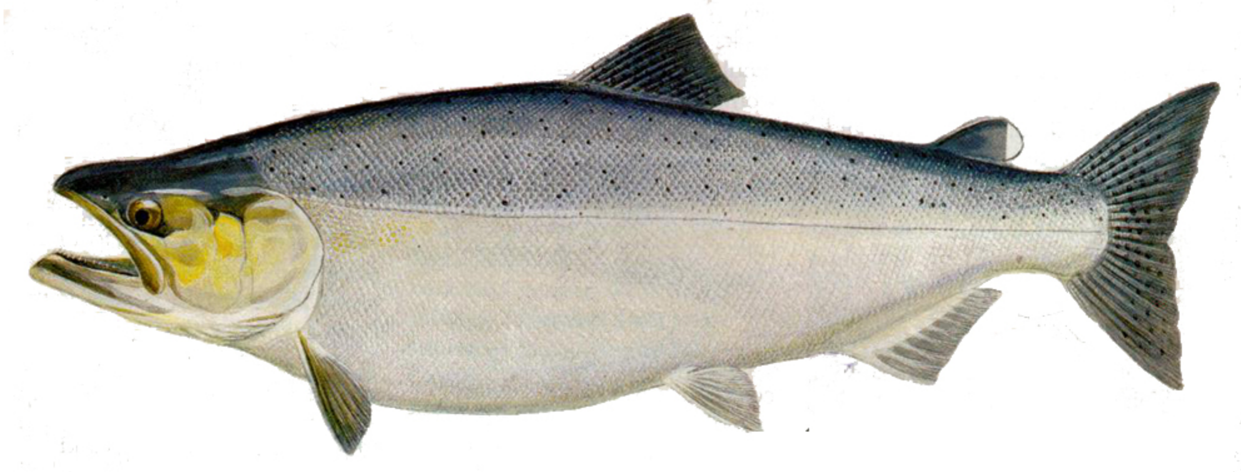


Columbia River Hydrosystem

The Story of The Columbia River

Good Intentions, Technology and the Unfortunate Outcome

November 3, 2007

Margaret J. Filardo, Ph.D.

Outline

- History
  - Development of Hydrosystem
  - Governance
  - Fish Passage Center
- Effects of Hydroelectric Development
  - Habitat
  - Hydrology
  - Passage
- Results
  - Mitigation that doesn't work
  - Mitigation that does work
- Summary
  - Take-home message

Columbia River Information

- Length 2032 Km
- Drainage area: 668,000 Km^2. Larger than France, Belgium, & Netherlands combined.

Historical Development

Pre Development

- Columbia River Salmon runs historically estimated at 10 to 16 million fish

- Now estimated at 1.5 to 2 million, with approximately 75% of those being hatchery fish.


Columbia River Basin
Corps of Engineers Dams
Dams owned by Others
Bureau of Reclamation Dams
Mica
Revelstoke
Arrow Lakes
Duncan
Kootenay Lake
Keenleyside
Canada
U.S.
Grand Coulee
Chief Joseph
Albeni Falls
Libby
Hungry Horse
Wells
Noxon
Columbia R.
Rocky Reach
Pend Oreille Lake
Flathead Lake
Rock Island
Kerr
Little Goose
Seattle
Lower Monumental
MT
Wanapum
Lower Granite
Priest Rapids
WA
Dworshak
Ice Harbor
The Dalles
Portland
McNary
Hells Canyon
Bonneville
John Day
Oxbow
ID
Brownlee
Willamette R.
OR
Jackson Lake
Boise Projects
Snake R.
CA
NV
N

Good Intentions

- Throughout history we never intended to drive Columbia River salmon to near extinction.

- Regional intent was to preserve the fish population and the sport and commercial economies that relied upon fisheries.

Hydropower Mitigation Governance

Laws were put in place with the intent to protect salmon.

- NW Power Act 1980
  Fish and Wildlife Program
- ESA Listing 1990's
  Biological Opinion released in 1993, 1995, 1998, 2000, 2004, 2008
- Combination of 2008 Biological Opinion and 2005 Court Ordered Operations

Where Are We Now?

Fish Passage Center

- Established in first Fish and Wildlife Program.
- Provide technical assistance to state, tribal and federal fishery agencies.
- Smolt Monitoring Program – juvenile migration characteristics.
- Comparative Survival Study (1997).


Legend
Dam
Trap
WASHINGTON
IDAHO
OREGON
Chief Joseph
Grand Coulee
Wells
Rocky Reach
Rock Island(SMP)
Wanapum
Priest Rapids
Lower Granite(SMP)
Snake River
Dworshak
Lower Monumental (SMP)
Little Goose (SMP)
Snake River Trap(SMP)
Clearwater Trap
Ice Harbor
Grande Ronde Trap(SMP)
Columbia River
John Day(SMP)
McNary(SMP)
Bonneville (SMP)
The Dalles
Salmon River Trap (SMP)
Imnaha River Trap(SMP)

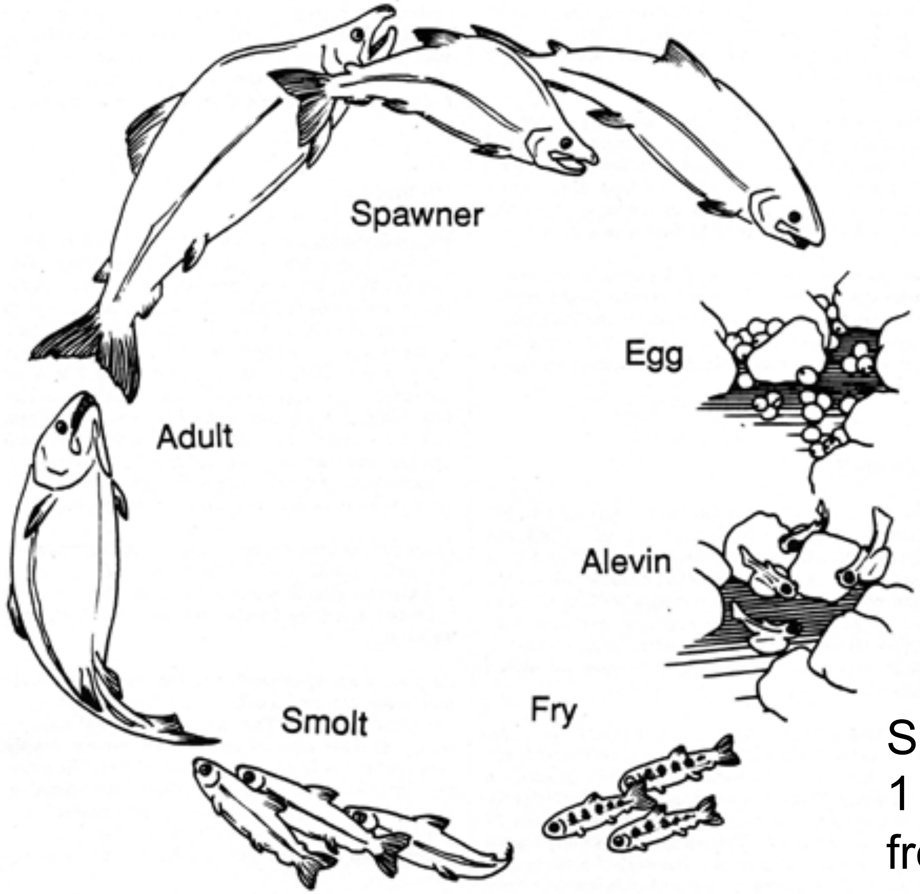
Effects of Dams on Salmonids

- Spawning Habitat
- Hydrology
- Passage

Columbia River Chinook Life-Cycle

Spawn in Fresh Water

2-4 years in ocean



Juveniles emerge and forage

Spend ½ to 1 ½ years in fresh water

Migrate through hydrosystem Apr-Aug

Spawning Habitat

- Blocked passage – 1/3 of spawning habitat blocked by high head dams.
- Operation of projects affects spawning habitat by limiting availability downstream.

Hatcheries

- It was believed that we could control the reproduction of economically important fishes and, that in doing so we could increase the abundance of salmon.

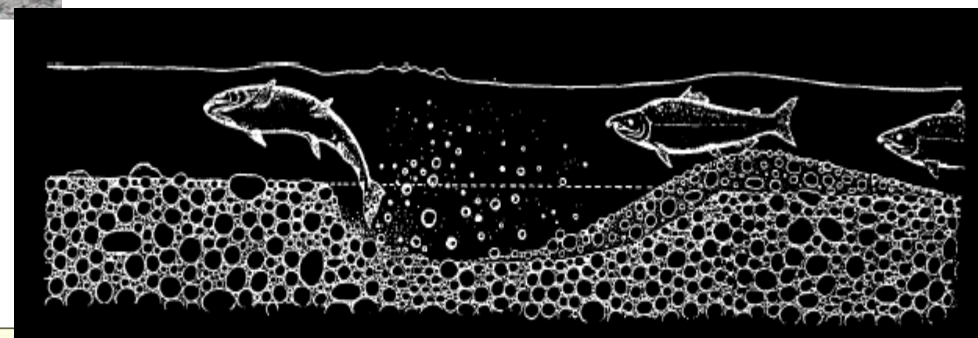
- As a consequence, hatcheries were constructed and used as mitigation for habitat loss.

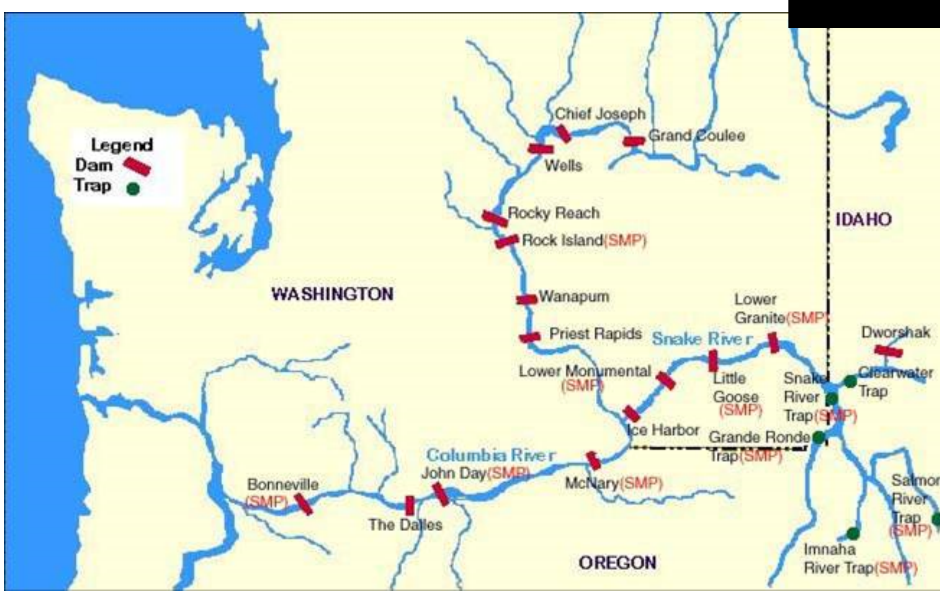
What Have We Learned?

- Artificial propagation was not able to maintain the abundance of salmon.
- As wild populations declined with the loss of habitat the number of adults that hatcheries were able to produce became a larger and larger part of the total run.
- Salmon of hatchery origin are now the dominant fish in the Columbia Basin.

Spawning Habitat Availability

Spawning area restricted by holding a low tailwater elevation.



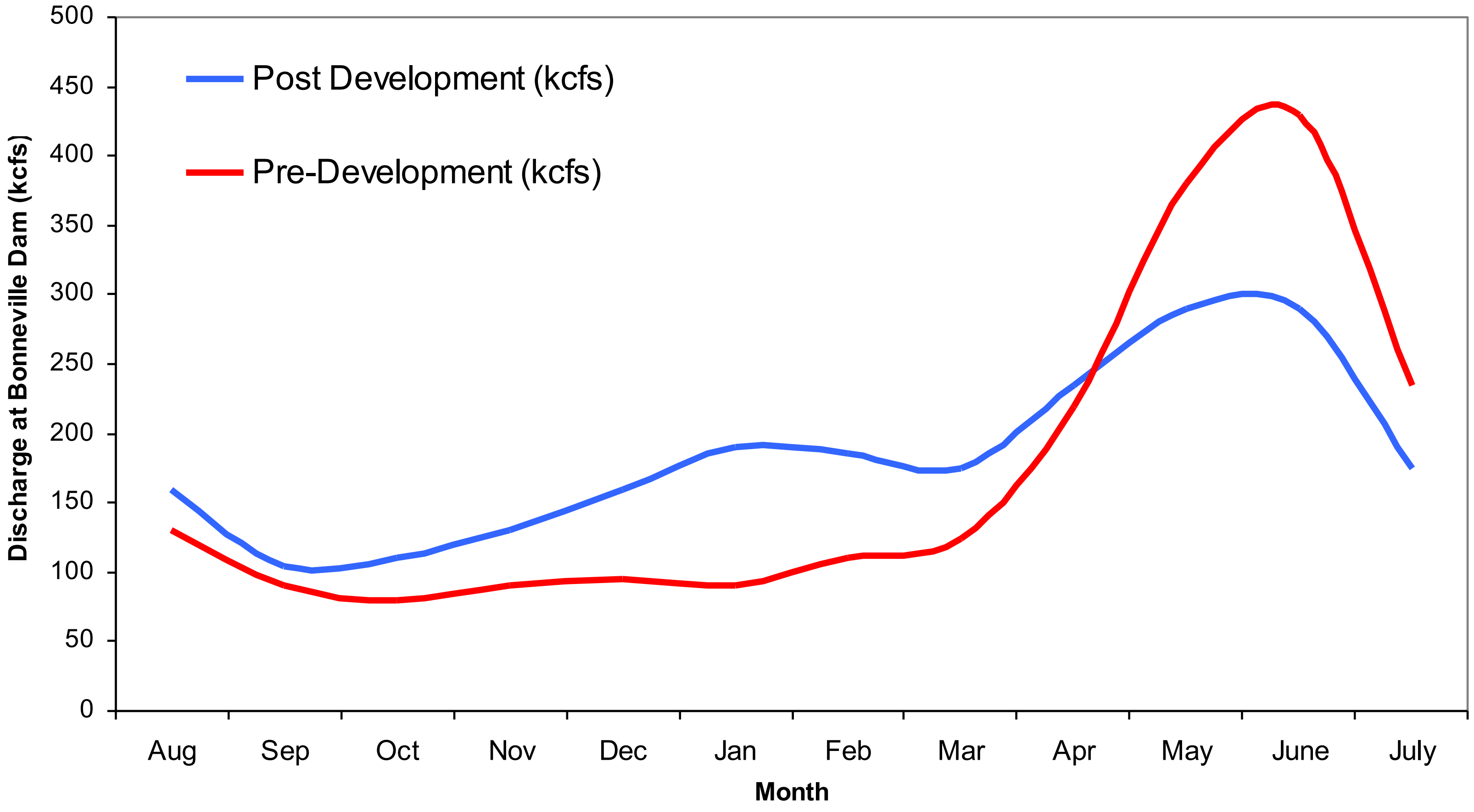


What Have We Learned?

- Ives/Pierce Island Complex – chum salmon populations continue to decline.

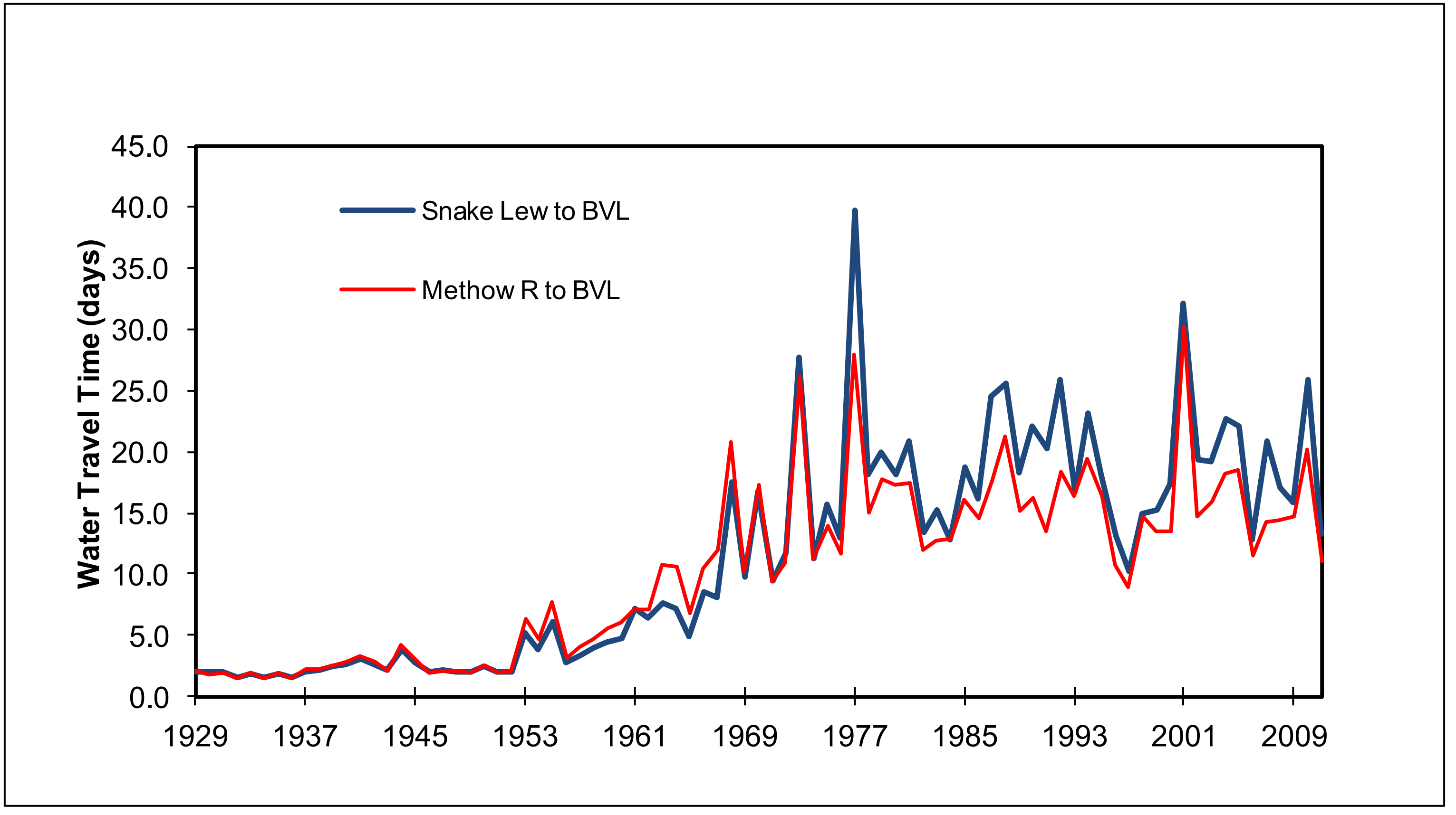
- Total mainstem spawning habitat has been reduced by 80%.

Hydrology



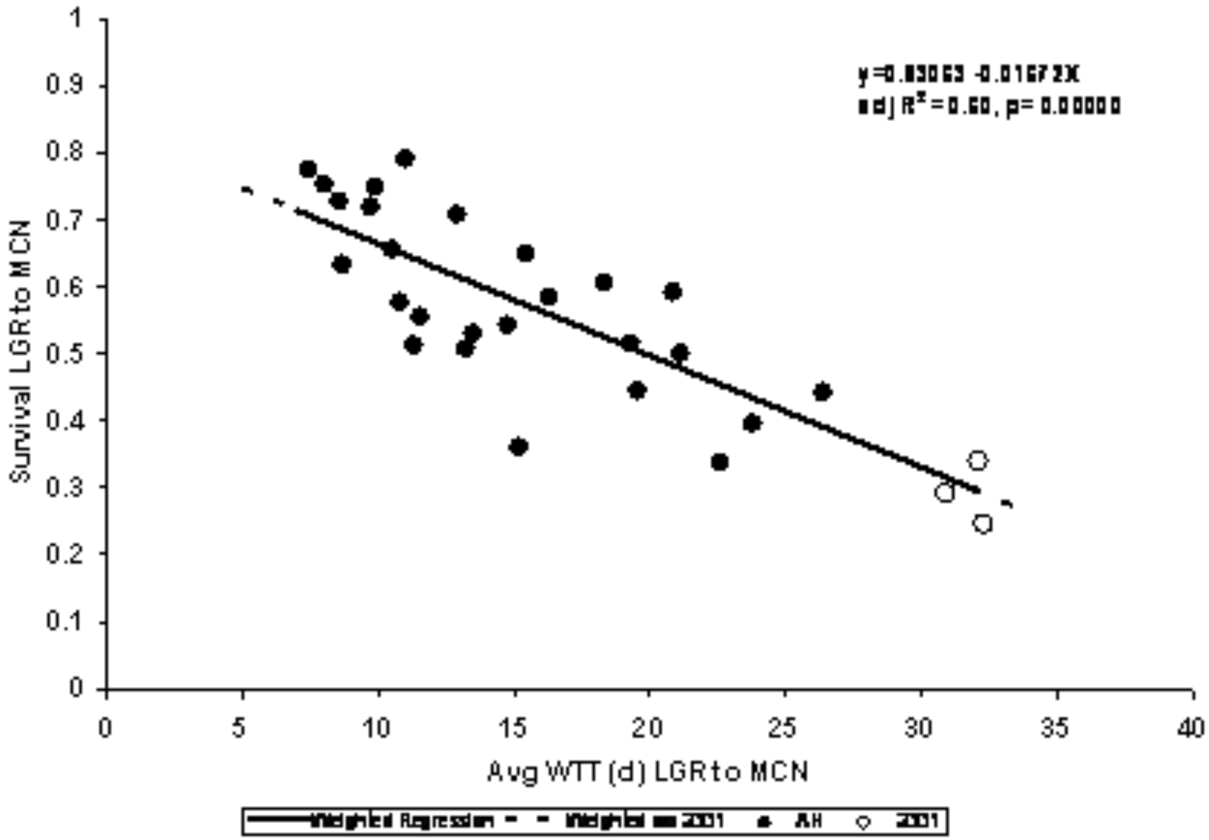
Post Development (kcfs)
Pre-Development (kcfs)
Discharge at Bonneville Dam (kcfs)
500
450
400
350
300
250
200
150
100
50
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Month

Historic Water Travel Times
WTT = Volume/Flow



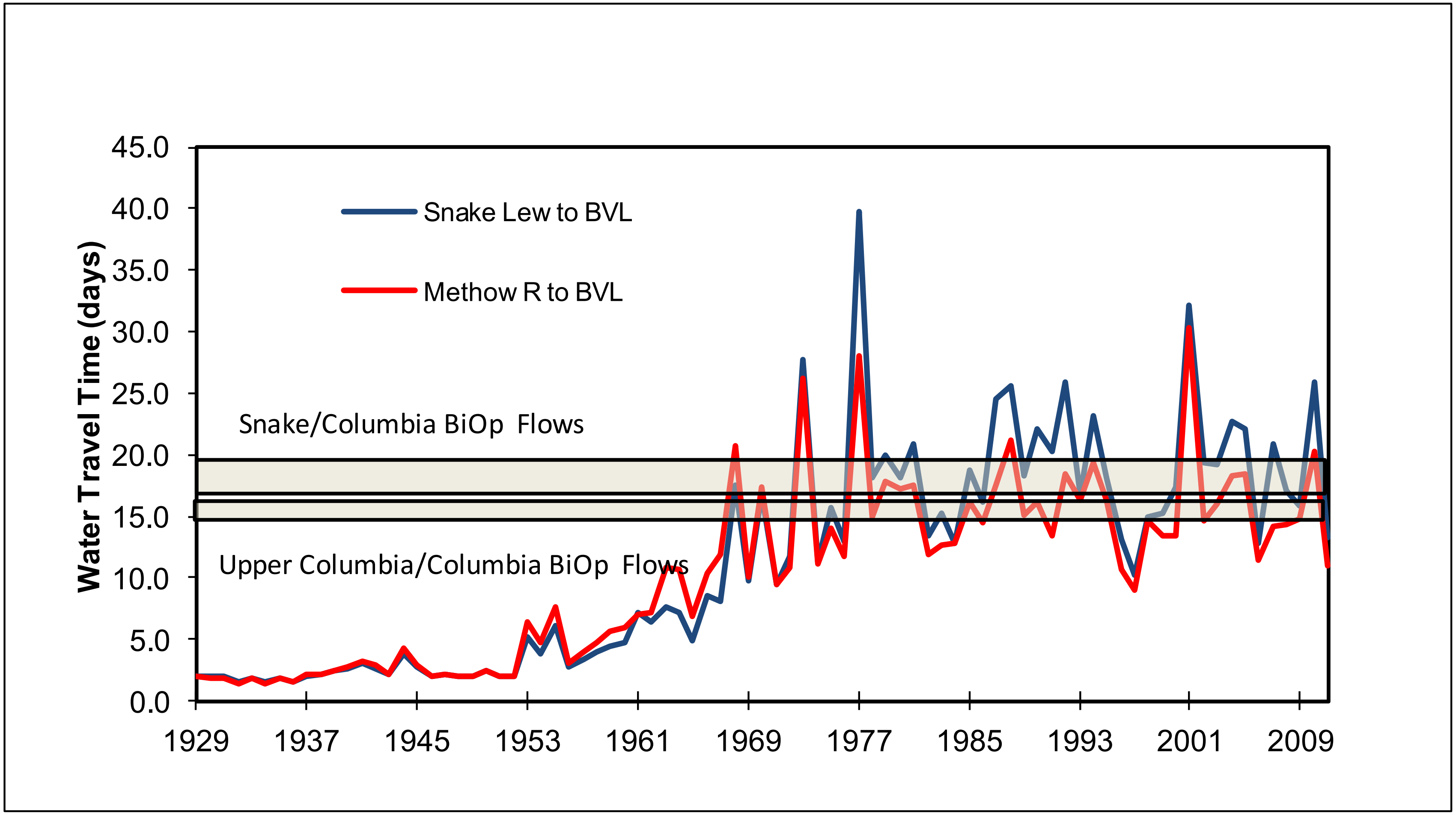
Chinook Subyearling Survival Versus WTT

High Correlation FTT to WTT



Actions Taken to Address Hydrology Alteration

- Attempt to return to more "normative" flow regime.
  - Hydrosystem changed reservoir refill practices.
  - Reservoirs "drawn-down" 5 feet to alter geometry and increase water transit time.

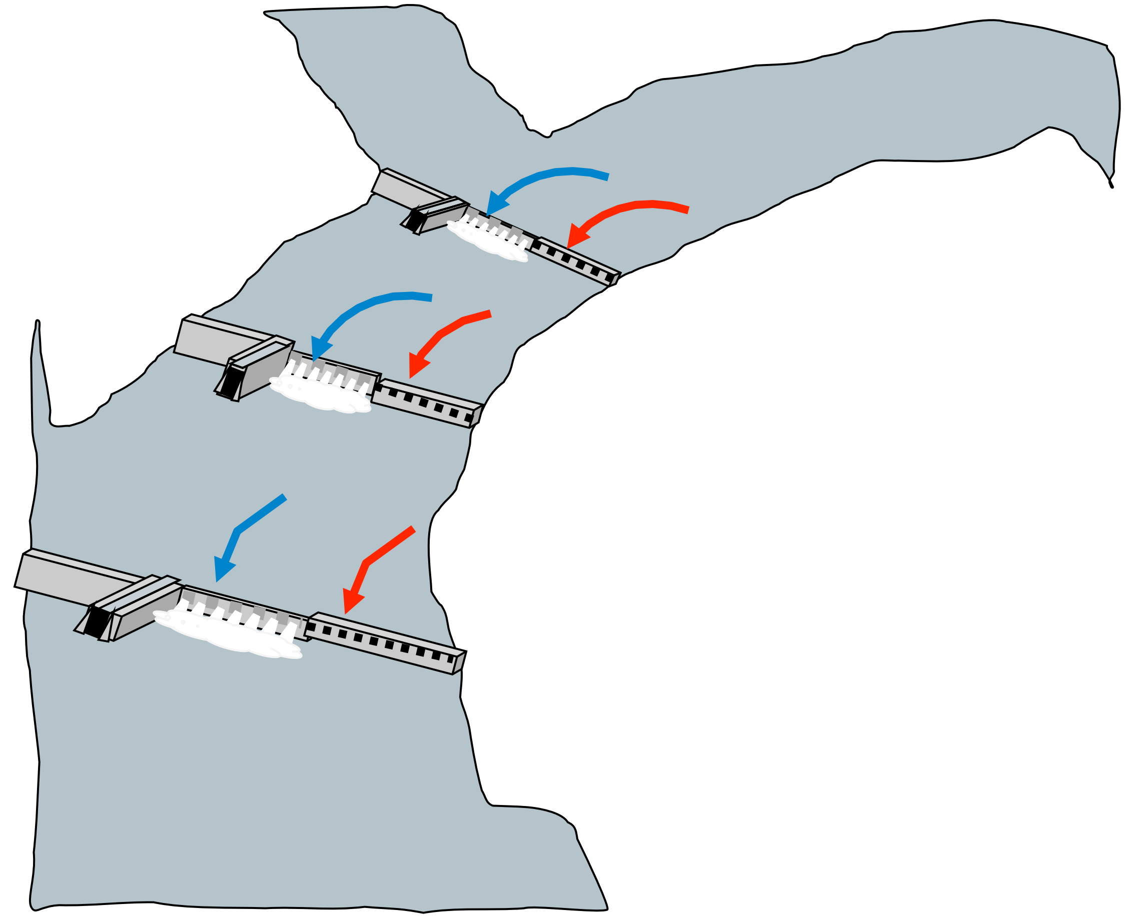


Water Travel Time (days)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Snake Lew to BVL
Methow R to BVL
Snake/Columbia BiOp Flows
Upper Columbia/Columbia BiOp Flows
1929
1937
1945
1953
1961
1969
1977
1985
1993
2001
2009

What Have We Learned?

- Flows provided for fish are seasonal averages.
- Flow for fish mitigation is not guaranteed and is costly to the hydrosystem.
- Can never return to pre-development water transit times or fish travel times.

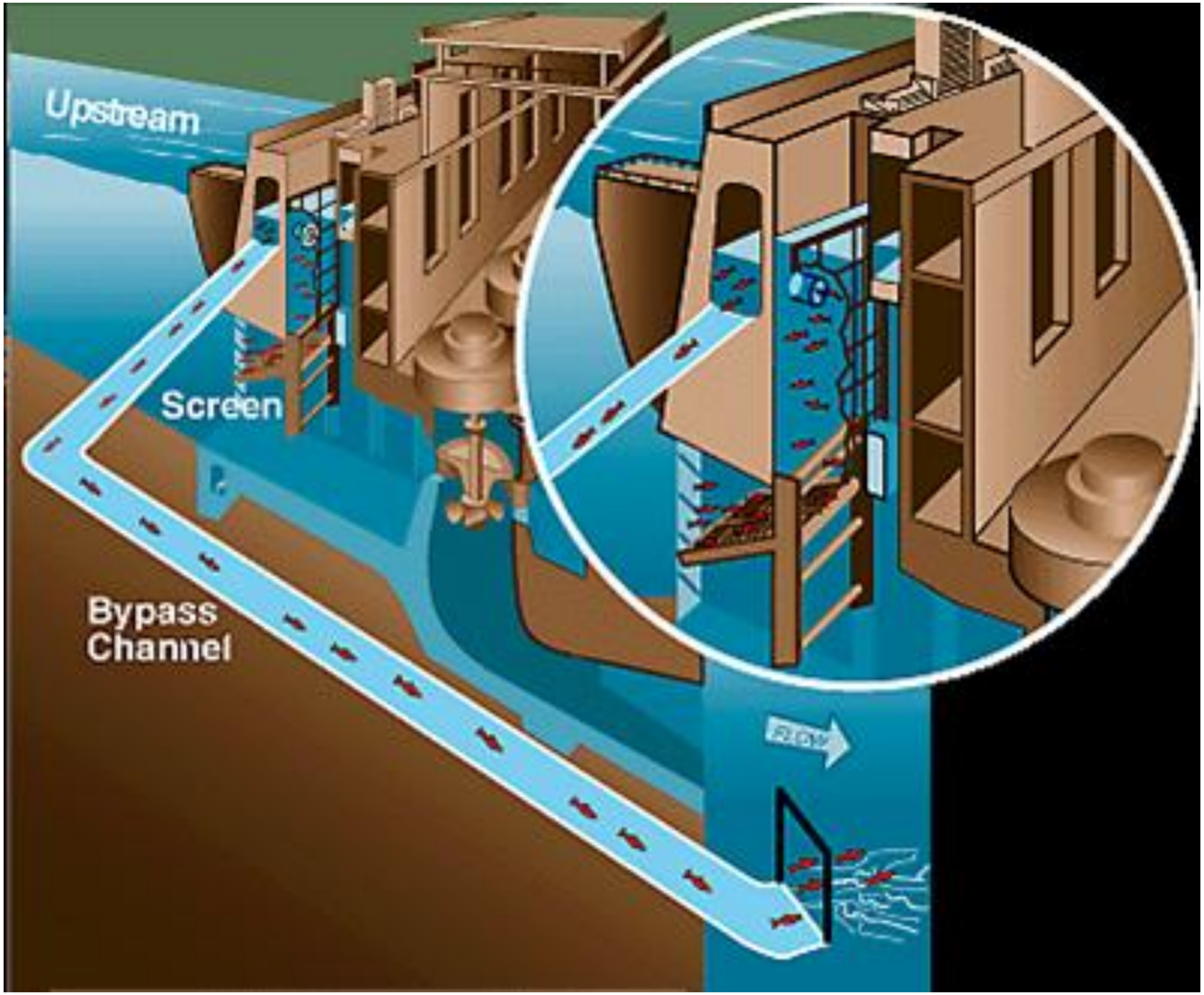
Passage

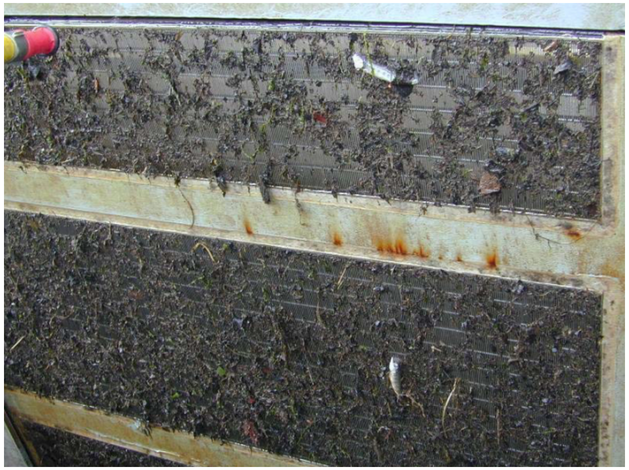


Juvenile Project Passage

- Bypass Structures
  - Transportation
- Spill
  - Surface Spill Collection

Juvenile Bypass Structures





What have we learned?

- Screen effectiveness limited in terms of fish guidance.
- Every project is unique.
- Require continuing maintenance and modifications.

Transportation Program

- Reservoirs slow migration.
- Powerhouse passage affects survival.
- Spill is costly.
- Take fish out of the river and transport them via barge or truck.

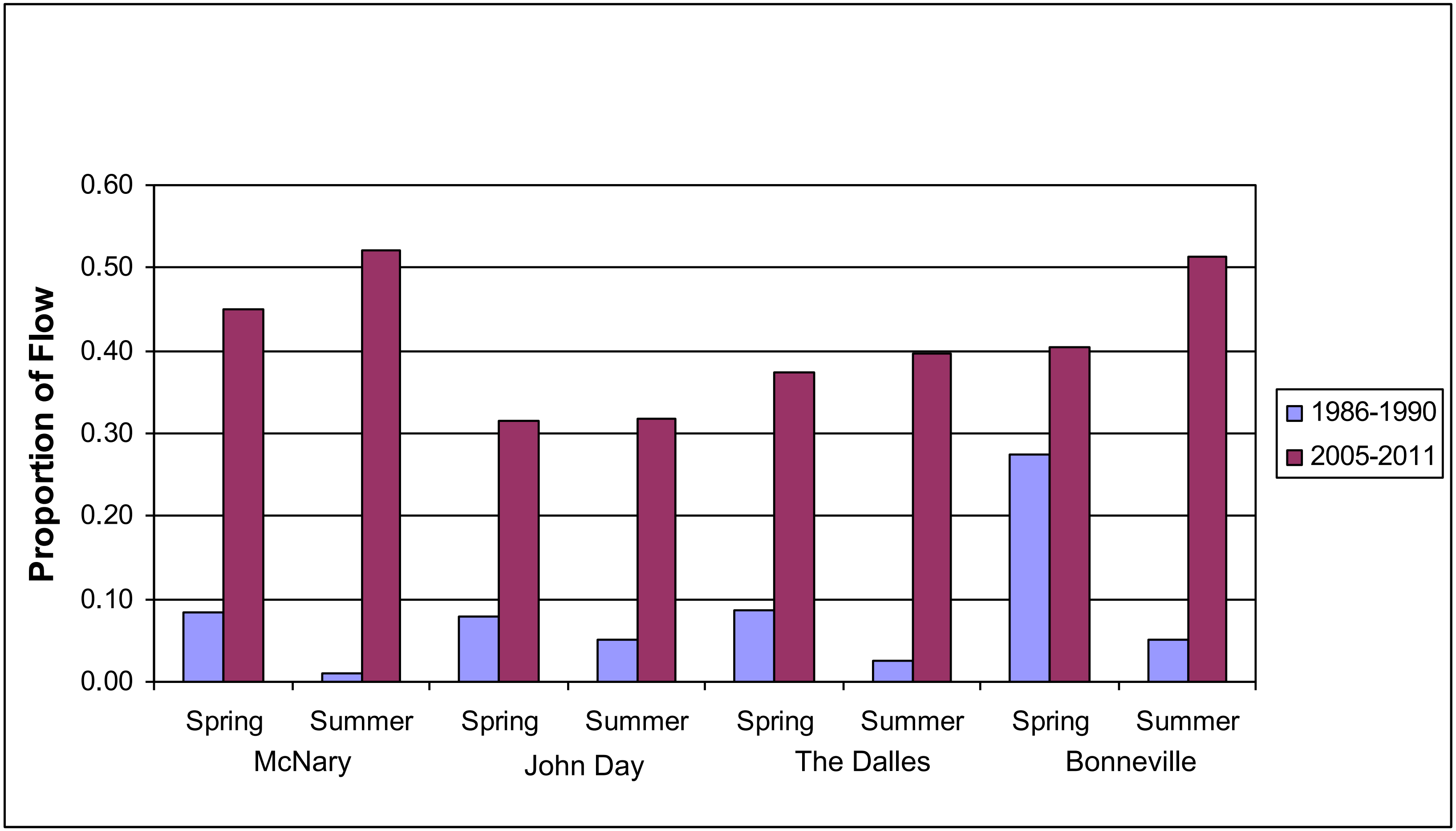

WET SEPARATOR

What Have We Learned?

- Implemented since the early 1970's.
- Comparison of survival of in-river to transported fish at Bonneville shows a differential survival post hydro-system.
- Increased stray rates associated with returning adults.
- Smolt to adult return rates not sufficiently high to recover stocks.

Spill Passage

Proportion of Flow Passed as Spill



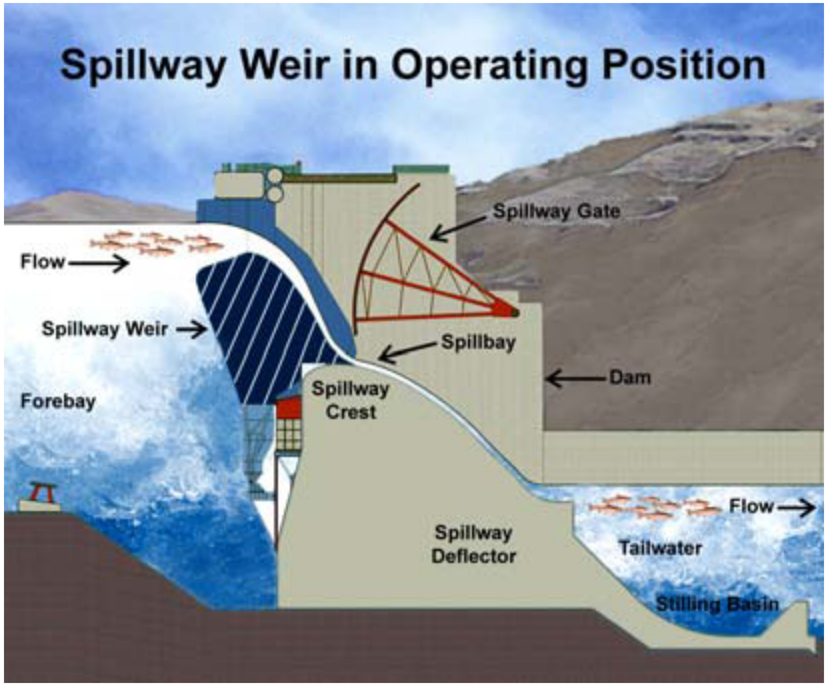
What Have We Learned?

- Spill has consistently been the passage route associated with the highest juvenile survival.

- Spill has been shown to reduce forebay passage delay and disperse predators in the tailrace area.

- Spill is expensive and de-rates the hydrosystem in terms of foregone energy production.

Surface Bypass Collection



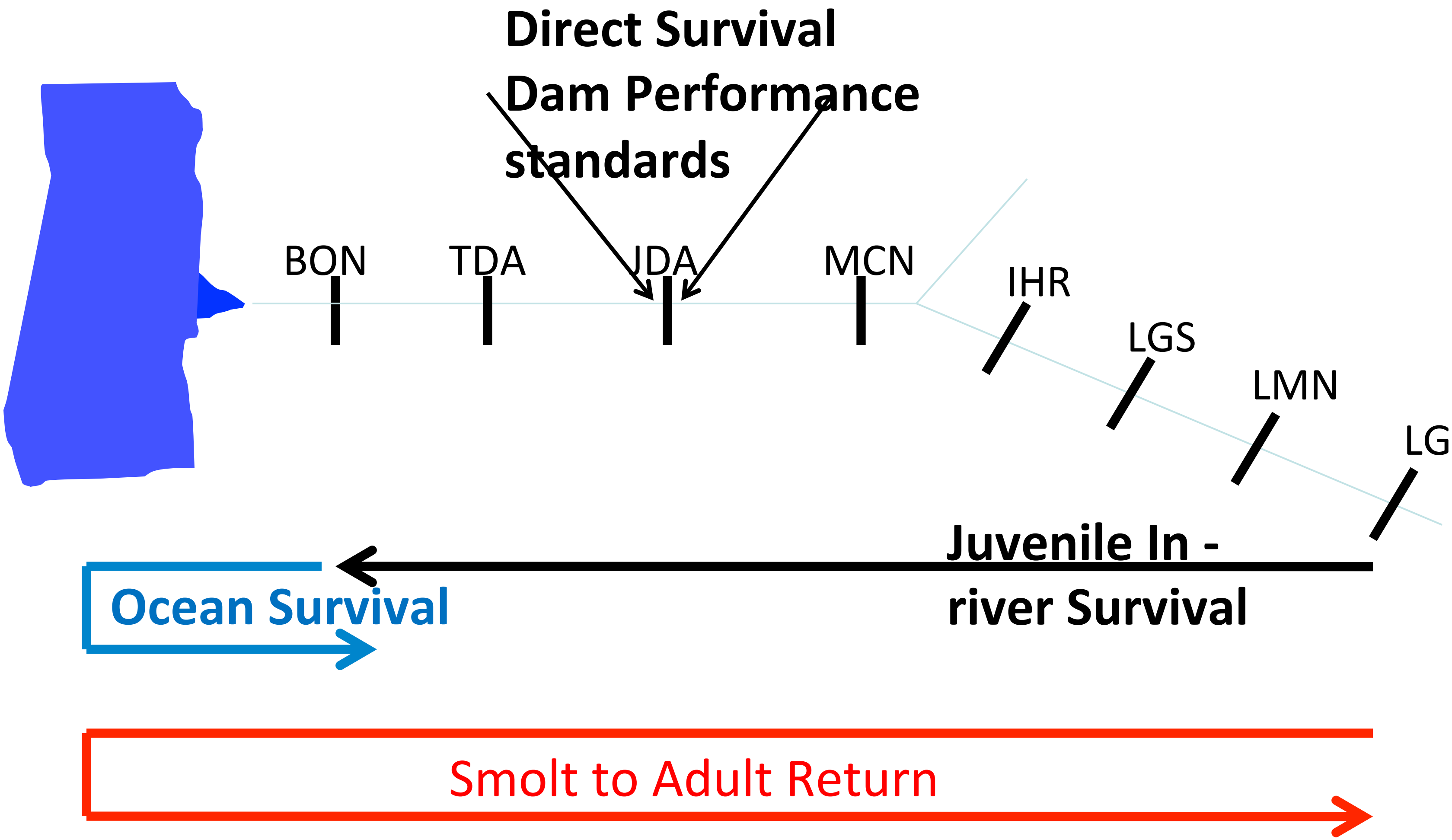
What Have We Learned?

- Attracting fish to the spillbay area requires a sufficient proportion of flow.
- Therefore, spill has not decreased.

Present Status
Has Anything Worked?

- How do you measure success?

Survival Rate Stages



Route Specific Direct Mortality Estimates

- Provide overly optimistic estimates of survival.
  - Misrepresent the impact of dams on fish. Do not capture indirect effects of project passage, primarily delayed or latent mortality associated with bypass system passage.

- Delayed or Latent Mortality –
  - Mortality related to passage through the hydrosystem that is expressed at later life stages of the estuary or early ocean phase.

- Juvenile Reach survival estimates provide more information, but may miss longer-term effects.
- Therefore, need to evaluate success in terms of smolt to adult survival performance standards.

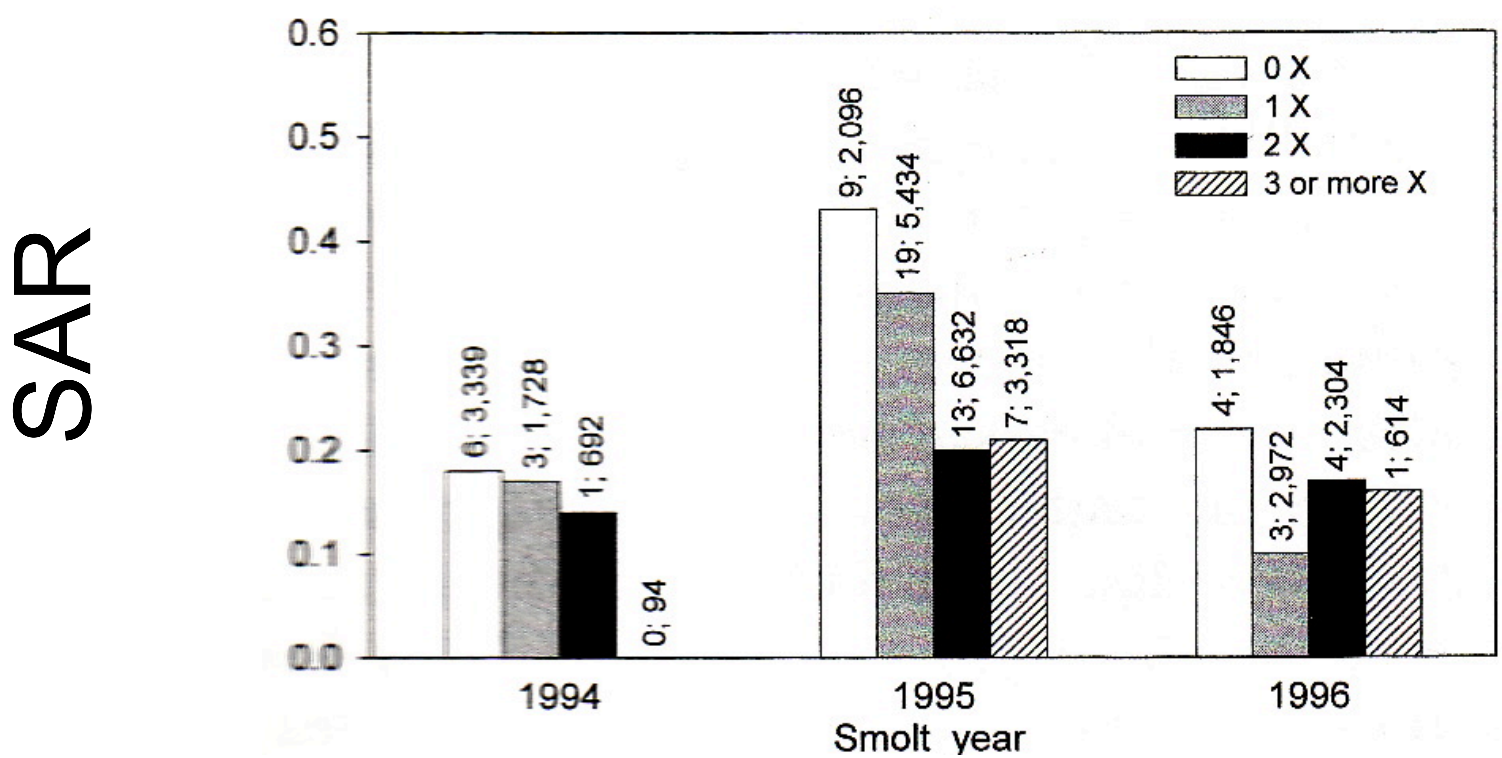
Early Evidence for Delayed Hydrosystem Mortality

(Budy et al., 2002)

- Effect of dam passage not necessarily expressed in "direct" dam survival or juvenile reach survival estimates.
- Powerhouse passage associated with
  - Mechanical injury
  - Migration Delay
  - Stress
  - Increased Predation

Delayed Mortality

Direct evidence of delayed mortality from PIT tag data: in-river



Mechanisms for Delayed Mortality

- Primary factors affecting survival are inter-related;
  - Migration Delay
  - Predation
  - Stress

Migration Delay

- Migration rates decrease significantly as fish approach a project associated with declining water velocities near the dam.
- Overall migration travel time increases with bypass passage getting fish to the estuary later, possibly later than the "biological window" for seawater entry.
- Concentration of smolts at forebay results in high predation rates of smolts near the dams.

Predation

- Juvenile Bypass Systems concentrate prey in both the forebay and tailrace.
  - Northern Pikeminnow – primary pescivorous predator below project.
  - Avian Predation – caspian terns, cormorants and pelicans.

Stress

- Physical disturbance:
  - Leads to increase in metabolic rate causing decreased energy reserves and overall decrease in performance.
  - Increase in disease associated with less mucous production and lowered immune function.
  - Migration delays interfere with on-going osmoregulation changes possibly causing reversion to parr–like physiology.

Passage Success

- Must be measured in terms of adults returned.
- Recognize that ocean factors are important in determining survival to adulthood.
- Are there juvenile factors that can affect survival to the adulthood and what are the mechanisms?

Recent Studies

- As more data were collected the attempt has been made:
  - to evaluate the Budy et al. (2002) hydrosystem-related delayed mortality hypothesis.
  - to quantify the influences of freshwater and marine environmental factors on life stage-specific survival rate estimates of Snake River spring/summer Chinook salmon and steelhead.

- Petrosky and Schaller, 2010 utilized a long time series of smolt to adult return rates in multiple regression models.

- They found that survival rates during the smolt to adult and first year ocean life stages for both Chinook and steelhead were associated with both ocean and river conditions.

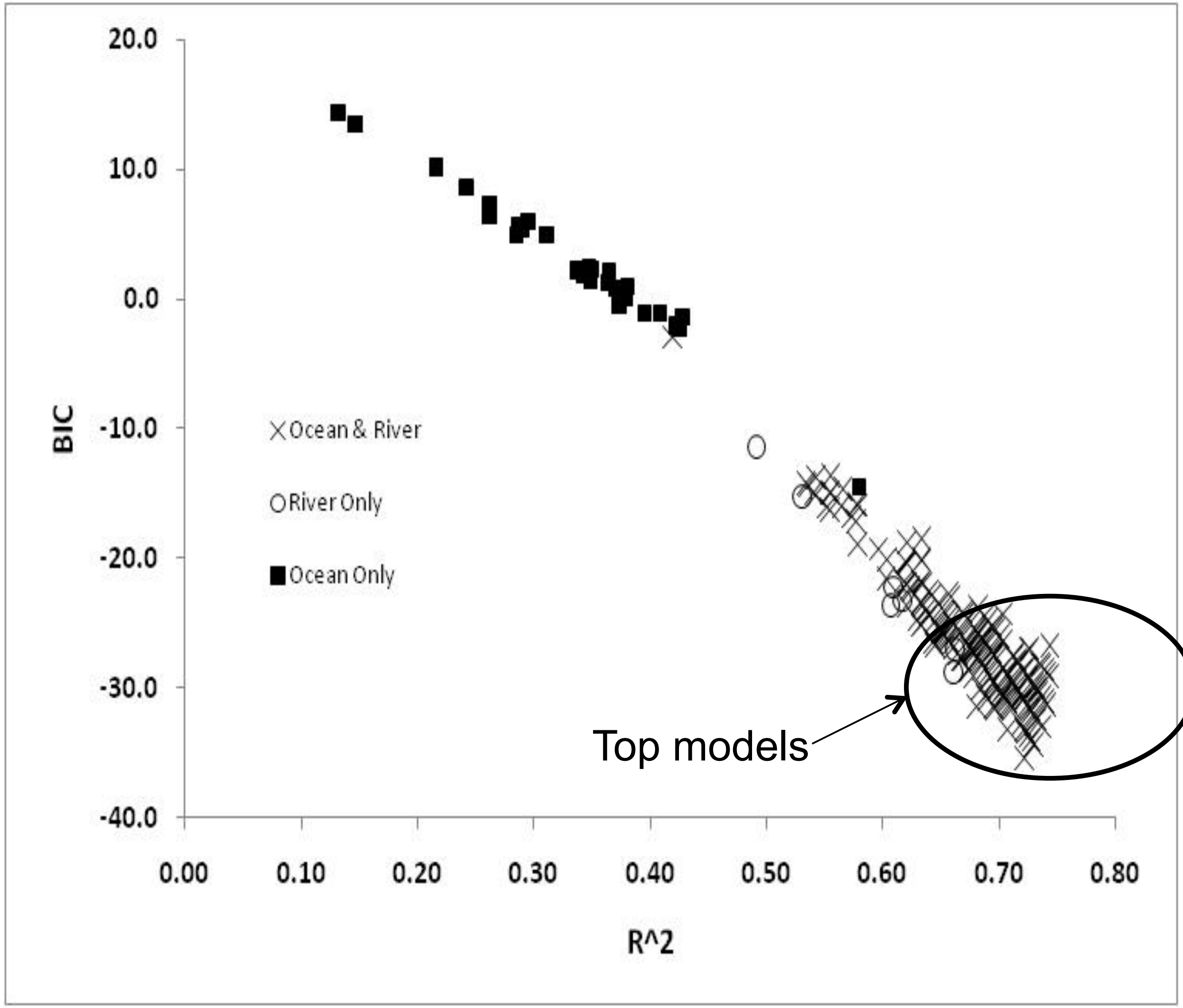
Survival Rate Indices Chinook

Best fit, simplest models indicate that lower survival rates for Chinook salmon are associated with:

• warmer ocean conditions,

• reduced upwelling in the spring and

•slower river velocity during the smolt migration or multiple passages through powerhouses at dams.

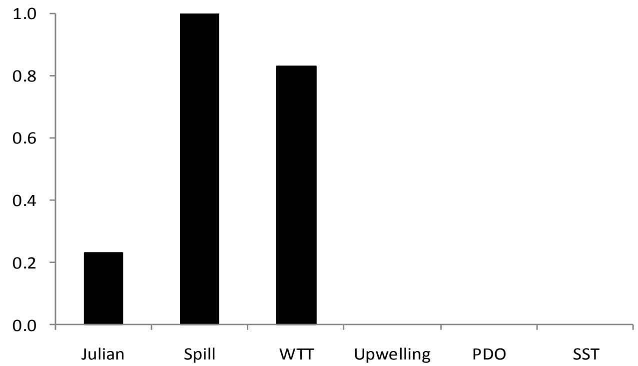


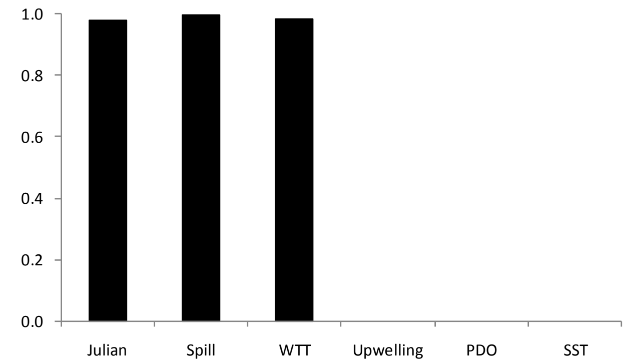
Relative variable importance

(Haeseker et al., 2011) (1993-2006).

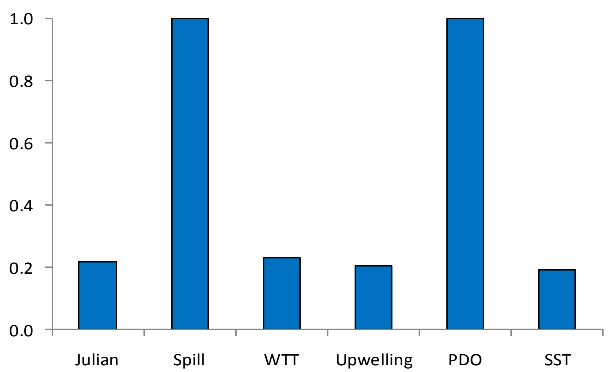
Chinook | steelhead

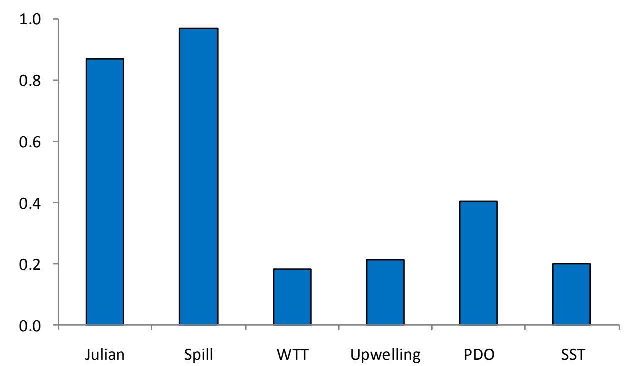
Juvenile In-River survival



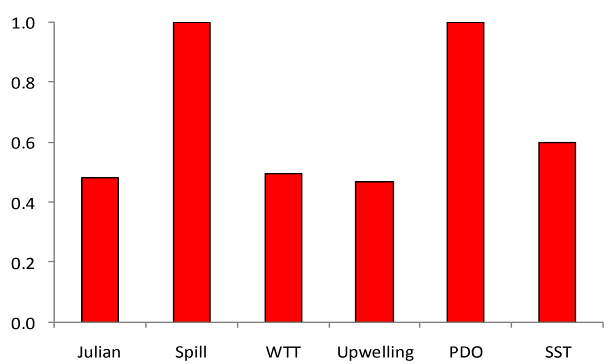


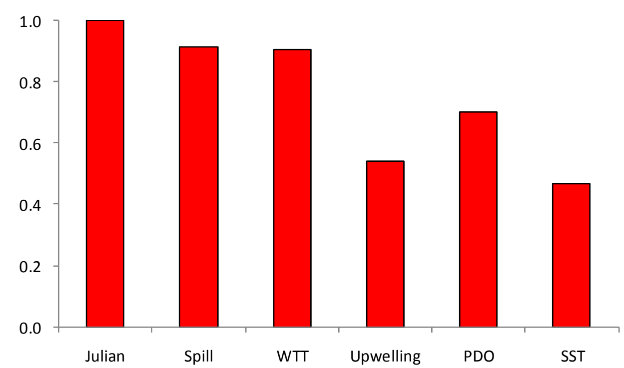
Ocean survival



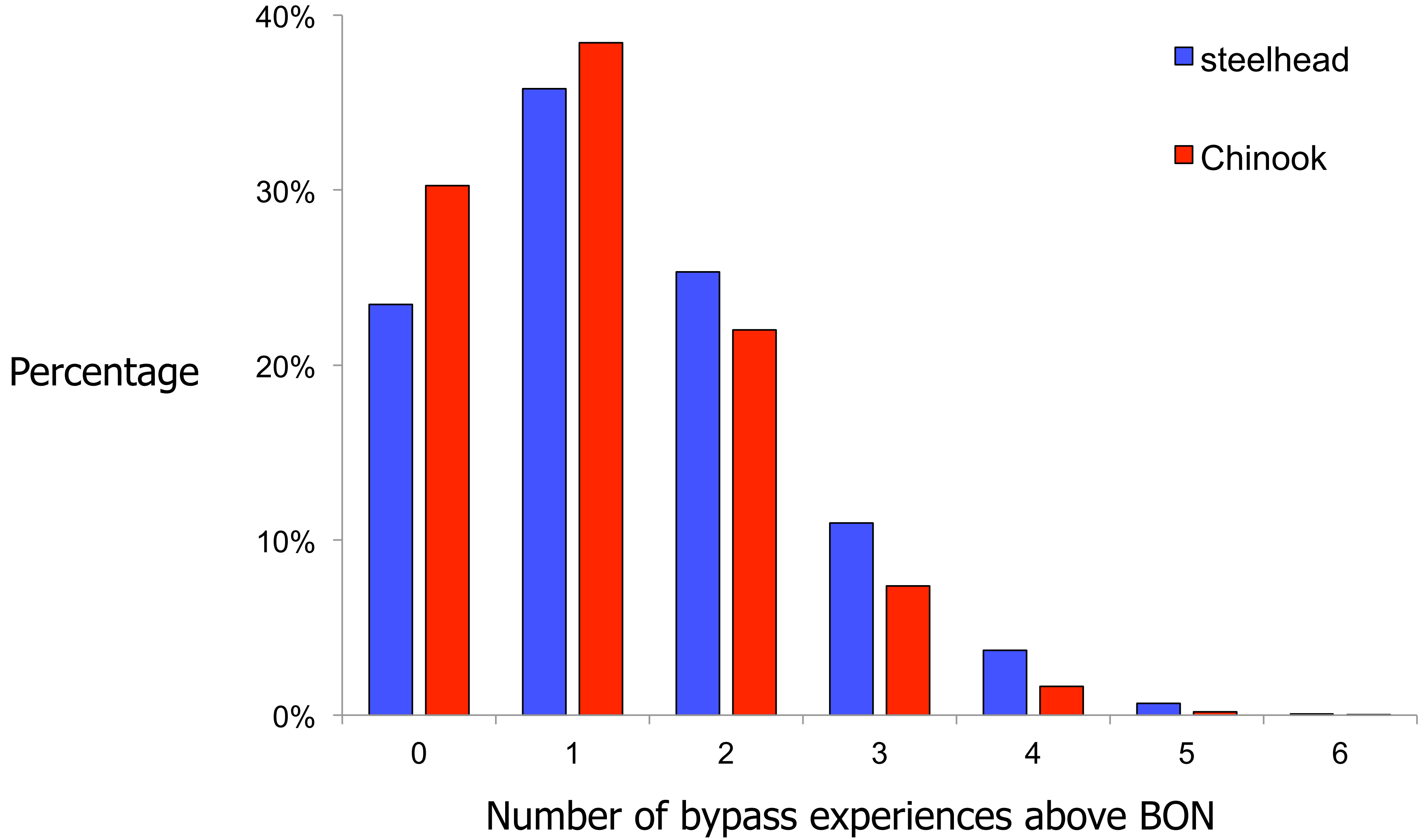


Smolt to Adult Survival





Bypass Experience



Results

Wild Chinook

Each bypass event reduced post-BON SARs by 11%.

Wild steelhead

Each Snake bypass event reduced post-BON SARs by 8%.

Each Columbia bypass event reduced post-BON SARs by 18%.

What Do We Know?

- Bypass passage is a factor causing delayed mortality.
- Measures that affect smolt travel time (flow and spill) are most important in determining SARs.
- The importance of spill as a variable is likely related to both decreasing smolt travel time, and to the avoidance of powerhouse passage.

Summary

- In the Columbia River we have and continue to address hydrosystem passage issues with state of the art technology. In spite of over 35 years of implementing bypass technologies, and our good intentions, we have failed to recover populations.

- More and more evidence is showing the delayed mortality effects of juvenile passage through the hydrosystem and the mechanisms responsible.

Summary

- Data is now emerging to show that the delayed mortality component of survival to adulthood is likely related to the number of times fish are passed through state of the art bypass collection systems.

- Our data show that the most important variables in increasing juvenile, and subsequently adult survival, are decreasing migration time and avoiding powerhouse passage. Both are affected by the provision of flow and spill.

Take Home Message

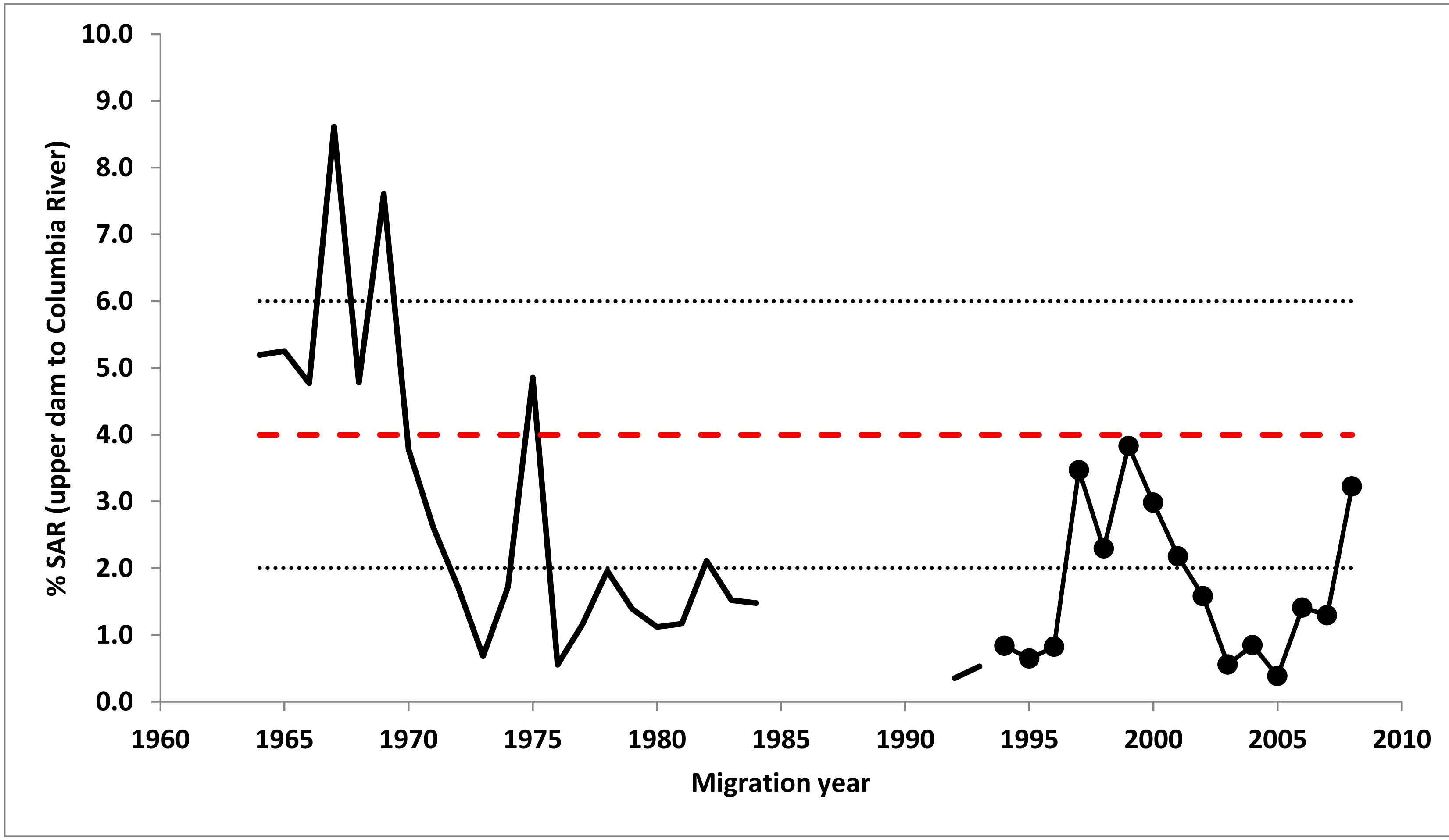
- Flow and spill are the mitigation measures that help to make the hydrosystem more “invisible “ to fish.

- However, both flow and spill have considerable impact on the ability to produce power during the juvenile migration period. Both measures de-rate the hydrosystem net revenue. Therefore, fish protection in the Columbia is, and will remain, a contentious issue.

- Our experience in the Columbia River should be used to dispel the conclusion that productive wild fish populations can be maintained in a hydro-developed river through the use of technology.

Questions?

SARs from smolts at uppermost Snake River dam to Columbia River returns for Snake River wild Chinook



SARs based on run reconstruction (1964-1985, 1992-1993, solid line) and CSS PIT-tags (1994-2008, dots and solid line).