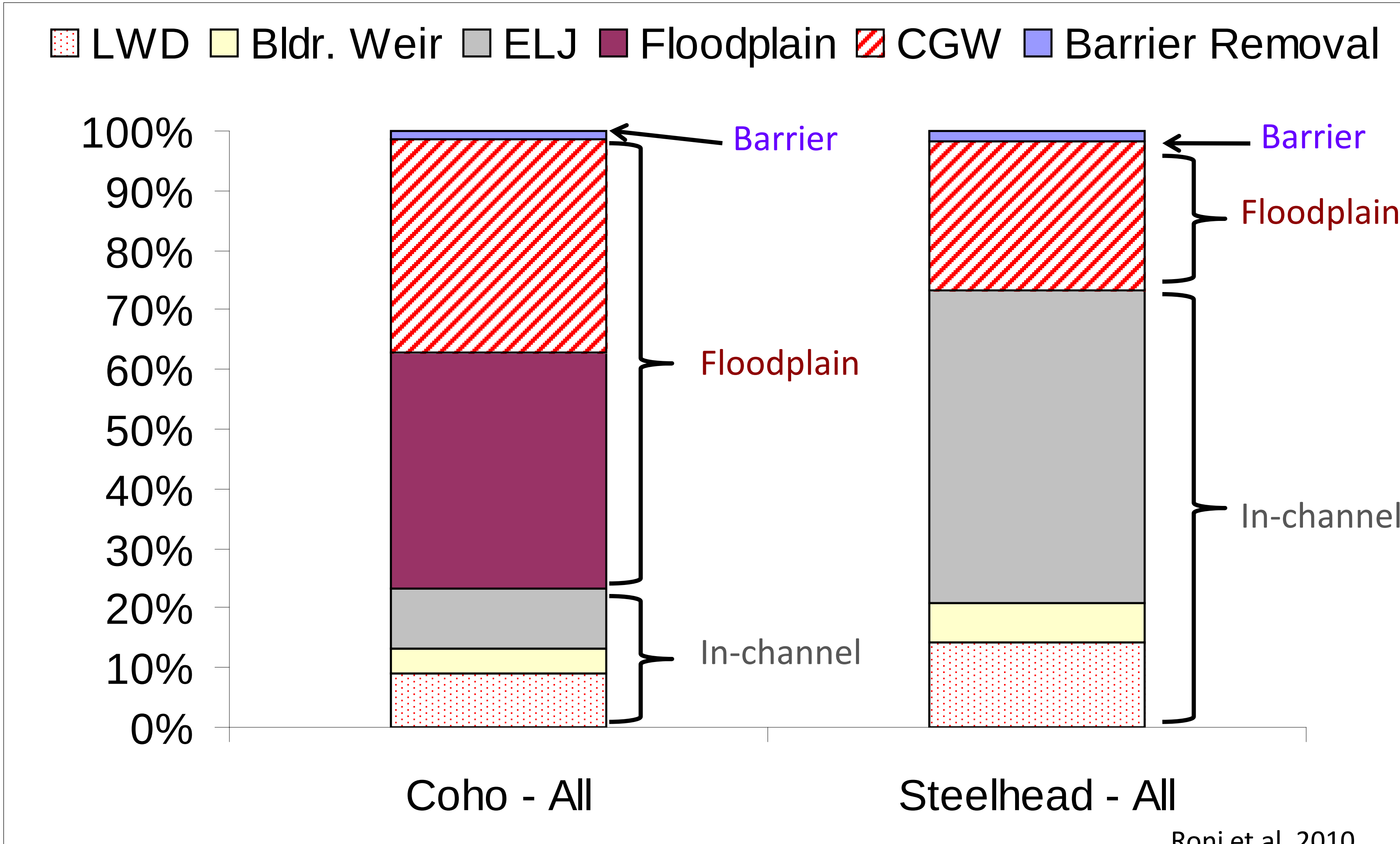


Roni et al. 2010

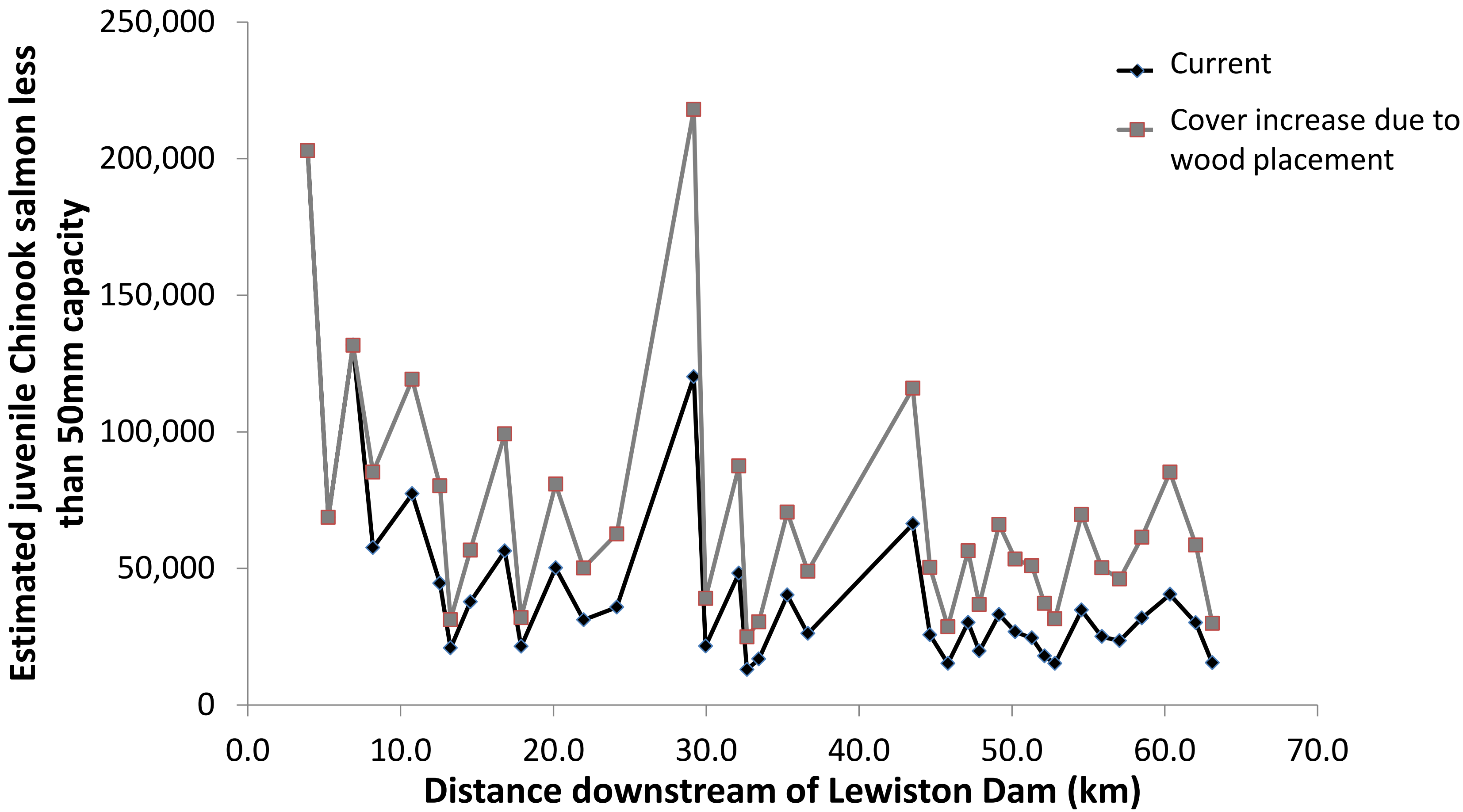
Increase in Steelhead Smolts



Compare virtual "increase by restoration action" to assess relative change in habitat capacity & fish use



Compare virtual "before v. after" to assess relative change in habitat capacity & fish use by a one or several restoration actions



Beechie et al. in press

Conclusions & Key Points

- Important to understand habitat requirements when planning restoration
- Different restoration actions will address different habitat requirements
- Target the right life stage and focus on limiting factors
- However, fish use whole watershed and restoration/improvement needs to address this and restore watershed

Conclusions & Key Points (cont.)

- Document approach for identifying current conditions and improvements due to restoration

- Acknowledge limitations of approach(es) used

- For long-term recovery need to couple
  - short-term habitat improvement with
  - long-term restoration

References

- Achord, S, B.P. Sanford, S.G. Smith, W.R. Wassard, and E.F. Prentice. 2012. In-Stream Monitoring of PIT-tagged Wild Spring/Summer Chinook Salmon Juveniles in Valley Creek, Idaho. AFS Symposium 76

- Allen, M.A. 2000. Seasonal Microhabitat Use by Juvenile Spring Chinook Salmon in the Yakima River Basin, Washington. Rivers 7:314-342.

- Allen, M. A. and T. J. Hassler. 1986. Species profile: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) -- Chinook Salmon, Fish and Wildlife Service, U. S. Army Corps of Engineers: 26.

- Barnhart, R. A. (1986). Species profile: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) -- steelhead, Fish and Wildlife Service,U. S. Army Corps of Engineers: 21.

- Baigu´n, C. R. 2003. Characteristics of deep pools used by adult summer steelhead in Steamboat Creek, Oregon. North American Journal of Fisheries Management 23:1167–1174.

- Bell, M.O. 1990. 1991 Fisheries Handbook of engineering requirements and biological criteria. USACE, Portland, OR

- Beechie, T.J., G.R. Pess, and H. Imaki. 2012. Estimated changes to Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) habitat carrying capacity from rehabilitation actions for the Trinity River, North Fork Trinity to Lewiston Dam. Report to USFWS, Arcata, CA.

- Beechie, T. J., M. Liermann, E. M. Beamer, R. Henderson. 2005. A classification of habitat types in a large river and their use by juvenile salmonids. Transactions of the American Fisheries Society, 134:717-729.

- Beechie, T.J., H. Moir, and G. Pess. 2008. Hierarchical physical controls on salmonid spawning location and timing. Pages 83-102 *in* D.A. Sear and P. DeVries, editors. Salmonid spawning habitat in rivers: physical controls, biological responses, and approaches to remediation. American Fisheries Society, Symposium 65, Bethsda, Maryland.

- Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. In Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. Edited by William R. Meehan. American Fisheries Society Special Publication 19:83-138

- Bradford, M. J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences 52(6): 1327-1338.

- Greig, S. M., D. A. Sear, et al. 2005. "The impact of fine sediment accumulation on the survival of incubating salmon progeny: Implications for sediment management." Science of the Total Environment 344(1-3): 241-258.

References

- Hayes, S. A., M. H. Bond. C. V. Hanson, E. V. Freund, J. J. Smith, E. C. Anderson, A. J. Ammann, and R. B. MacFarlane. 2008. Steelhead growth in a small central California watershed: upstream and estuarine rearing patterns. Transactions of the American Fisheries Society 137(1):114-128.
- High B, Perry CA, Bennett DH 2006. Temporary staging of Columbia River summer steelhead in cool-water areas and its effect on migration rates. Trans Am Fish Soc 135:519–528
- Jensen, D. W., E. A. Steel, E. A. Fullerton and G. Pess. 2009.. Impact of fine sediment on egg-to-fry survival of Pacific salmon: a meta-analysis of published studies. Reviews in Fisheries Science 17(3):348–359
- Johnson, C. P. Roni and G. Pess. In press. Parental effect as a Primary Factor Limiting Egg-to-Fry Survival of Spring Chinook Salmon *Oncorhynchus tshawytscha* in the Upper Yakima River Basin. Transactions of American Fisheries Society. (accepted with minor revision)
- Keefer, M. L., C. A. Peery, T. C. Bjornn, M. A. Jepson, and L. C. Stuehrenberg. 2004a. Hydrosystem, dam, and reservoir passage rates of adult Chinook salmon and steelhead in the Columbia and Snake rivers. Transactions of the American Fisheries Society 133:1413–1439.
- Montgomery, D.R., Buffington, J.M., Smith, R.D., Schmidt, K.M., and Pess, G. 1995. Pool spacing in forest channels. Water Resour. Res. 31: 1097-1105.
- Montgomery, D.R., Beamer, E.M., Pess, G.R., and Quinn, T.P. 1999. Channel type and salmonid spawning distribution and abundance. Can. J. Fish. Aquat. Sci. 56: 377–387.
- Nakamoto, R. J. 1994. Characteristics of pools used by adult summer steelhead oversummering in the New River, California. Transactions of the American Fisheries Society 123: 757-765.

References

- Pess, G. R., D. R. Montgomery, T. J. Beechie, L. Holsinger. 2002. Anthropogenic alterations to the biogeography of salmon in Puget Sound. Pages 129-154 *in* Montgomery, D. R., S. Bolton, D. B. Booth. (Eds.) Restoration of Puget Sound Rivers. University of Washington Press, Seattle, WA.
- Peters, R., C. Cook-Tabor, T. Levy, D. Lantz, and M. Liermann. In prep. Habitat selection by juvenile Chinook salmon: Multi-scale assessment. Report for Seattle Public Utilities, Seattle, WA.
- Raleigh, R.F. W.J. Miller, and P. C. Nelson. 1986 Habitat suitability index modesl and instream flow suitability curves: chinook salmon. USFWS Biological Report 82(10.122).
- Raleigh, R.F. , T. Hickman, R.J. Solomon, P.C. Nelson. 1984. Habitat suitability information: rainbow trout. USFWS Biological ReportOBS82/10.60
- Roni, P., G. R. Pess, T. J. Beechie, S. A. Morley. 2010. Estimating salmon and steelhead response to watershed restoration: How much restoration is enough? North American Journal of Fisheries Management, 30:1469-1484.
- Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, G. R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management, 22(1):1-20.
- White, S. C. Gowan, K. Fausch, J. Harris, and C. Saunders. 2011. Response of trout populations in five Colorado streams two decades after habitat manipulation. CJFAS 68: 2057-2063
- Whiteway, S.L., Biron, P.M., Zimmerman, A., Venter, O., and Grant, J.W.A. 2010. Do in-stream restoration structures enhance salmonid abundance? a meta-analysis. CJFAS 67: 831– 841. doi:10.1139/F10-021.
- Wissmar and Simenstad 1998