Insights from attempting to apply adaptive management to aquatic and terrestrial ecosystems

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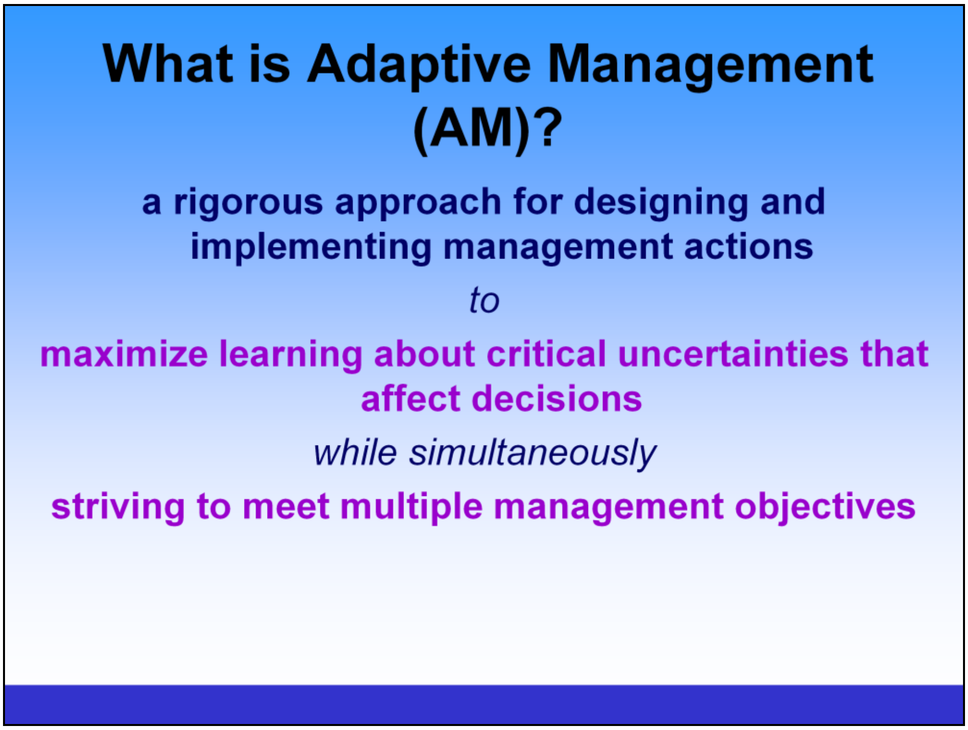
Today I'm going to present some insights on AM based on my experience over the last three decades. ESSA grew out of UBC back in 1979, and we are immensely grateful to Carl, Buzz Holling, Ray Hilborn, Randall Peterman and others who were, and remain, our mentors.

There's been a lot written, by Carl, Buzz and others, about the factors affecting the success or failure of AM. Today I'm going to try to convince you that many of these factors are driven by spatial scale.

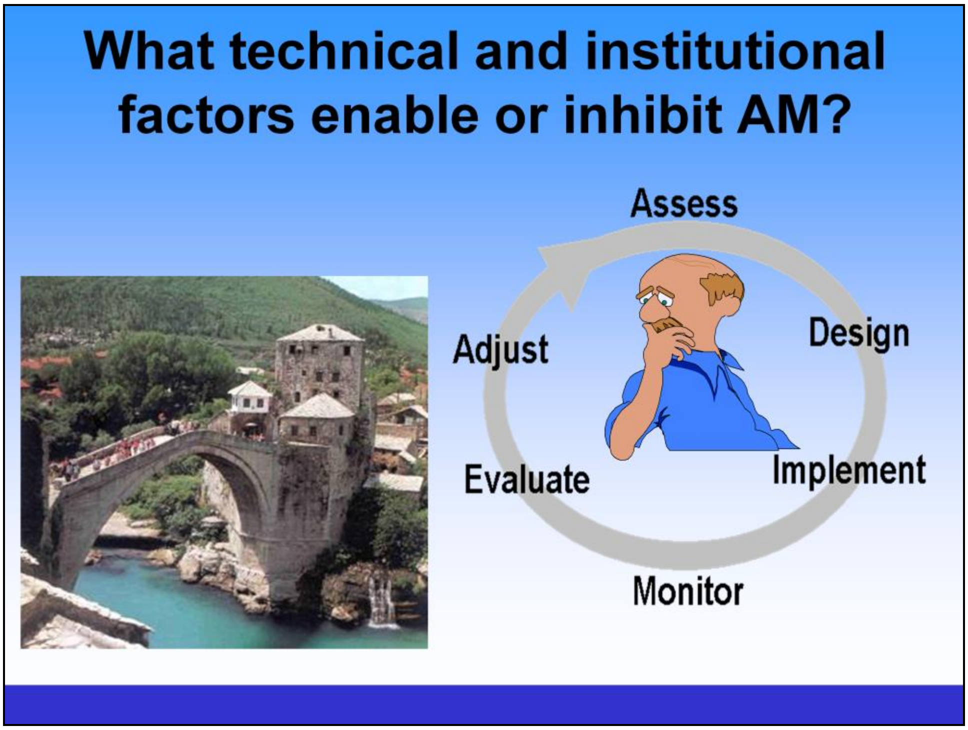
3 key points

1. Spatial scale is a *master variable* affecting both technical and institutional feasibility of AM
2. For river basins, rigorous AM is:
   – *difficult* when basin size > 100,000 km^2
   – *impossible* when basin size > 250,000 km^2 ??
3. AM success most likely with <15 people involved in making key decisions



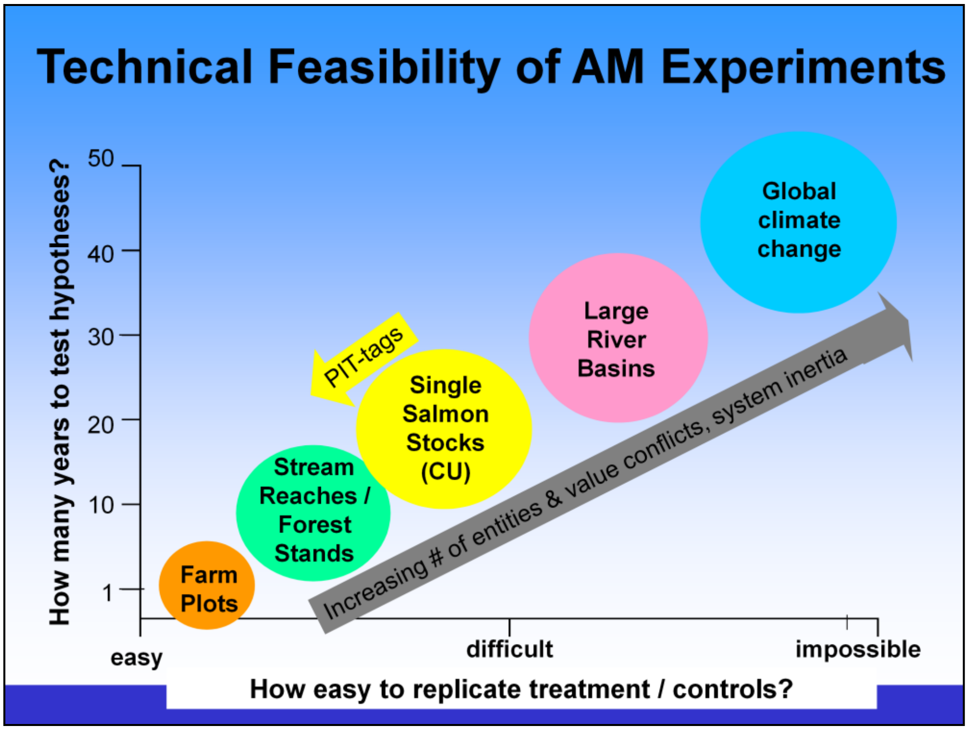
Here's my definition of rigorous adaptive management. You can read it faster than I can say it.

By rigorous, I mean "the application of precise and exacting standards", including careful experimental design to test hypotheses, the selection of appropriate monitoring protocols, and thorough data analyses to generate defensible evaluations of outcomes as input to management decisions.



AM involves bridging the gap between scientists and decision makers, keeping scientists focused on critical management uncertainties, and persuading managers to reduce or resolve those uncertainties in a rigorous manner.

A successful AM project could be defined as one which rigorously goes through all of the 6 steps shown here.



Ray Hilborn first used a figure like this in an AM course we gave in Banff in the late 1980s.

The critical thing required for AM is contrast over space and time. *Start at lower left and proceed to upper right. EXPLAIN AXES.*

Orange – farmers have been practicing AM for years, with replicated field plots receiving different treatments, and rapidly responding within 1-2 years

Green – mostly habitat restoration. Spatial replication is reasonably easy; can control for site to site differences; habitat indicators generally respond within 5-10 years, within manager and public attention spans and budget cycles

Yellow – Salmon populations are inherently more variable due to variation in freshwater and particularly marine conditions, so confidently detecting population changes usually involves about a decade of monitoring before and after the restoration treatment. On the spatial axis, it's very difficult outside of public lands to have the institutional control to maintain both treatment and control watersheds for two decades. AM is possible, but difficult, and increasingly more difficult as watershed size increases.

Blue – Global climate change. It will take ~50 years to know the full effects of our actions, at which point irreversible changes are almost certain. The feedback loop is too slow, and there's only one Earth; no replicates. You can't do AM on a planetary scale. Take your most prudent actions and see what happens.

BUT ADVANCES IN TECHNOLOGY CAN INCREASE ABILITY TO DETECT TREATMENT EFFECTS. In the Columbia River, PIT-tags on 800,000 fish have greatly shortened the time required to evaluate alternative hypotheses regarding the effects of the hydrosystem on various survival rates.

Institutional Factors Affecting AM

(2006 ESSA study of 20 forest management projects)

Potentially Enabling Factors	Forest AM Projects (20)	
	"Success" (14)	"Failure" (6)
Problem Context	E/I	E/I
Leadership	**E**	**E**
Executive direction	**E**	**I**
Problem definition	E/I	E/I
Communication & Org. Structure	E/I	E/I
Community involvement	**E**	**I**
Planning	E/I	E/I
Funding	E/I	E/I
Staff Training	E/I	E/I
AM Science	**E**	**I**

In 2006 we used an interview and survey process to examine 20 forest management projects that had applied the principles of adaptive management: 13 public, 6 private and one NGO. Fourteen of these were considered successful in that they got all the way around the AM loop and adjusted management actions, such as new forest practice rules for leave strips on fish bearing streams, measures to improve ungulate winter range, snags for cavity nesting birds and prescribed fire. The other six projects were not necessarily failures, but they didn't complete the last step.

We asked each project leader to grade their project on its application of AM (A, B, C or D) and also to assess the degree to which each of the factors inhibited or enabled AM. We were particularly interested in differences between the more successful projects and the other ones.

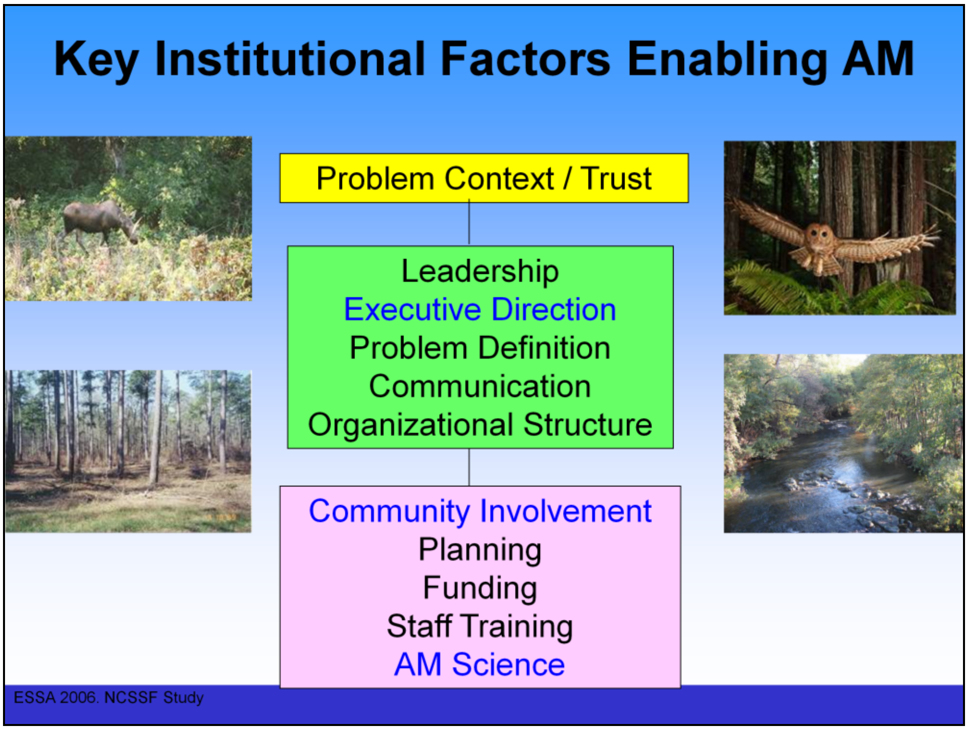
Two interesting results:

1) Everyone found that leadership was enabling, regardless of how successful the project was. Leadership is a necessary but not sufficient condition for closing the loop.
2) Three factors were more enabling in the more successful projects and more inhibiting in the others: the executive mandate to conduct AM, community involvement and AM science.

Executive direction includes both legal requirements to implement AM, as well as executive direction from within through corporate wide commitment to learning.

Community involvement is essential to ensure you do the right things.

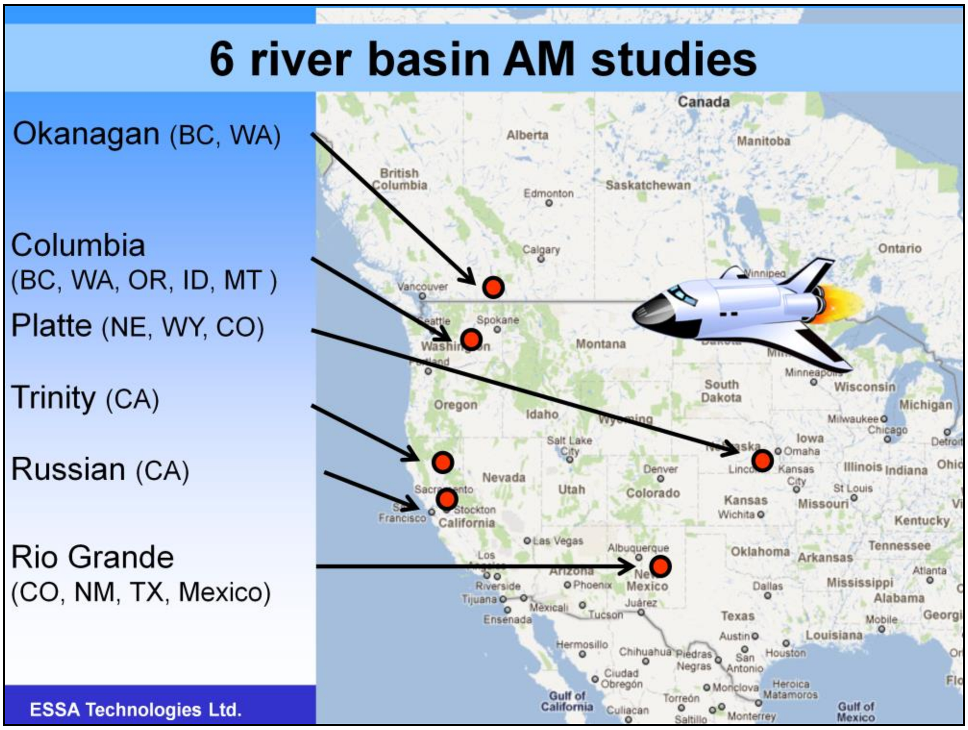
AM science is essential to ensure you do things right.



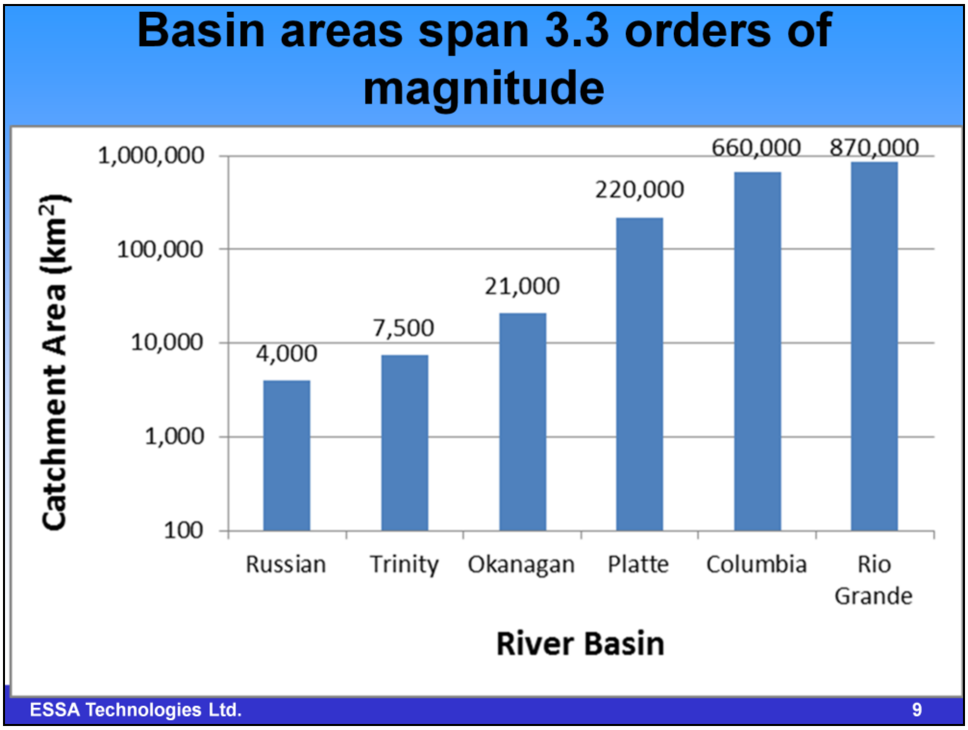
We reviewed the results of the study at a 2-day workshop in Portland OR with some very experienced AM practitioners, and that meeting generated this hierarchy.

At the top of the hierarchy is the problem context, and the conflicts over alternative actions, which determine the need for AM (e.g. moose, spotted owl), the stakeholder relationships, and the appropriate project structure.

We came to the conclusion that there were five primary factors which were absolutely critical for success (the green box). If you did well with the things in the green box, then it was likely that the other necessary attributes for success (the pink box) would also be established. But all of the factors in green box become more challenging as the spatial scale increases.



I'm going to use 6 case studies of river basins we've worked on over the last 20 years (not a huge sample) to try to convince you of my key points. The river basins are shown here together with their catchment size in square miles, and the province, states or countries which overlap with the catchment.



Rio Grande is 5th largest river basin which flows through part of the U.S.. The two largest rivers are the Mississippi and Missouri, and both have AM programs deeply embedded in the institutional inertia of the US Army Corps of Engineers .

Russian River Basin (4000 km^2)

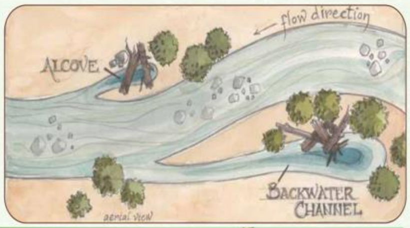
- **Context:** 2 Dams, water supply & flood control for 600,000 people in Santa Rosa area (wine country)
- **Executive Direction:** 2008 Biological Opinion on CA coho and steelhead (7 yrs negotiation)
- **Leadership:** NMFS, Sonoma County Water Agency (SCWA)
- **AM:** Create 6 miles of low velocity, coho rearing habitat in Dry Ck ($50M) from 2008-2023 or build a pipeline ($100M)

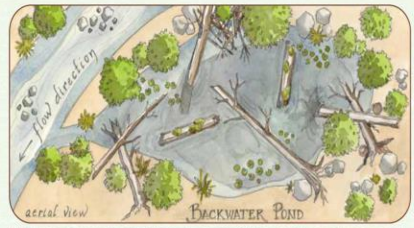
The Russian River is about 100 km N of San Francisco.

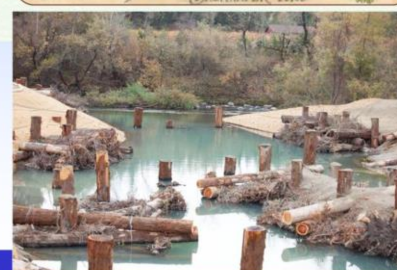
Took about 4 years to negotiate Biological Opinion, then 3 years to finalize the first 1-mile demonstration project, and how to evaluate it. Everybody involved in the decisions (15 or so) could fit in one room.

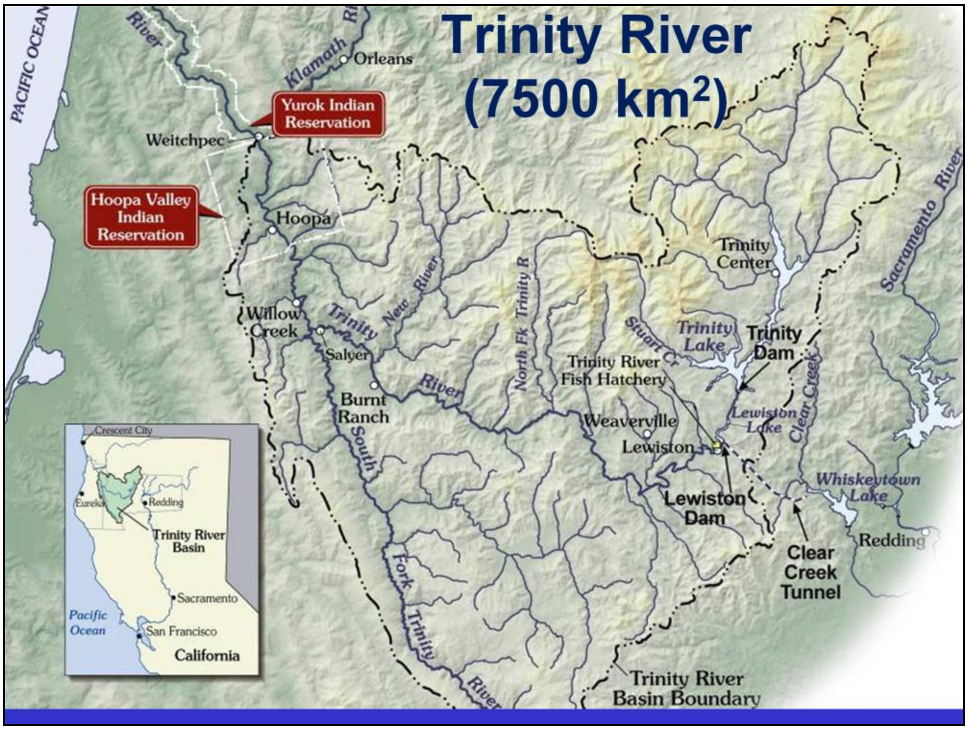
Russian R - AM Actions and Evaluation

- Low Velocity Backwater Pools, Alcoves Side Channels
- Monitoring of physical habitat suitability, spawning, rearing, fish movement (PIT-tags), smolt production (RST)





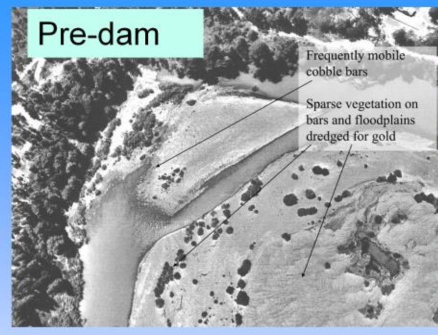


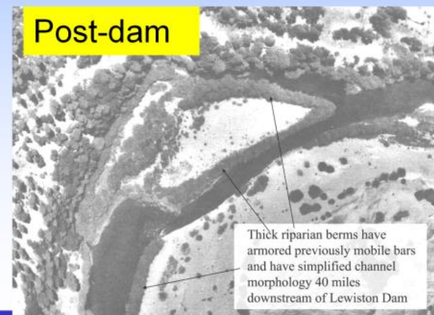


Trinity River
(7500 km²)
PACIFIC OCEAN
Klamath River
Orleans
Yurok Indian Reservation
Weitchpec
Hoopa Valley Indian Reservation
Hoopa
Willow Creek
Salyer
Trinity River
New River
North Fk Trinity R
Burnt Ranch
South Fork Trinity River
Trinity Center
Trinity Lake
Trinity Dam
Stuart C
Trinity River Fish Hatchery
Weaverville
Lewiston
Lewiston Lake
Clear Creek
Lewiston Dam
Whiskeytown Lake
Redding
Clear Creek Tunnel
Sacramento River
Trinity River Basin Boundary
Crescent City
Eureka
Redding
Trinity River Basin
Sacramento
Pacific Ocean
San Francisco
California

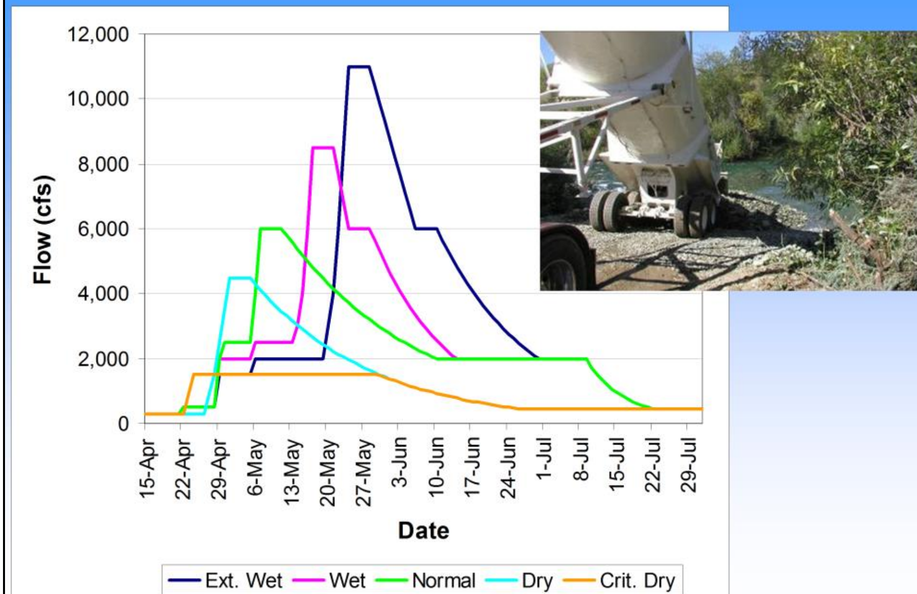
Trinity River

- **Context:** 90% Trinity R flow diverted to Sacramento R, Chinook ⇓, 11 lawsuits over tribal trust (~15 yrs negotiation)
- **Executive Direction:** 2000 Record of Decision (AM)
- **Leadership:** US Bureau of Reclamation, USFWS, Hoopa & Yurok tribes, USFS
- **AM:** Restore habitat forming processes in top 40 miles by flow scheduling, adding gravel, channel rehabilitation (~$10M/yr)





Trinity R - AM Actions and Evaluation



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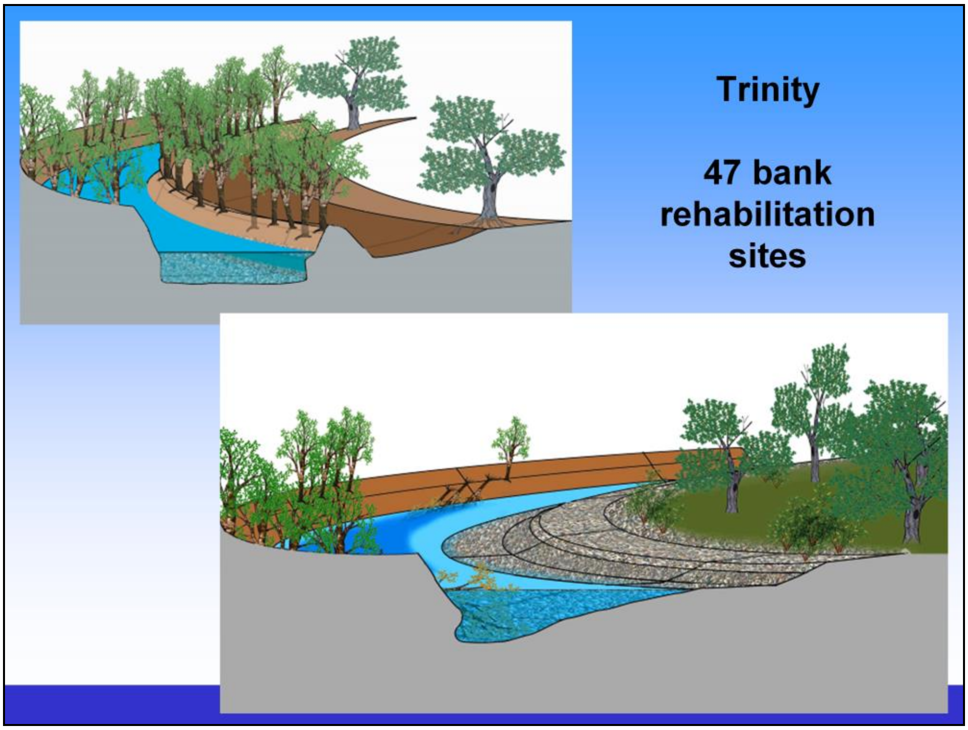
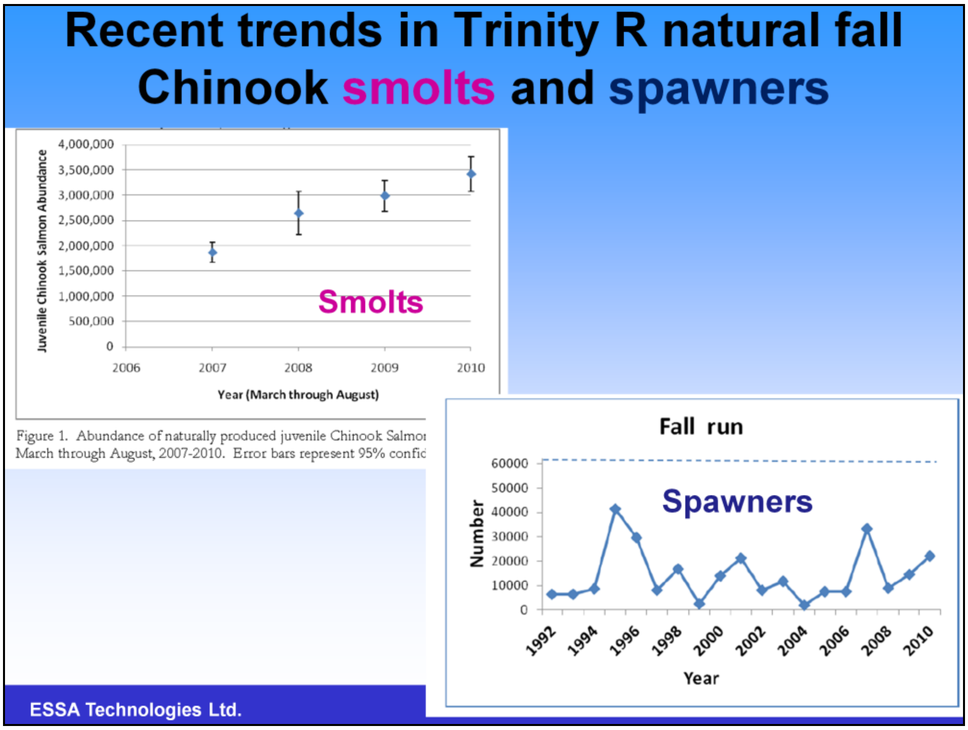
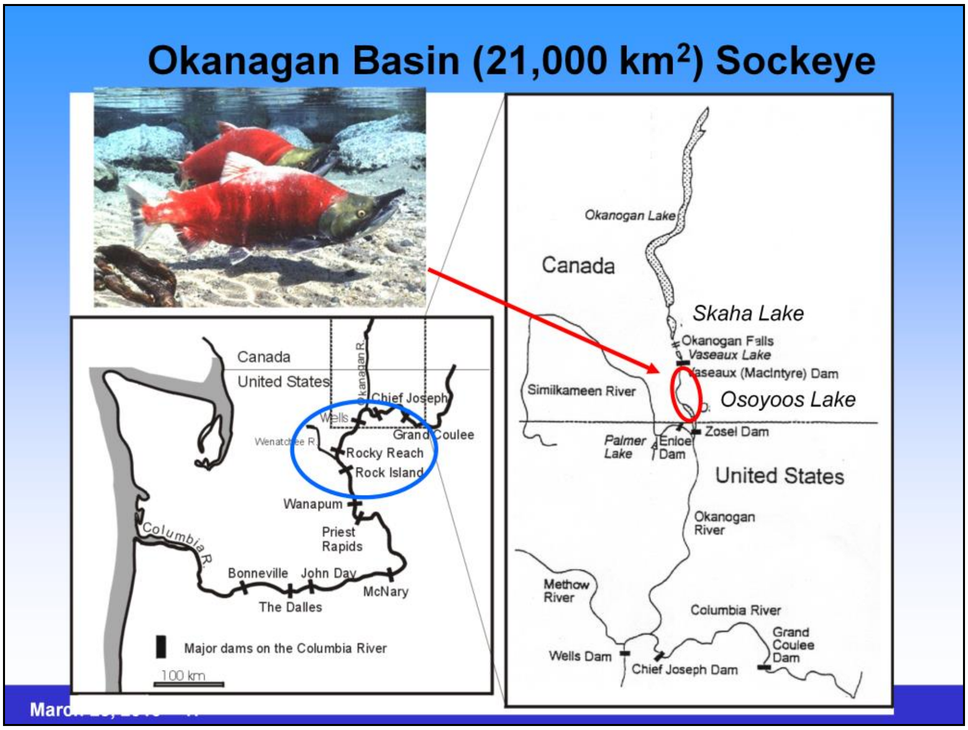

Trinity
47 bank rehabilitation sites



Jury still out on whether all this is working, but recent years' data show increases in smolt production. No trends in # adult Chinook, which are affected by coastwide generally poor marine survival.



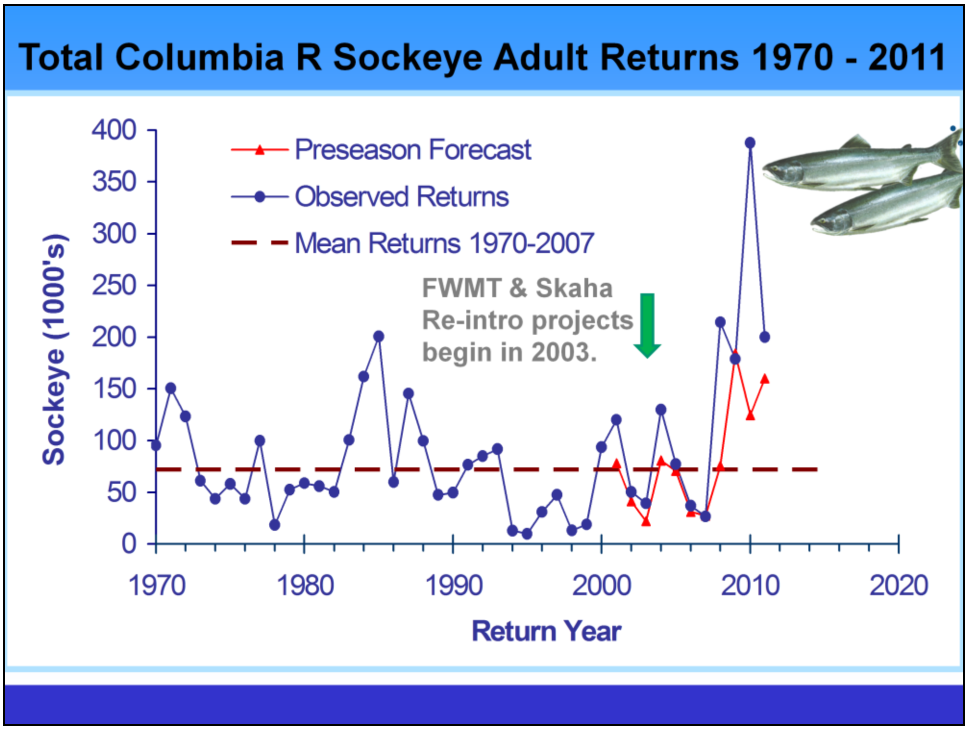
The **Okanagan River flows** south from Okanagan Lake in south-central British Columbia, across into Washington State, where it joins the Columbia River. **Most of the storage** for the Okanagan River is provided by the 120km long Okanagan Lake, with minor additional storage provided in tributary headwater reservoirs and in smaller downstream lakes.

These sockeye migrate about 1000 km up from the Pacific through the Columbia River and 9 major hydroelectric projects. This population is **one of only 2 remaining naturally reproducing sockeye stocks** on the Columbia River, the other being in Lake Wenatchee.

About **30 km downstream** from Okanagan Lake is the **terminal spawning area** for Okanagan River sockeye salmon, which then rear in Osoyoos Lake. The Okanagan Nation Alliance has recently begun an effort to re-establish sockeye in Skaha Lake, involving capturing eggs from returning spawners, raising them in a hatchery, and stocking them into Skaha Lake.

Okanagan River Sockeye

- **Context:** SK important to DFO, Okanagan FN; MOE concerned about kokanee, flooding, agric.
- **Executive Direction:** FERC licenses PUD dams; require mitigation; best opportunities in Canada (~2-3 yrs negotiation)
- **Leadership:** Okanagan FN, DFO, BC MOE, PUDs
- **AM:** Fish Water Management Tool, Re-introduction of sockeye into Skaha lake, habitat restoration



Columbia River sockeye returns dramatically declined over the course their history, ultimately resulting in the complete closure of the commercial fishery by 1972. Despite closures, returns remained depressed for the next 35+ years.

Annual returns over this period averaged approximately 72,000 fish.

However, the summer of 2008 marked an astonishing turnaround, with unprecedented numbers of sockeye returning to the Columbia - a trend that has continued through to this year.

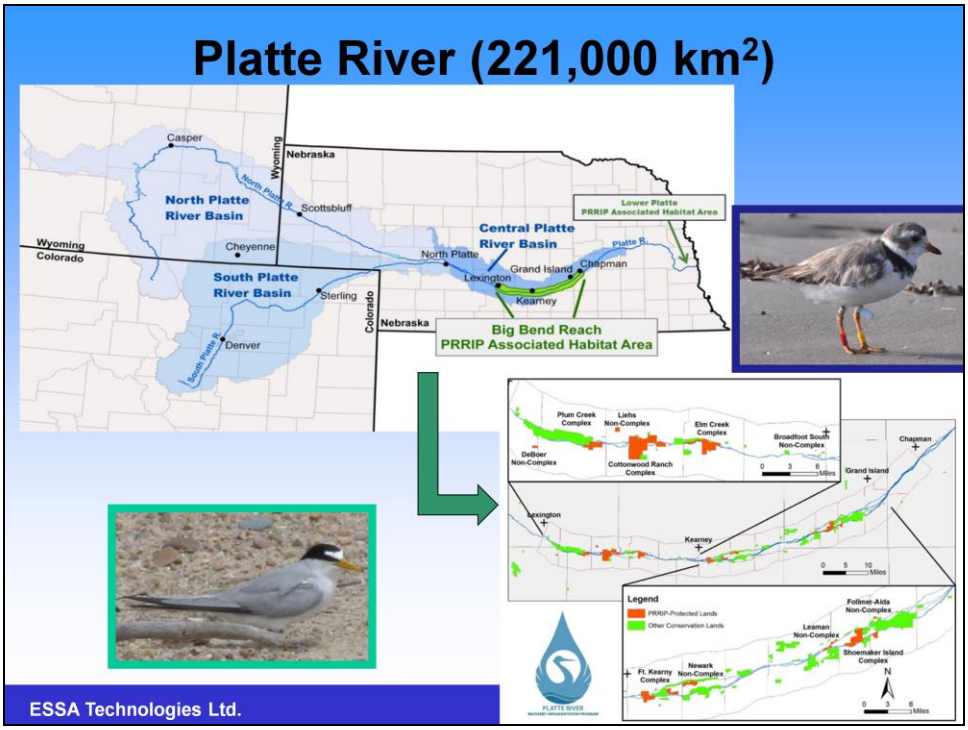
Okanagan make up, by far, the largest proportion of the Columbia sockeye population (averaging 75% over all years). More noteably, the overall proportion of Okanagan sockeye appears to be increasing in recent years.

Factors Contributing to Rebuilding of Okanagan Sockeye Salmon Since 2000

1. Revised escapement objectives to utilize full freshwater carrying capacity;
2. FWMT “fish friendly” flows reduce density independent mortality, and mitigate oxygen-temperature “squeeze” in Osoyoos Lake;
3. Supplemental production of hatchery-origin sockeye from Skaha Lake (< 10% returns);
4. Improvements for juvenile fish-passage in Columbia R;
5. Improved ocean survival for southern sockeye stocks (biggest factor).

There are multiple factors contributing to the resurgence of Columbia sockeye.

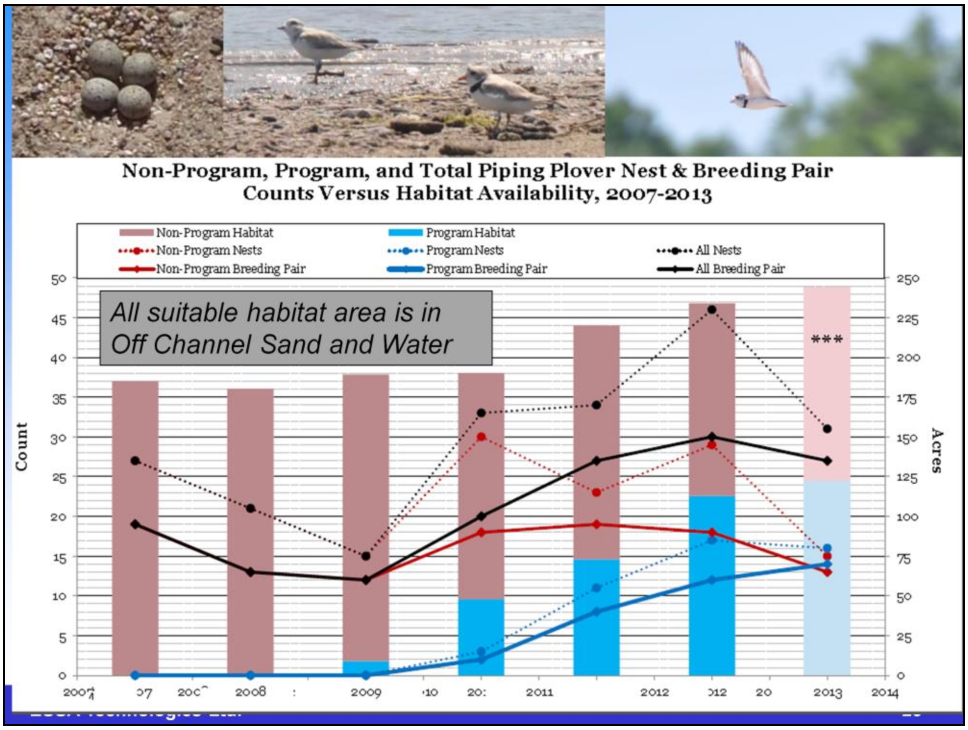
1) Historic low, escapement objectives had artificially capped total production far below the system’s true carrying capacity. These were revised in 1999.
2) Development and deployment in 2004 of the FWMT decision support system facilitated “fish friendly” flows in the Okanagan River and worked to reduce losses of eggs & fry to density independent mortality events (i.e. flood-and-scour and drought-and-desiccation induced losses),
3) Fish-Water-Management Tool identifies and enables mitigation of a late season oxygen-temperature “squeeze” in Osoyoos Lake which can lead to loss of juvenile rearing habitat
4) The Okanagan Nation Alliance introduction of hatchery stock into Skaha Lake; however, this amounts to less than 10% of production/returns
5) Continual improvements to juvenile bypass systems at Columbia River hydroelectric projects have no doubt benefited juvenile salmon
6) And a return to survival favourable conditions for southern sockeye stocks in coastal marine waters (biggest factor)



Platte River originates in Wyoming and Colorado and travels about 1500 km before joining the Missouri River.

The focus of this AM effort is to restore habitat for endangered terns, plovers and whooping cranes.

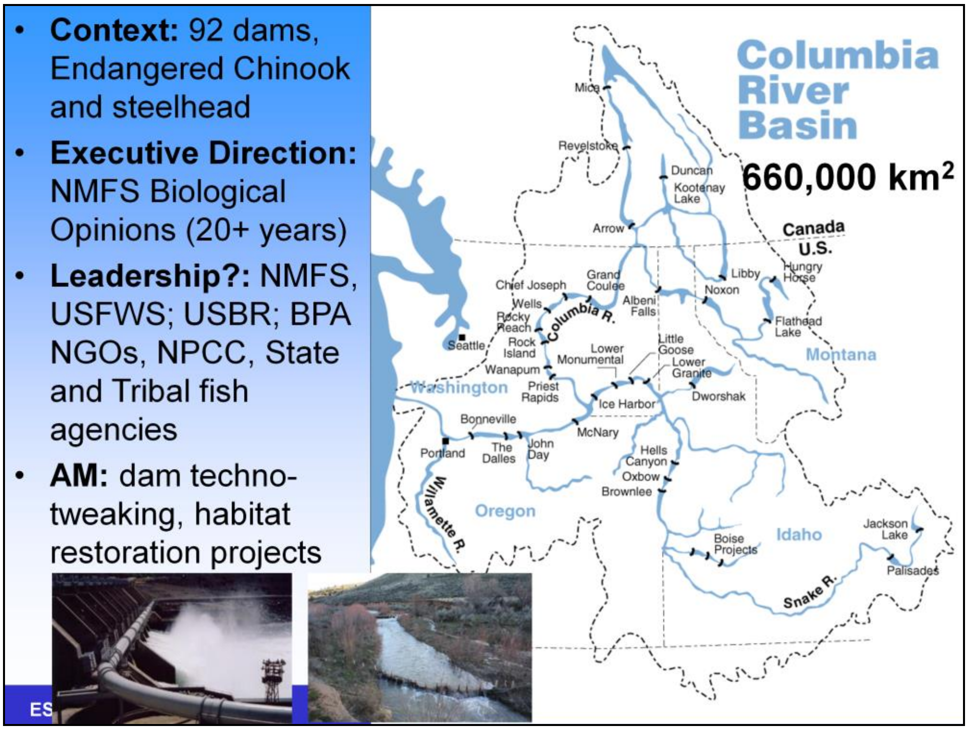
So far the sand pits are working really well, and the in-river islands are not. In dry years, they're no longer islands and the birds don't nest there. In wet years, and there have been some very high flows in the last 5 years, the islands wash away.



Blue bars are program habitat; **blue lines** are nests/breeding pairs on program habitat; both increasing. **Red bars** are non-Program habitat (decreasing); **red lines** are nests/breeding pairs on non-Program (fluctuating). **Black lines** are total nests/breeding pairs.

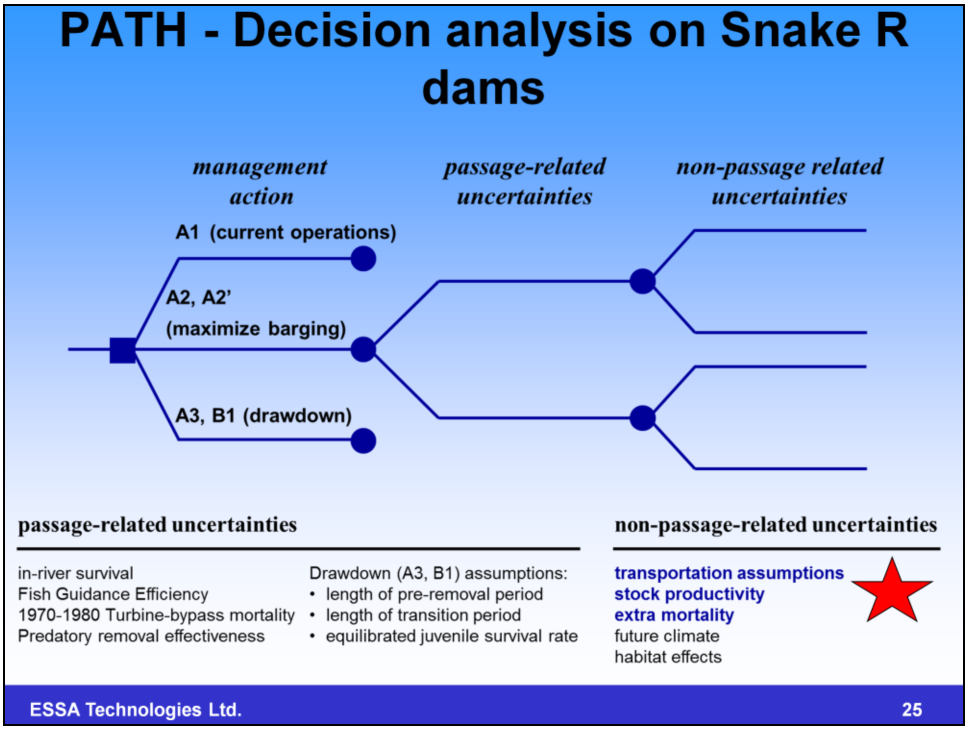
Alternative explanations for this pattern:

1) Increased Program habitat area and quality leads to better survival and birds return to same sites year after year (most likely)
2) Decreases in habitats outside Central Platte River (e.g. Lake McConaughy) ⇒ new birds coming to Central Platte River
3) Increases in overall meta-population (being investigated)
4) Birds moving from non-Program to Program lands (better predator protection)



Much of the Columbia Basin is inaccessible to salmon. The Grand Coulee Dam on the Columbia River (1941), and Hells Canyon Dam on the Snake River (1967) [black bars on slide] permanently blocked more than 30% of the basin's salmon habitat. The Mica Dam (in far north of basin) affects estuarine conditions at mouth of Columbia River, including flooding.

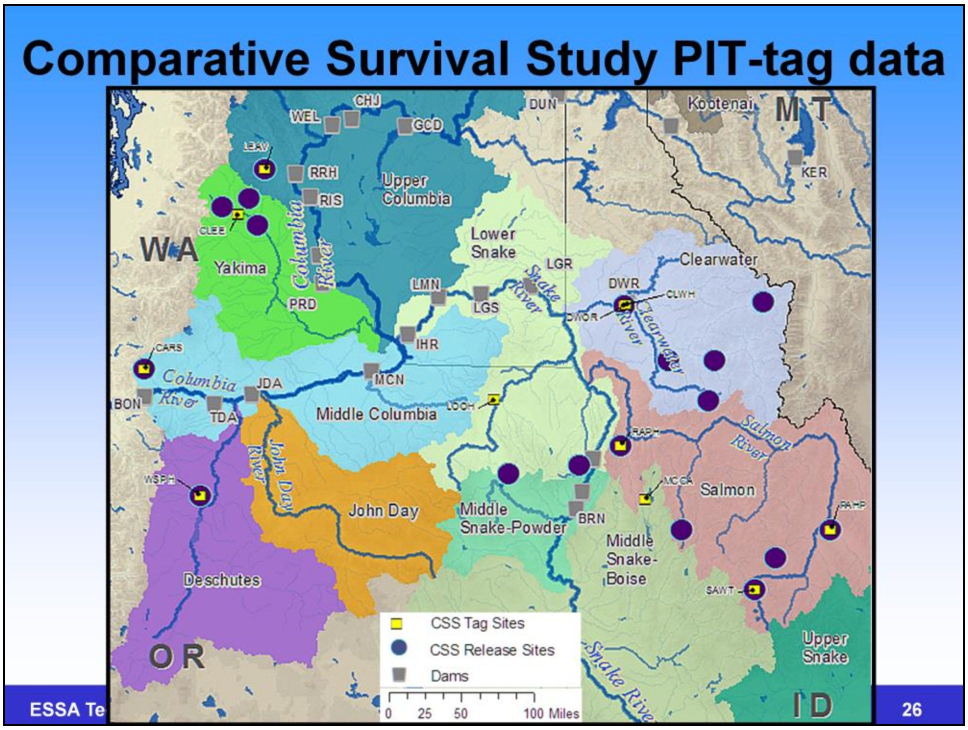
There are altogether 92 U.S. and Canadian hydroelectric dams on the Columbia and Snake Rivers, and their major tributaries. There are now a few intensively monitored habitat restoration projects with rigorous experimental designs on very small scales. However, it has proven to be extraordinarily difficult to apply AM to hatchery and particularly hydro management issues.



From 1996-2000, ESSA completed a detailed decision analysis of current operations, versus increased barging, vs removal of 4 Snake River dams. This was an exhaustive effort looking at alternative hypotheses for 15 uncertainties, which added up to about 2000 combinations.

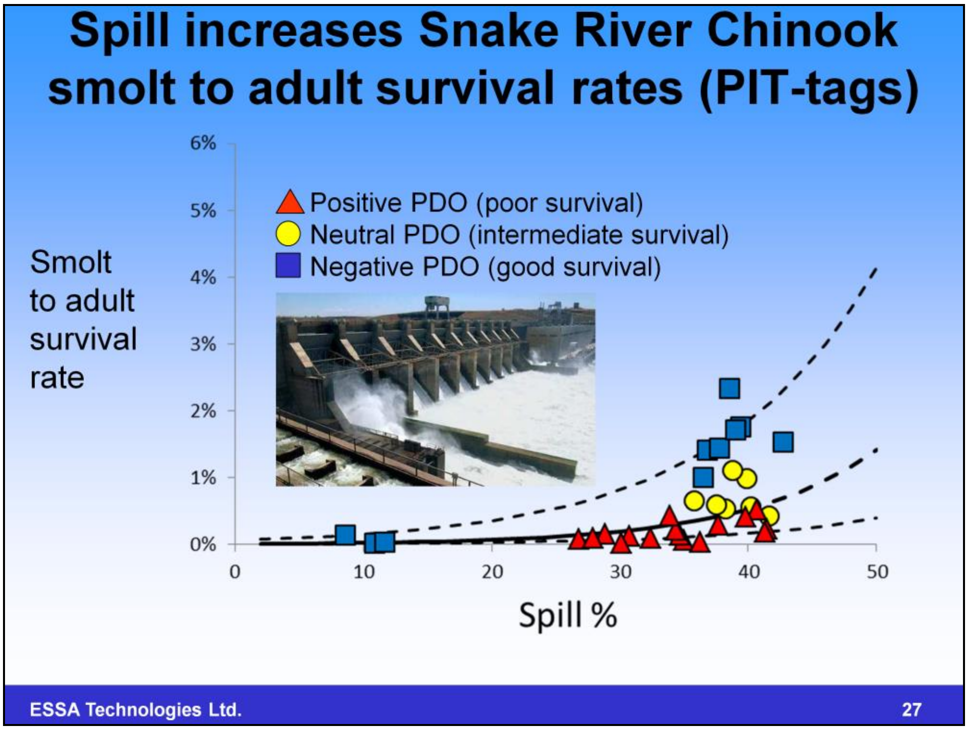
But only 3 of those 15 uncertainties actually affected the **relative** performance of the management actions: assumptions about transportation, stock productivity and delayed or extra mortality effects of the hydrosystem. This analysis allowed future monitoring to **focus** on collecting high quality data to assess these 3 key uncertainties.

Which leads to my next point…



Since the late 1990's the Comparative Survival Study (or CSS) has placed Passive Induced Transponders or PIT-tags on about 800,000 hatchery Chinook, and about 150,000 wild Chinook. The hatchery locations are shown with the yellow symbols, and the fish release sites are in purple.

These data have been enormously helpful for reducing key uncertainties identified in PATH, including the effectiveness of barging vs in-river passage, and smolt to adult survival rates of fish which have different passage histories. This rich data set has also revealed other patterns which suggest potential AM experiments.



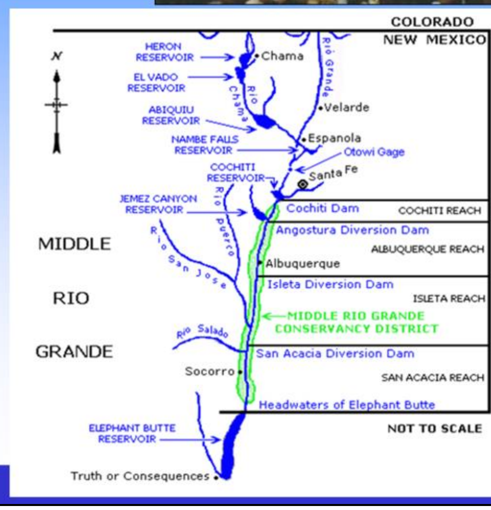
While focused originally on testing the key hypotheses that came out of the PATH process, analyses of the PIT-tag data have shown that smolt to adult survival rates improve with increased spill, though are also strongly affected by ocean conditions, as represented here by the state of the Pacific Decadal Oscillation or PDO.

Under high spill, smolt to adult survival rates are in the 1-2% range if ocean conditions are good (blue squares), but are < 0.3% if ocean conditions are poor (red triangles).

Folks in the Columbia Basin are currently working to develop and evaluate a 10-year AM experiment to increase spill, which obviously has both economic as well as biological consequences.

Rio Grande (870,000 km^2)

- **Context:** Endangered silvery minnow, SW willow flycatcher vs. agriculture
- **Executive Direction:** USFWS ESA Biological Opinion (but no AM)
- **Leadership?:** Middle Rio Grande Collaborative Pgm
- **AM:** ***V1 Plan*** but no action; due to lack of flexibility in dam operations, very limited water and extremely litigious environment.



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The MRG covers the Rio Grande river from the Colorado border down to Elephant Butte Reservoir, which is about 3/4 of its path through New Mexico. Above Elephant Butte, there’s one dam on the Rio Grande itself (Cochiti) and 5 dams on tribs, including 4 on the Rio Chama, which originates in Colorado.

3 key points

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2. For river basins, rigorous AM is:
   – *difficult* when basin size > 100,000 km^2
   – *impossible* when basin size > 250,000 km^2 ??
3. AM success most likely with <15 people involved in making key decisions

For more information

Columbia Basin:

Peters, C.N. and Marmorek, D.R. 2001. Can. J. Fish. Aquat. Sci. 58(12):2431-2446.

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Factors enabling / inhibiting AM

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