SALISH SEA

MARINE SURVIVAL PROJECT

A Salish Sea-wide anomaly

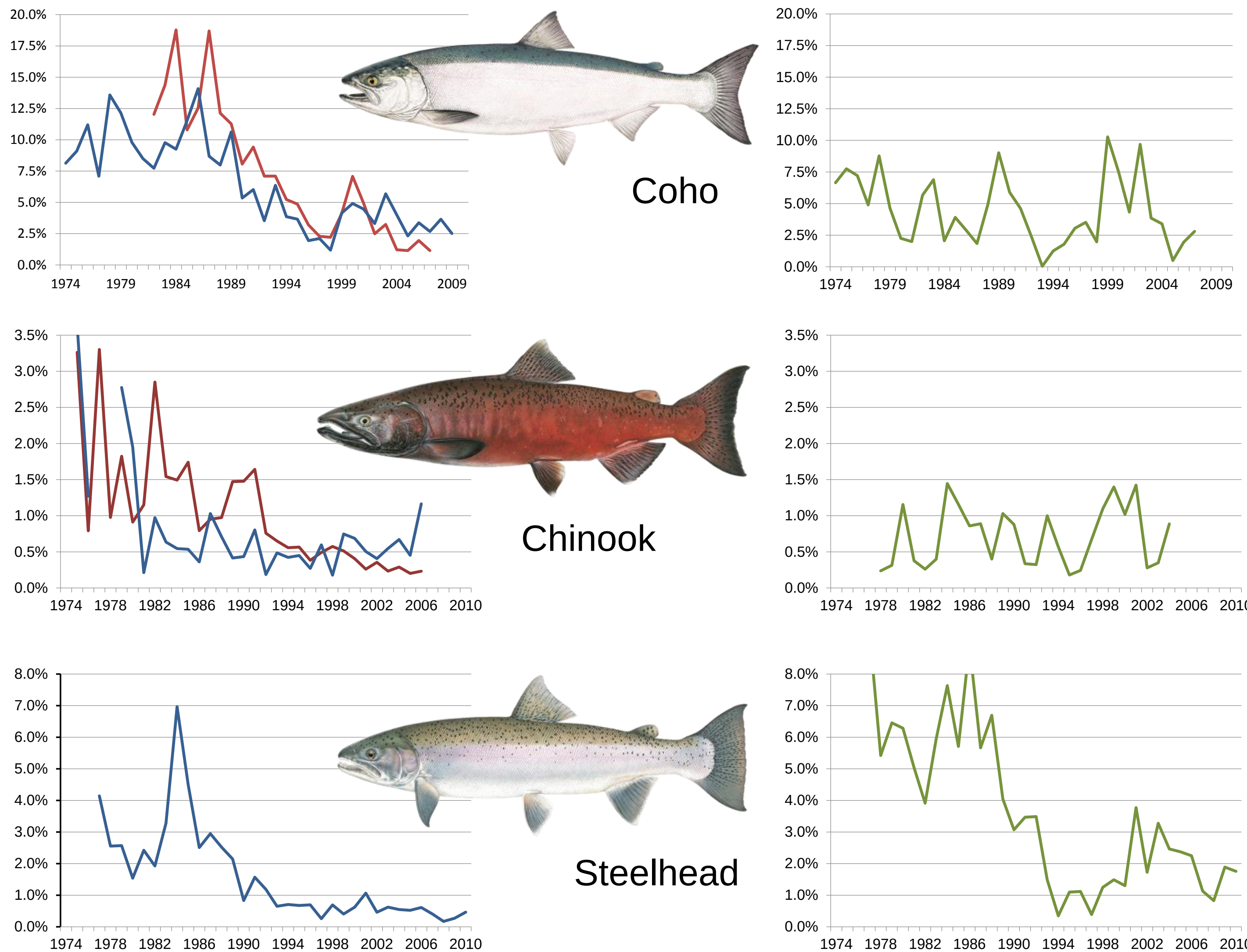
Decline in Salish Sea Marine Survival

Puget Sound

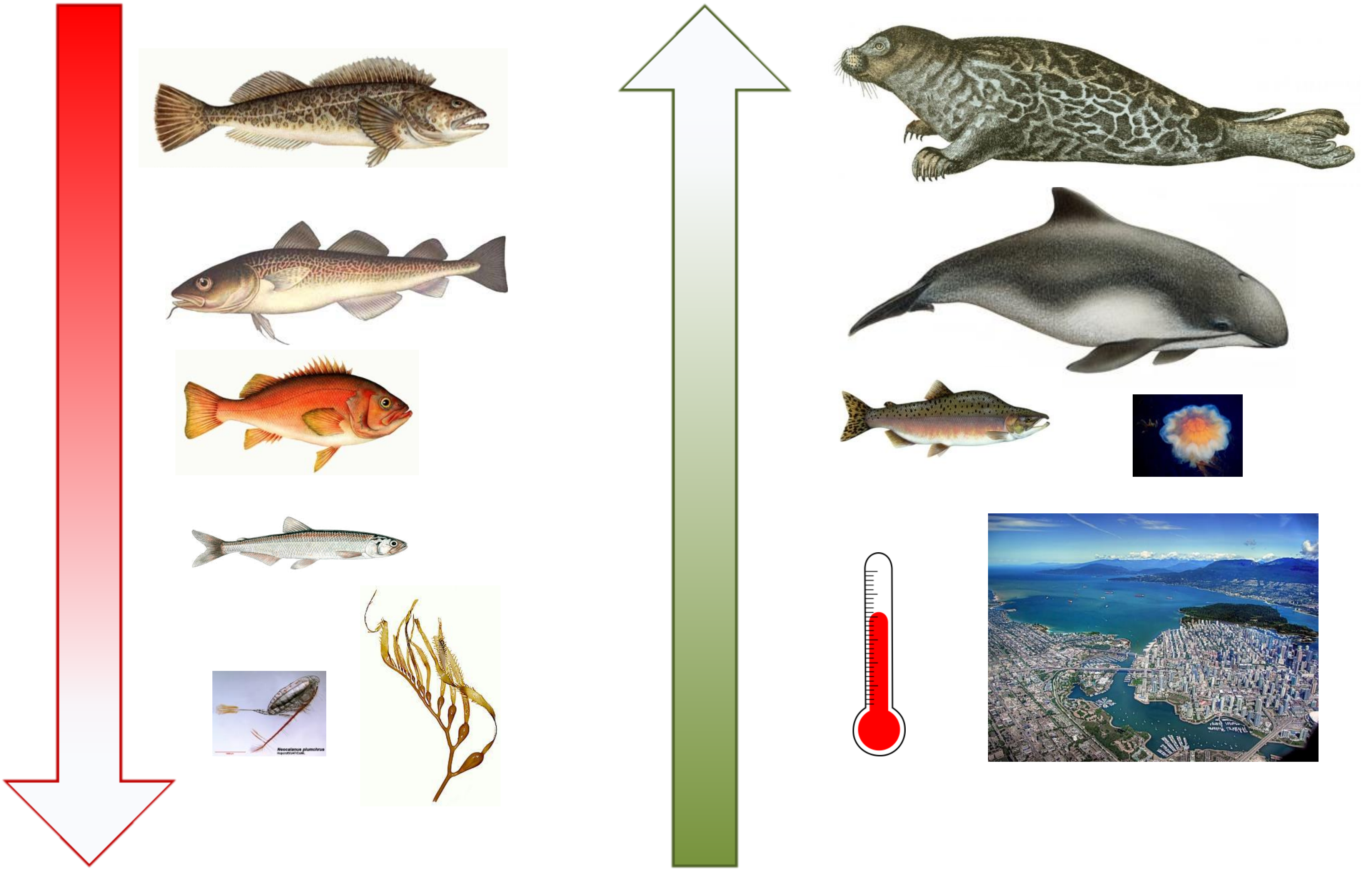
Strait of Georgia

VS

Washington / B.C. Coast



Other known significant changes in the Salish Sea



150+ participants

40+ entities

$20 million

5 years

2 countries

1 question

What are primary factors affecting juvenile Chinook, coho & steelhead survival in the Salish Sea marine environment?

SALISH SEA
MARINE SURVIVAL PROJECT

40+ Partners & Funders

PACIFIC SALMON FOUNDATION

LONG LIVE THE KINGS

VENUS
The Ocean Online, Real Time, Any Time

University of Victoria

Pacific Salmon
ENDOWMENT FUND
SOCIETY

PACIFIC SALMON COMMISSION

NISQUALLY INDIAN TRIBE

sitka foundation

NWIFC

SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

Canada
Department of Fisheries & Oceans

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Sea Grant
Washington

MUCKLESHOOT INDIAN TRIBE

UBC

UNIVERSITY OF WASHINGTON
1861

THE SEAL OF THE STATE OF WASHINGTON
1889

GOLDCORP

TULALIP TRIBES

LUMMI NATION
TREATY OF 1855

Port of Seattle

EPA
United States
Environmental Protection
Agency

EAGLE WING TOURS
passion • explore • inspire

FINEST AT SEA

PORT METRO vancouver

USGS
science for a changing world

NATIONAL FISH AND WILDLIFE FOUNDATION
NFWF

WASHINGTON STATE
RECREATION AND CONSERVATION OFFICE
Salmon Recovery
Funding Board

CANFISCO

Genome BritishColumbia

PugetSoundPartnership
LEADING PUGET SOUND RECOVERY

King County

KINTAMA

The Port Gamble
S'KLALLAM TRIBE

PACIFIC NORTHWEST
Salmon Center

Squaxin Island
Tribe

KWIÁHT

NMT

TROUT UNLIMITED

Funding Status

Budget	**$10 M**	**$10 M**
Raised	$5.5 M	$10 M

Highlights

- $5 M Southern Endowment Fund Pacific Salmon Treaty – split between US and Canada
- $1.6 M Washington State legislature
- 1:1 in-kind match by participating entities

Objectives

Advance wild salmon recovery and sustainable fisheries

- What happened since the 1980's and can we improve the situation for juvenile Chinook, coho and steelhead?

- How do we improve the accuracy of adult return forecasting with early marine survival data: to better manage harvest, hatcheries and natural spawning?

Hypotheses

A. **Bottom-up processes** that drive Chinook, coho and forage fish prey availability have changed, and salmon aren't able to compensate.

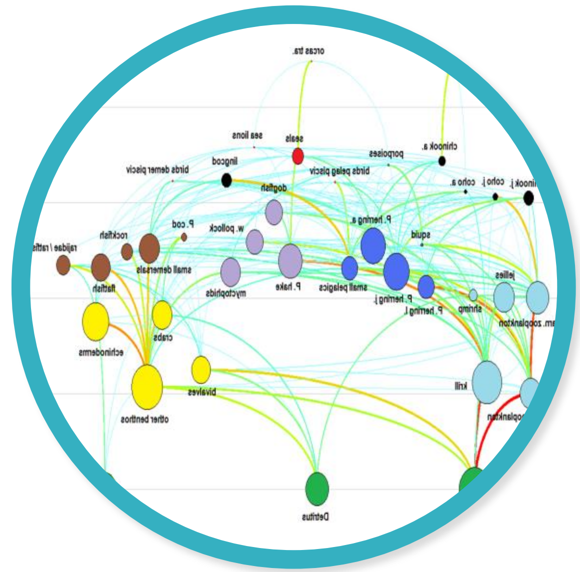
B. **Top-down processes contributing** – More predators making situation worse. Eating larger juvenile steelhead, resident salmon and forage fish.

C. **Other factors may compound the problem**:
   - Microbes & disease
   - Toxics
   - Habitat degradation (role of estuaries?)

Ultimately, must weigh the contribution of:

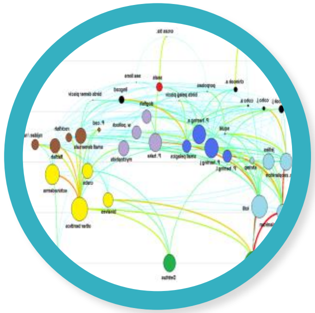
- Local, human influence (water quality, predator management, hatchery management)
- Regional or global impacts (climate change, ocean acidification, natural cycles)

Research Framework



Research Highlights

- Survival analyses nearly complete
- Improving physical>biological connection

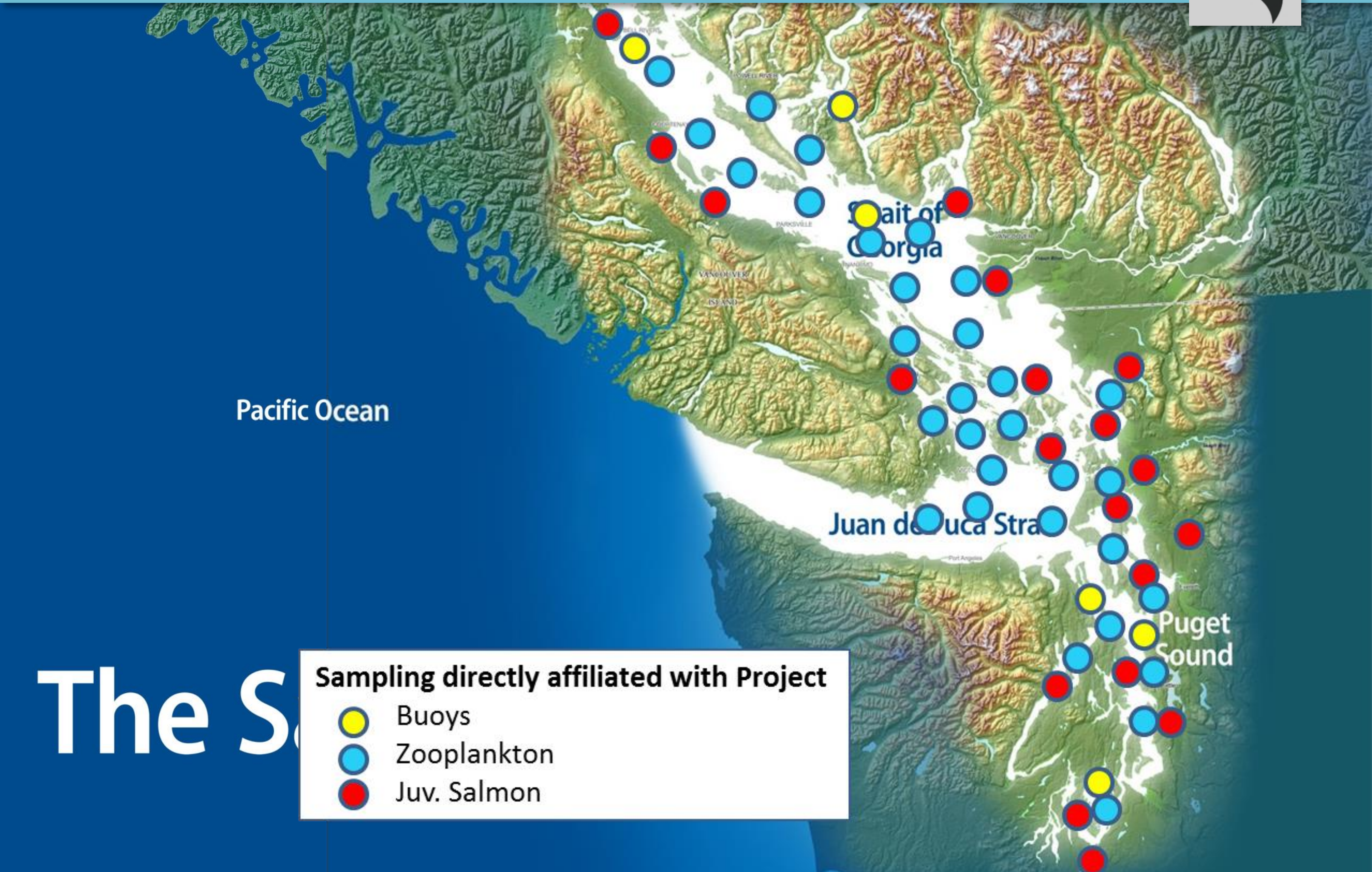


- Growth & survival studies underway
- Citizen Science in Strait of Georgia
- Sound-wide zooplankton program implemented

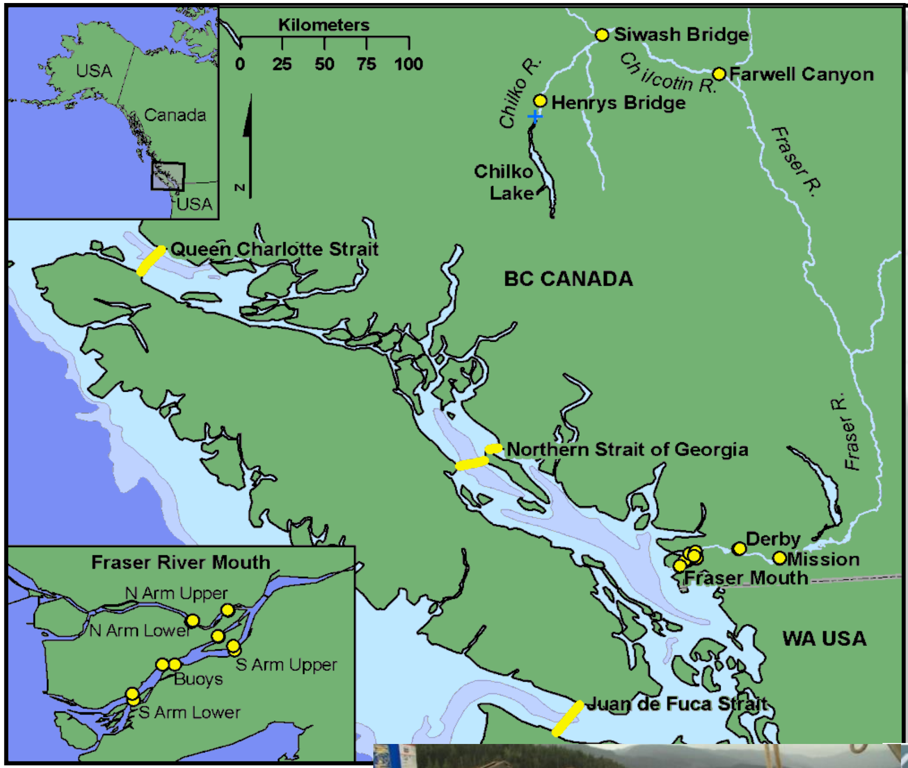
- Sound-wide contaminants assessment complete
- New tech - Seal head mounted PIT tag reader
- 9 Puget Sound steelhead studies

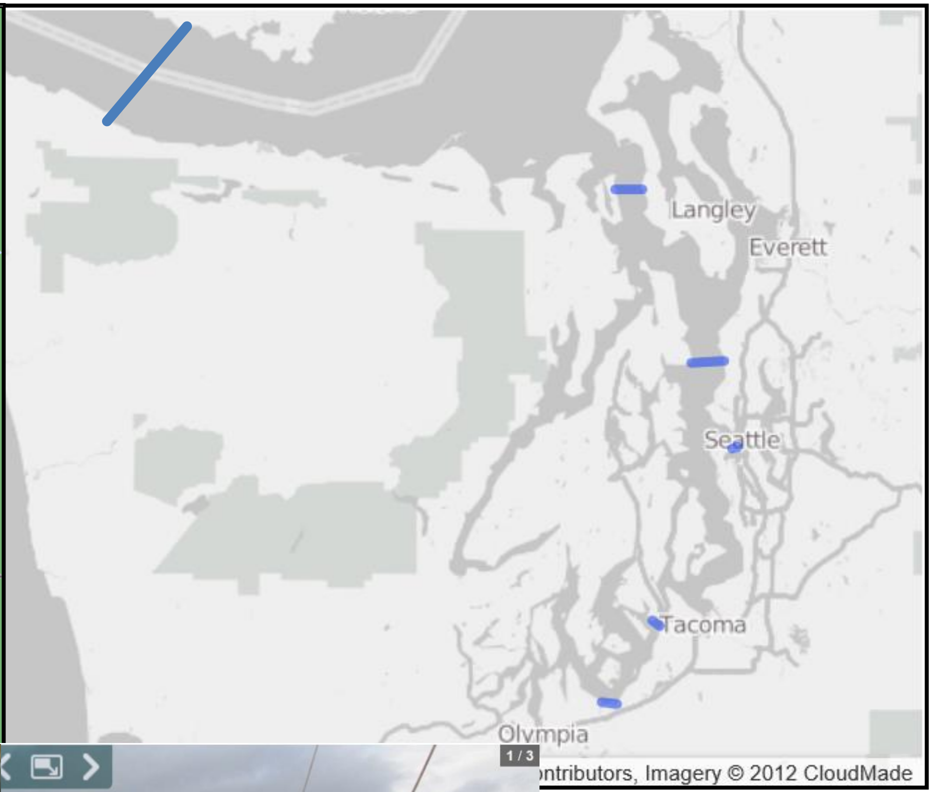
Growth & Survival: Building out from rivers

Salish Sea-wide Sampling Regime



Upgraded Acoustic Receiver Arrays





Puget Sound Steelhead

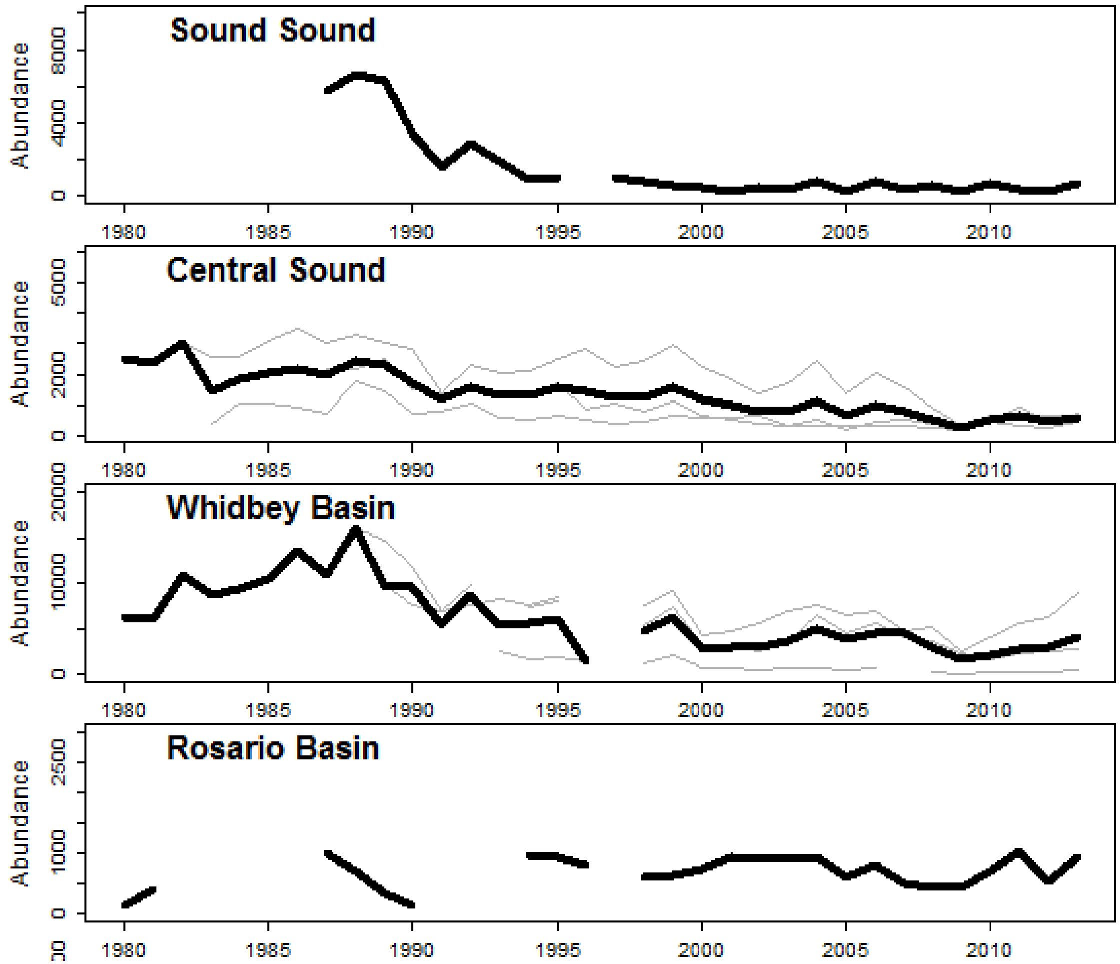
Steelhead Activities & Findings

9 Puget Sound steelhead studies to:

1. **Assess correlations between survival and ecosystem & fish characteristics**
2. **Identify locations, rate and timing of mortality**
3. **Evaluate disease, toxic contaminants, genetics, and predator-prey interactions to reveal the direct and underlying causes of mortality**

Abundance trends – South to North

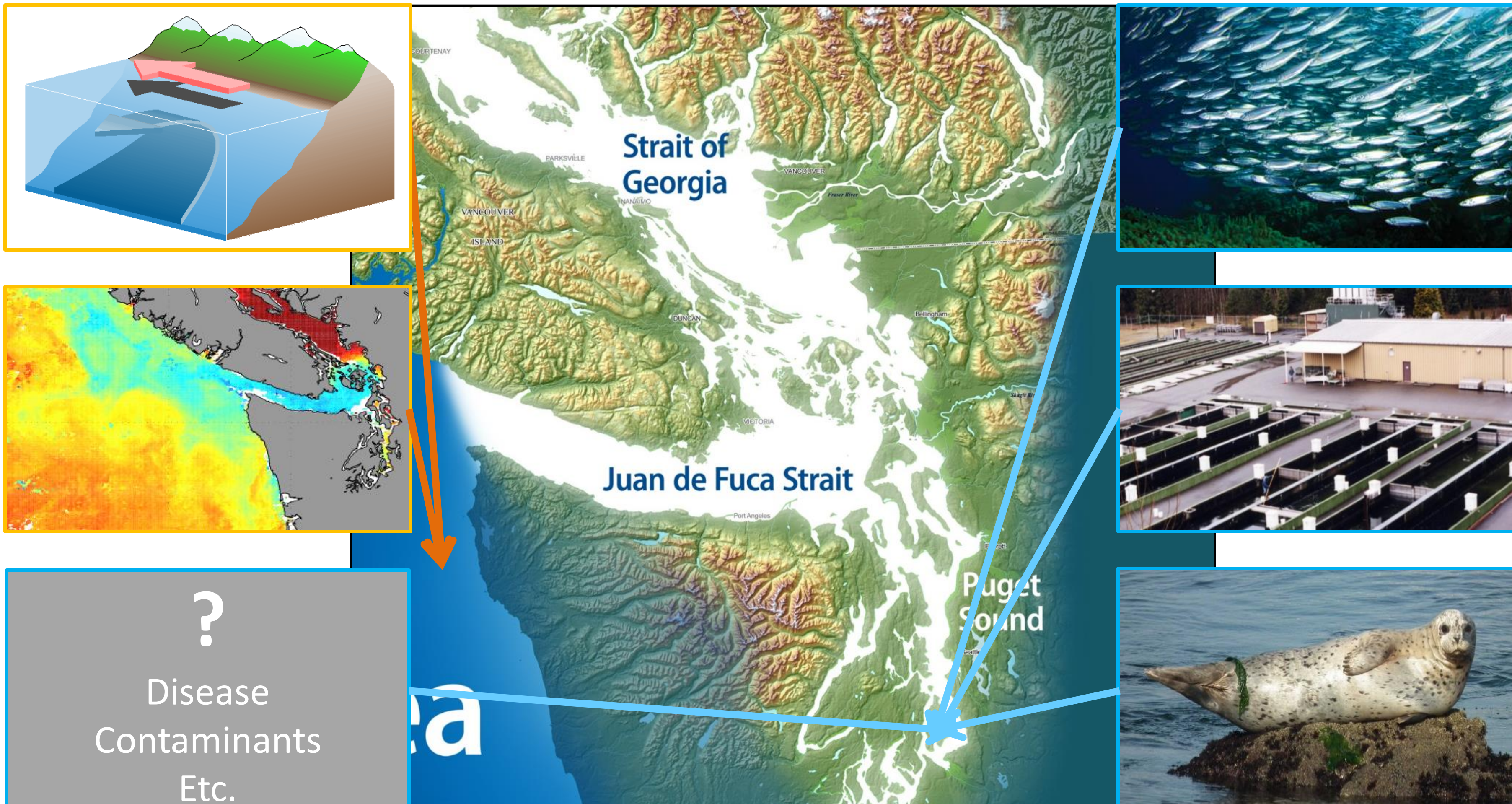
Declines increase from North to South Puget Sound



Kendall et al. (WDFW)

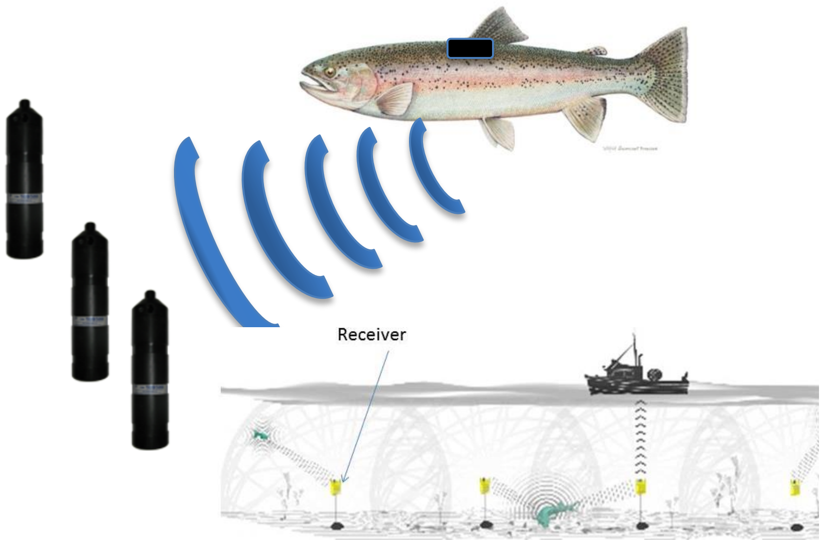
Environmental indicators & survival

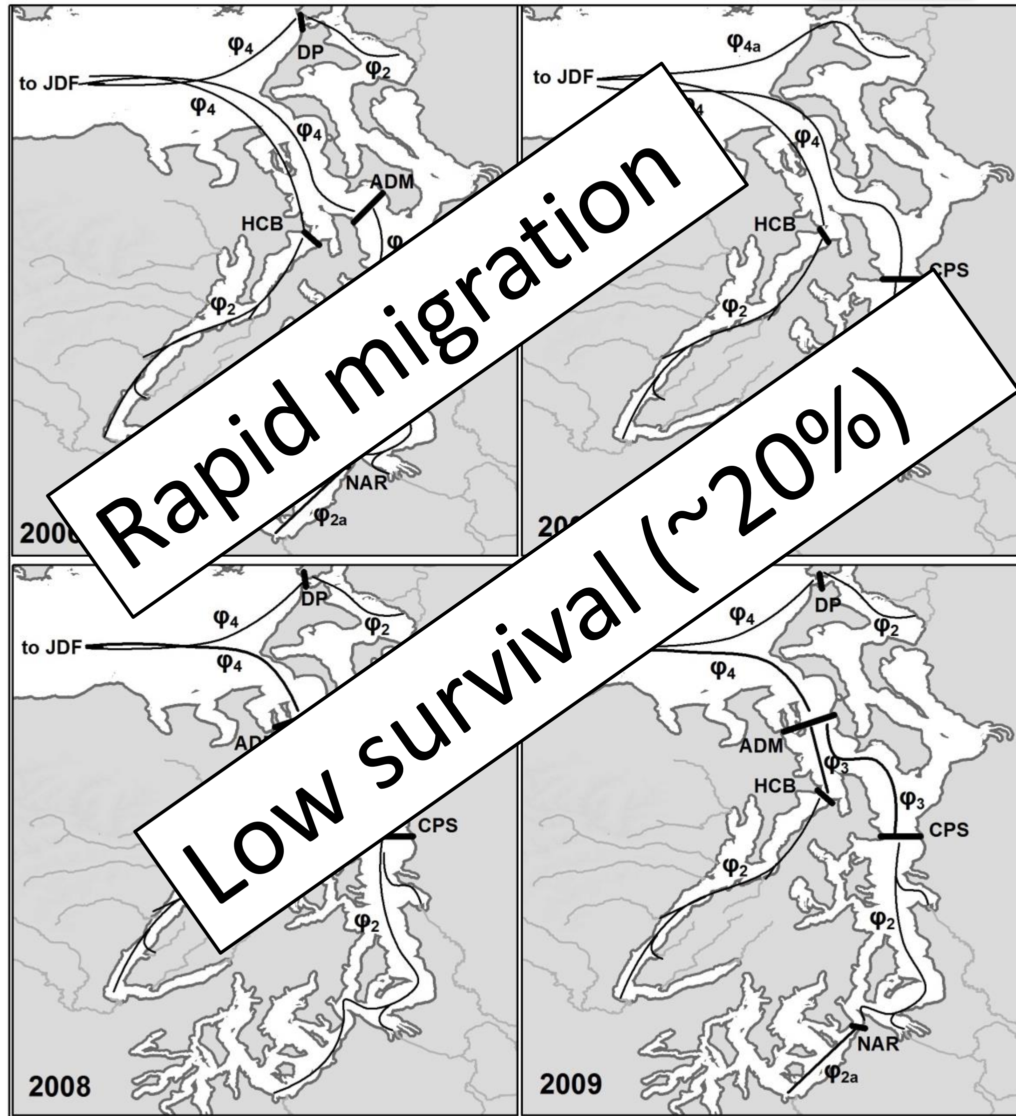
Indicators “with long-term data-sets”



Kendall et al. (WDFW)

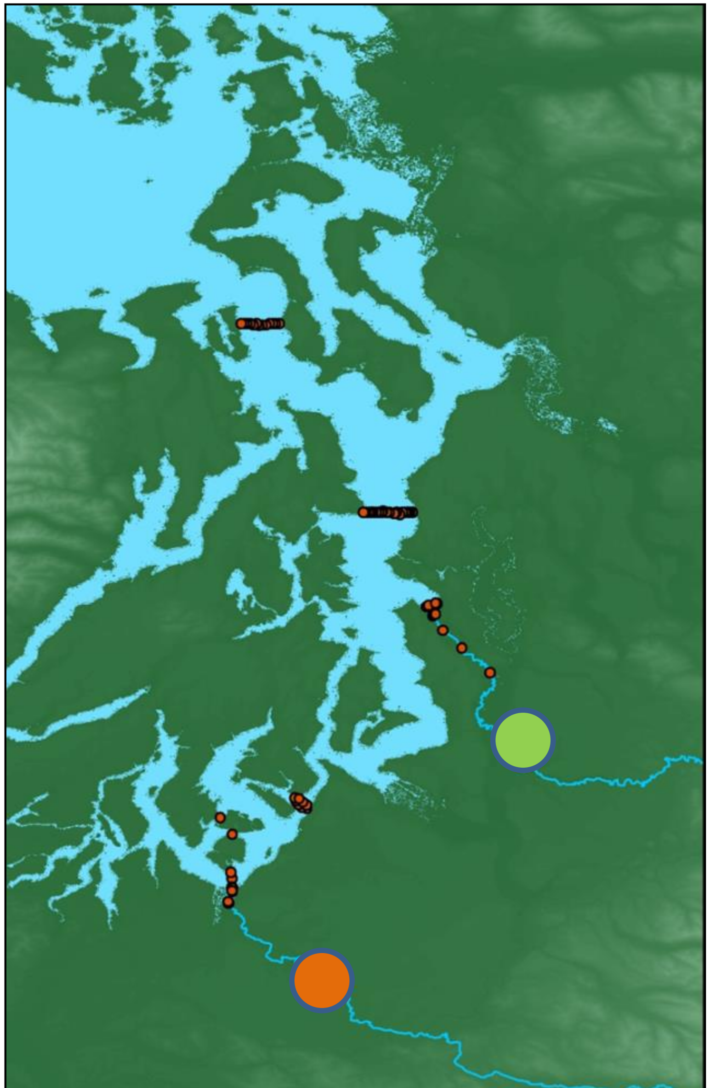
Smolt migration & survival



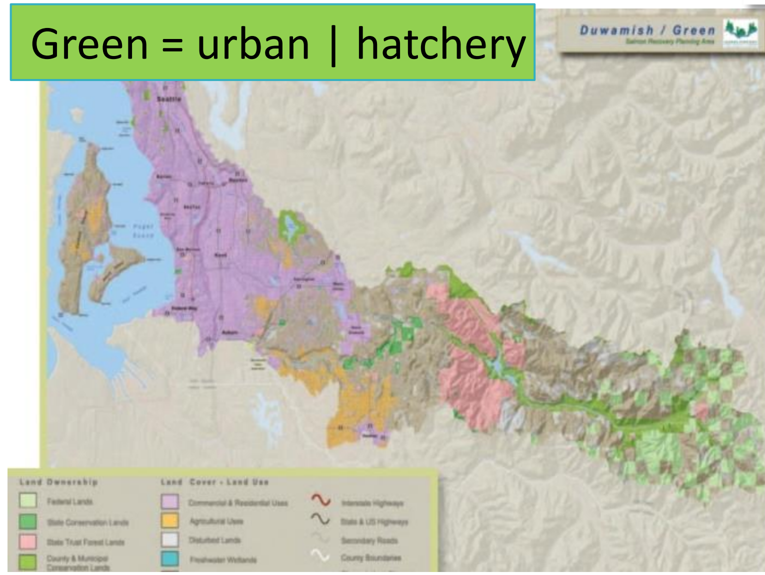


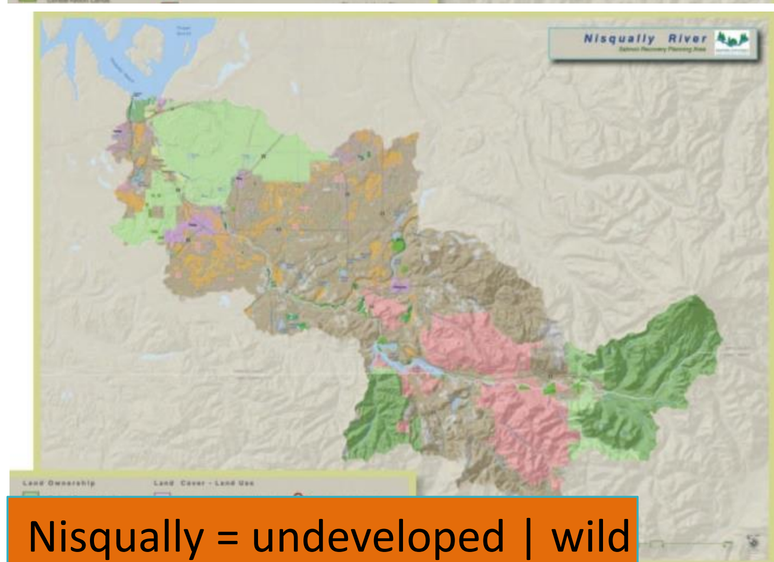
Moore et al. (Mar. Ecol. Prog. Ser. In review)

Freshwater and Marine Factors



Green = urban | hatchery





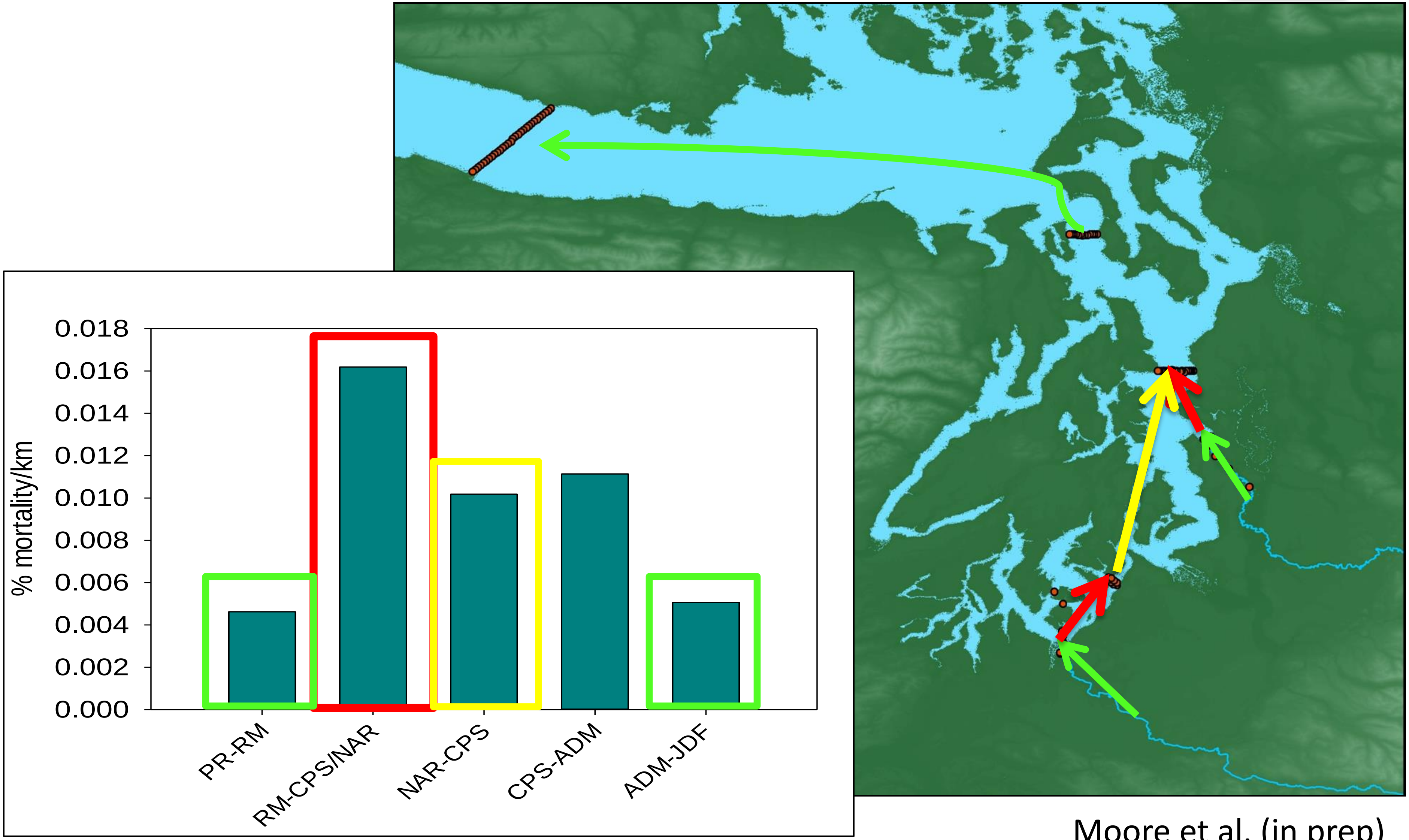
Nisqually = undeveloped | wild

Key Findings

- ✓ Migration rate is very rapid - about 2 weeks
- ✓ Survival of Puget Sound steelhead smolts to the Pacific Ocean is low Green – 17%, Nisqually – 6%)
- ✓ No apparent effects of population, translocation, or body size
- ✓ Release date was moderately important
- ✓ Highest mortality rates in the first marine segment
- ✓ Longer migrations through Puget Sound are associated with higher mortality

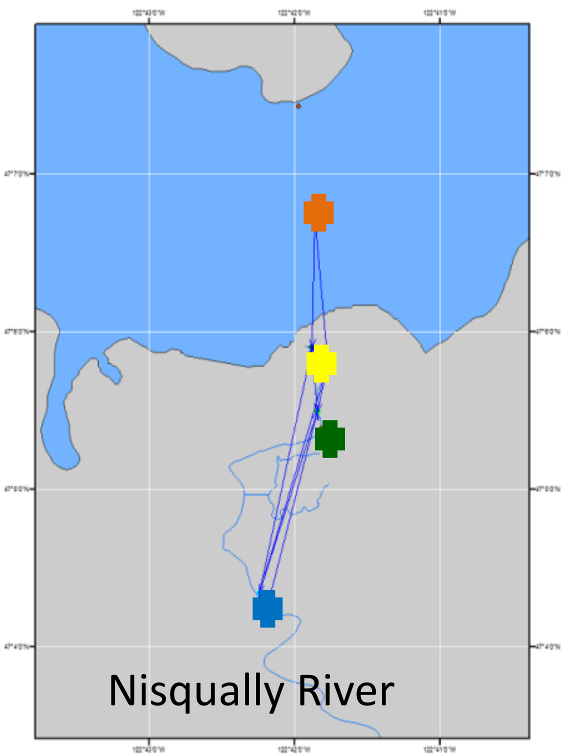
Moore et al. (in prep)

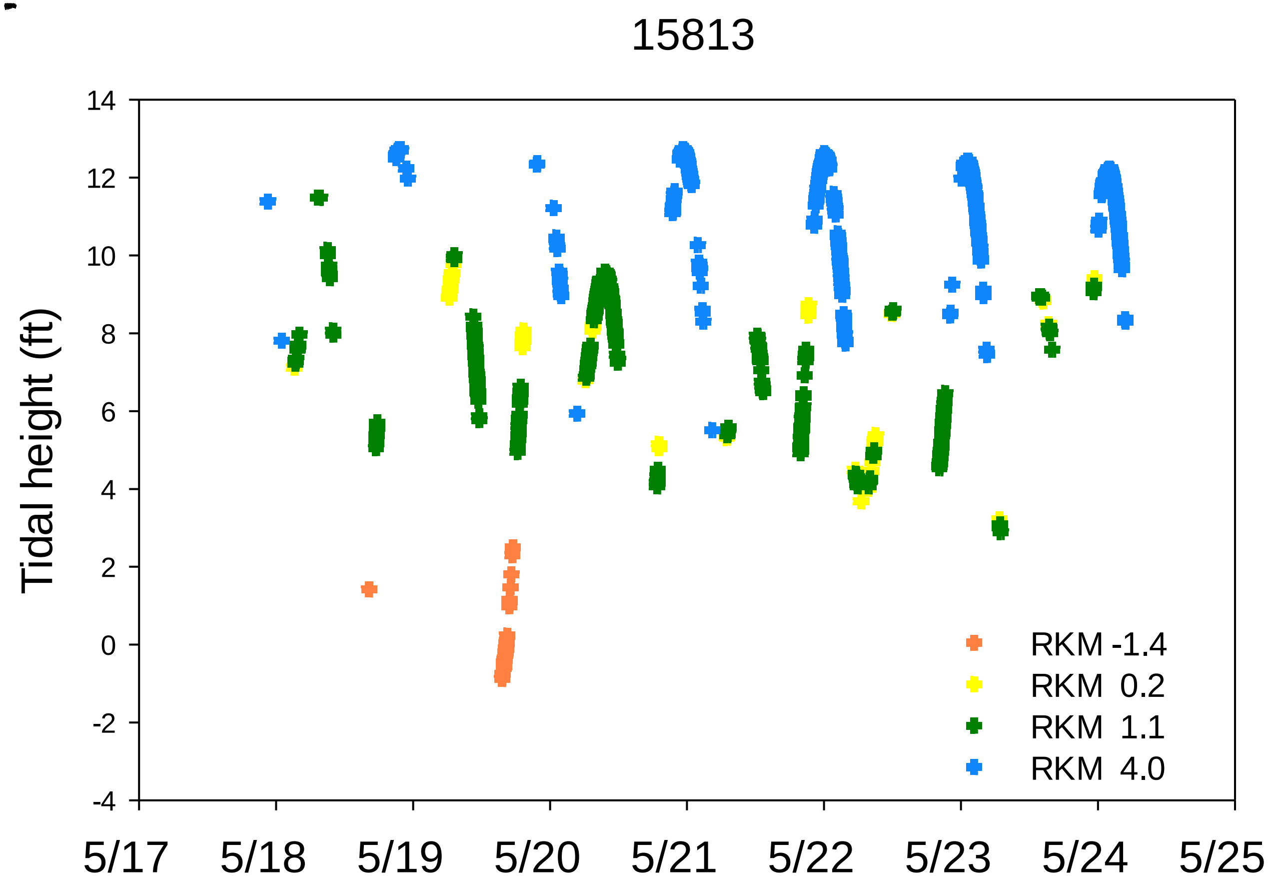
Where is mortality most acute?



Moore et al. (in prep)

Abnormal tag ‘behavior’ patterns





Identifying potential predators

<u>Top</u>

Harbor seal

Double-crested & Brandt's cormorants

Caspian terns

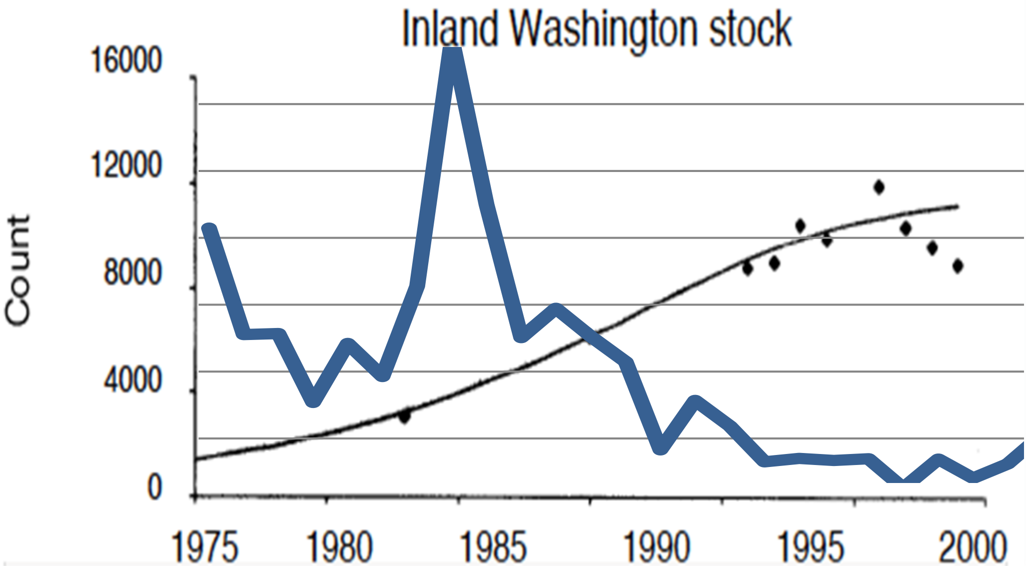
<u>Secondary</u>

Harbor porpoise

Common murre

Pearson et al. (WDFW)

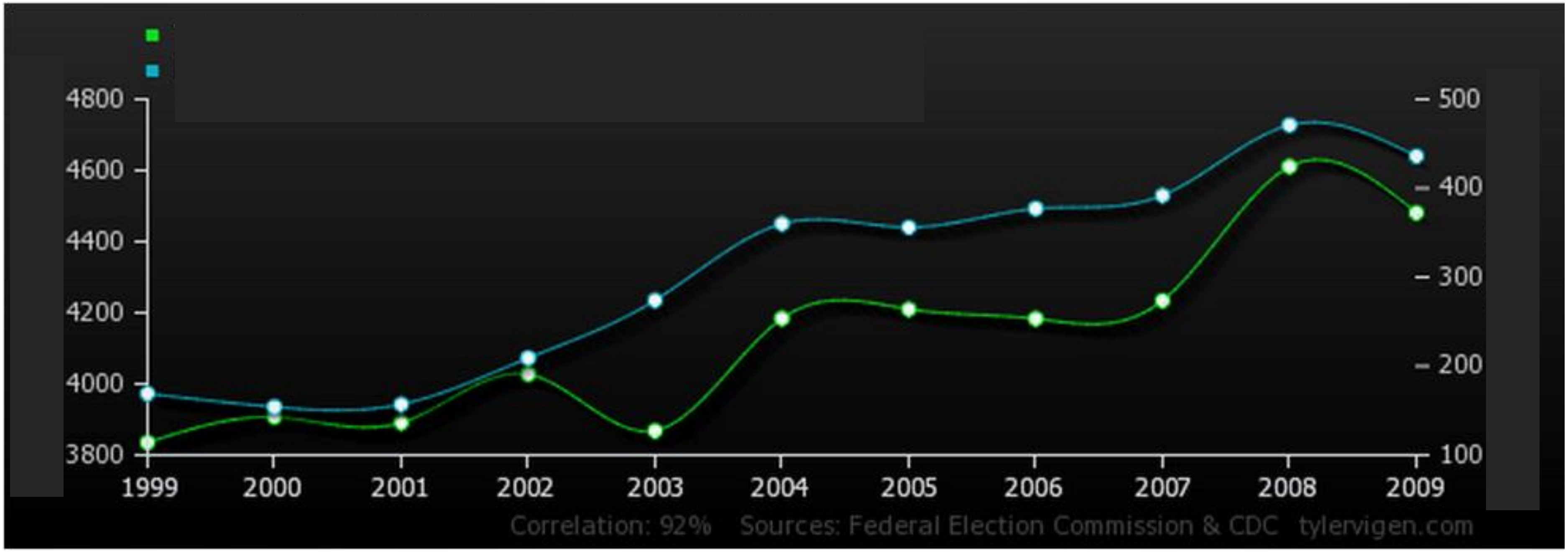
Steelhead and Seals



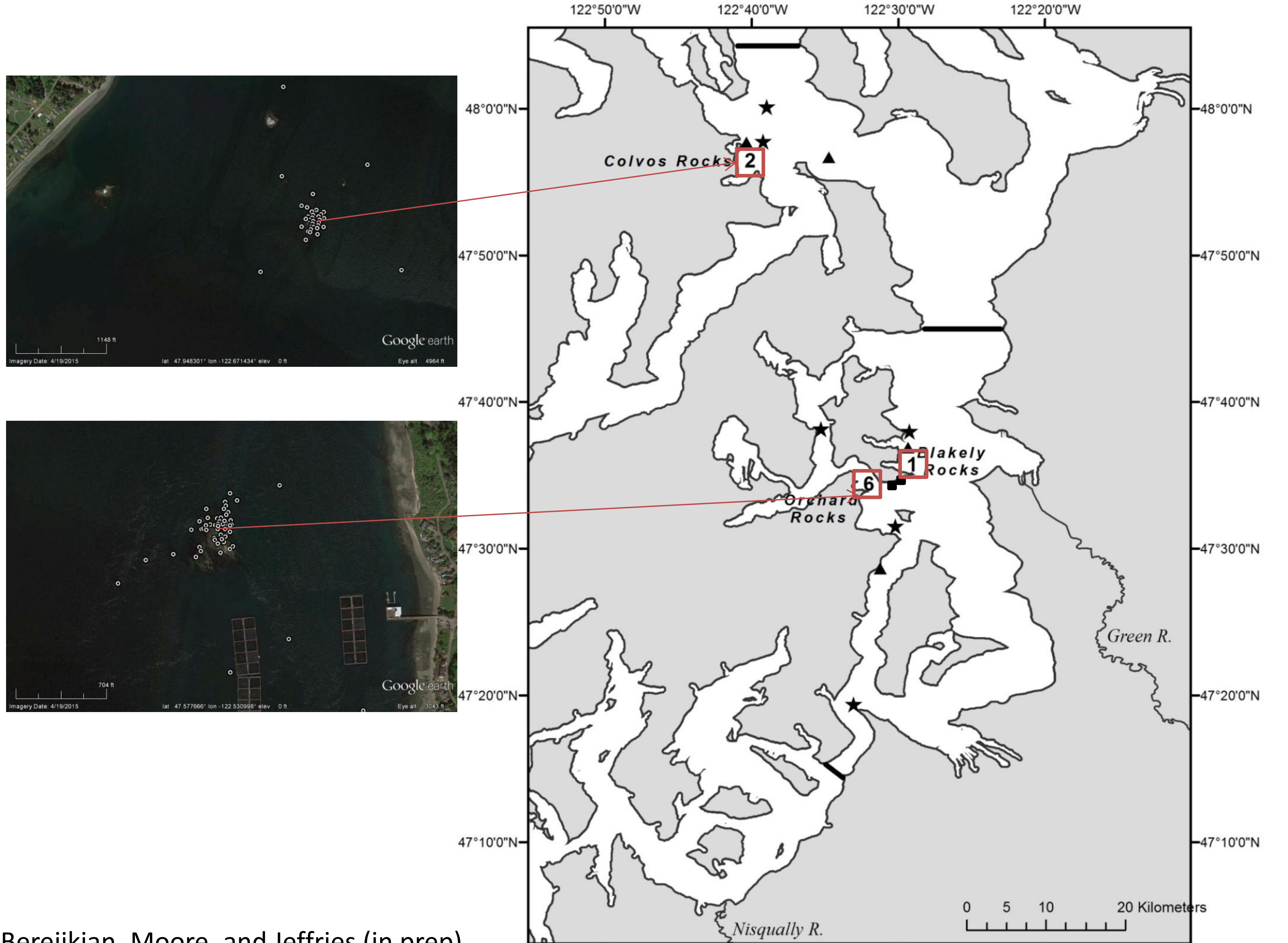
= Steelhead

= Harbor Seals

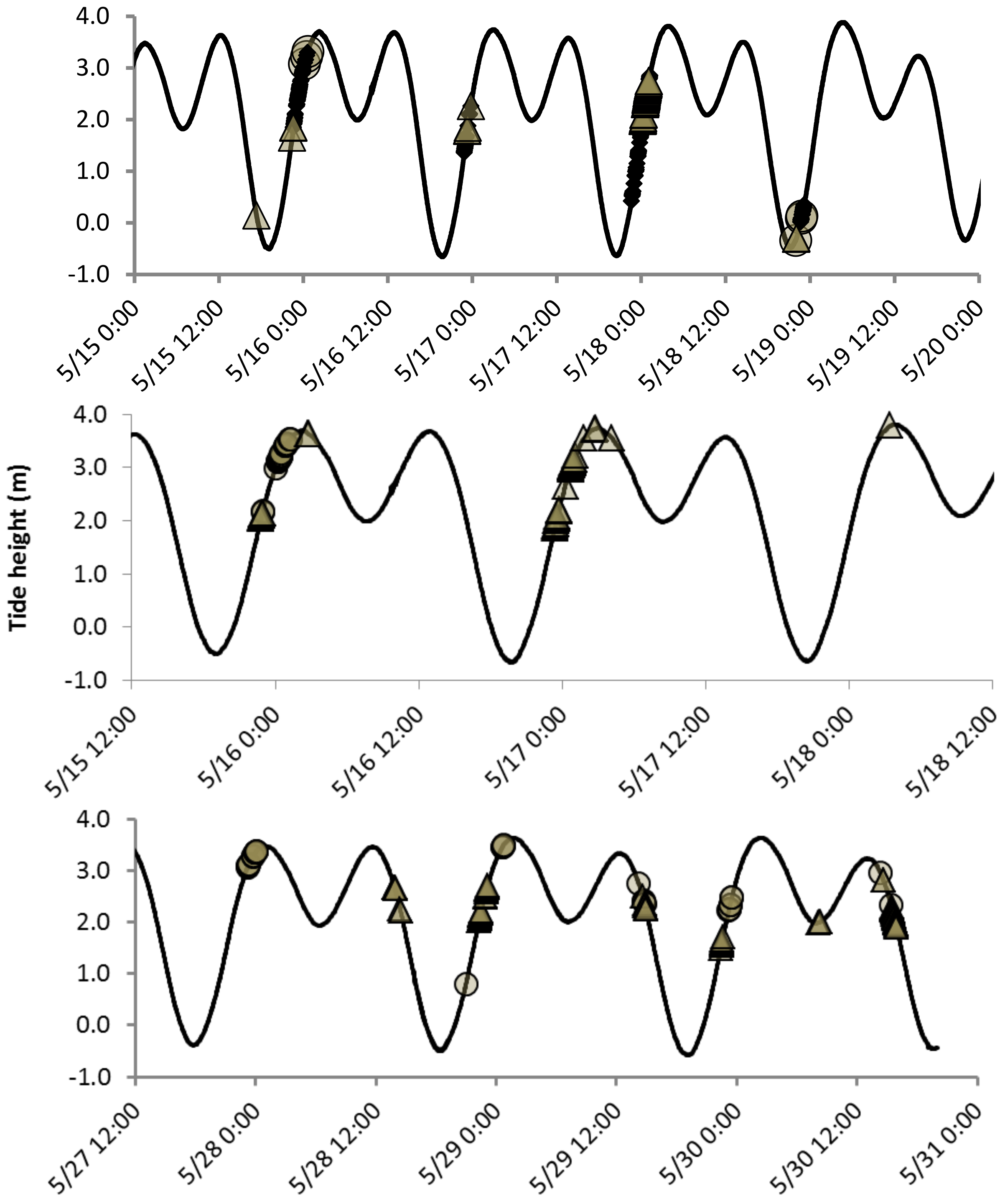
Warning: Correlation ≠ Causation



Steelhead and Seals



Berejikian, Moore, and Jeffries (in prep)



Berejikian, Moore, and Jeffries (in prep)

What is the role of fish condition?

Fish Health - Design

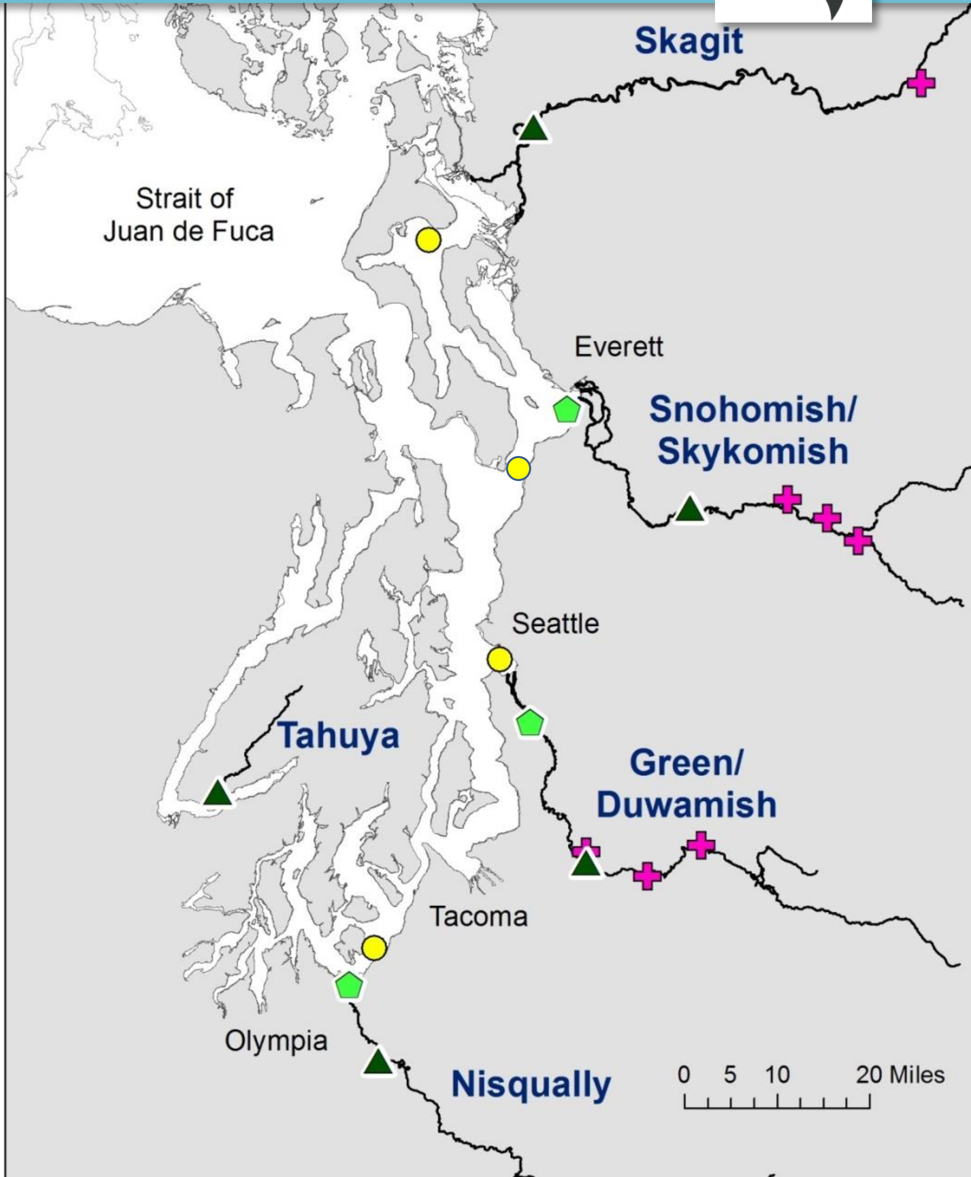
Sampling Design

5 Puget Sound watersheds

- Hatcheries
- Traps
- Lower River / Estuary

3 Offshore Areas

- Whidbey Basin
- Green / Duwamish
- Nisqually



Fish Health - Contaminants

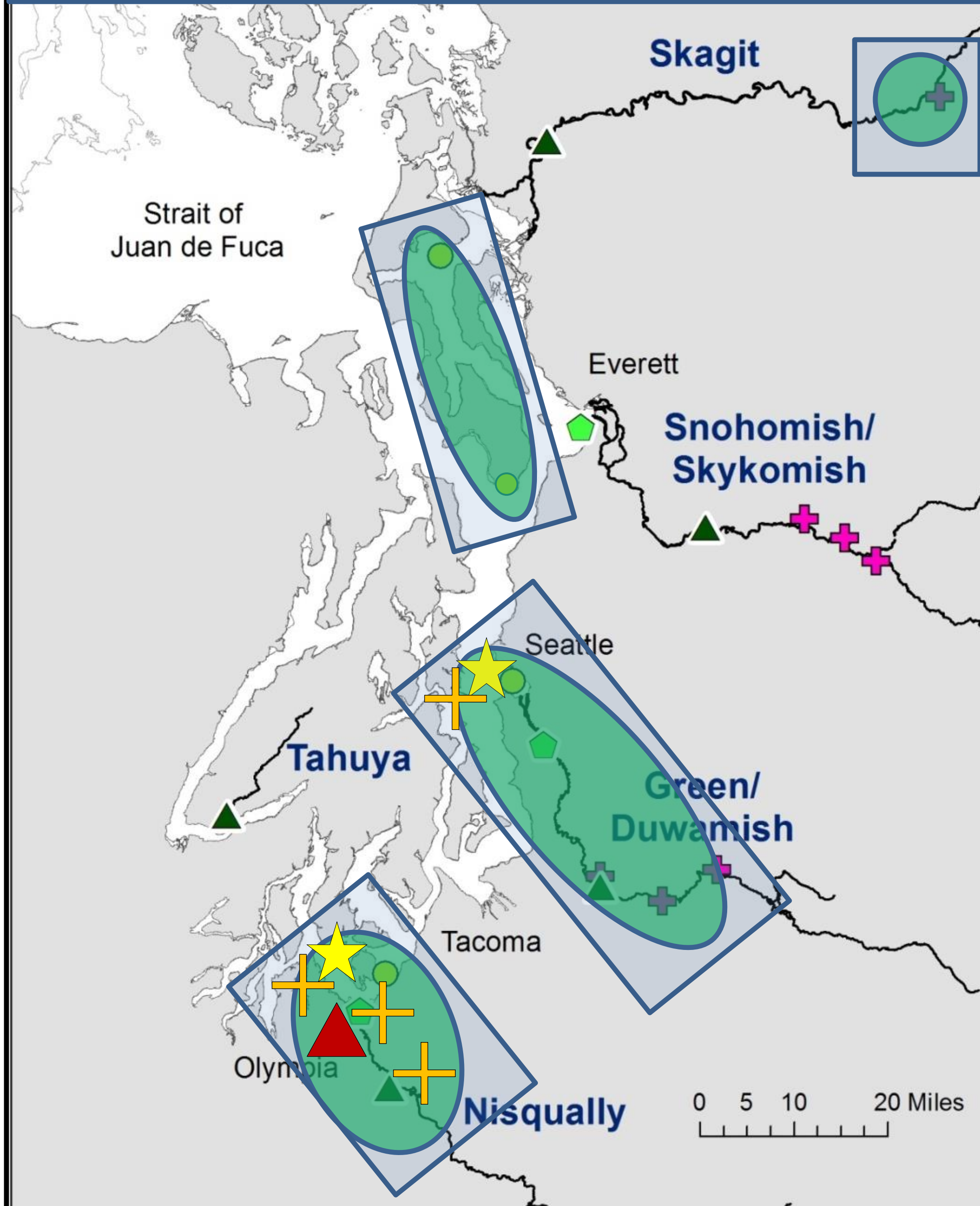
Steelhead **PCB levels** generally low: <u>1.4 – 2.2x **lower**</u> than Chinook at same locations.

16.7% Central and 25% South Puget Sound samples exceeded PCB adverse effects threshold.

Steelhead **PBDE levels** high in Nisqually, and <u>1.1 to 3 times **higher**</u> than Chinook at same locations.

25% Central and South Puget Sound, and 33% Nisqually River samples = increased disease susceptibility

33% Nisqually estuary samples = altered thyroid production



O'Neil et al (WDFW)

Fish Health - Disease

Nanophyetus (parasite)

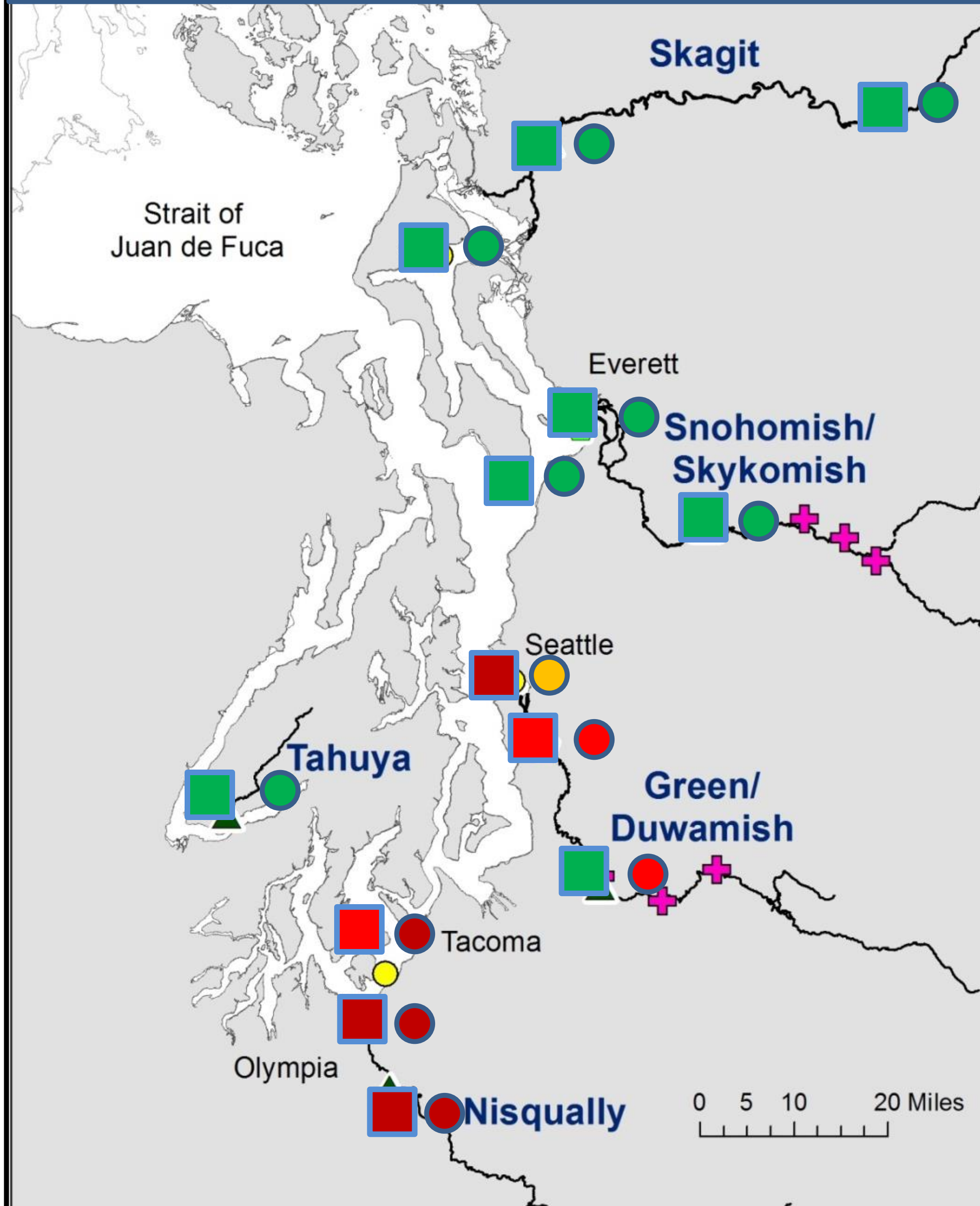
Key = 0, medium, high, very high

□ Infection prevalence

○ Parasite load

Findings

- ✓ No Nanophyetus in Skagit, Snohomish, Tahuya, Whidbey Basin
- ✓ Prevalence and parasite loads increase from trap to estuary in Green.
- ✓ Prevalence and parasite loads in Nisqually extremely high.



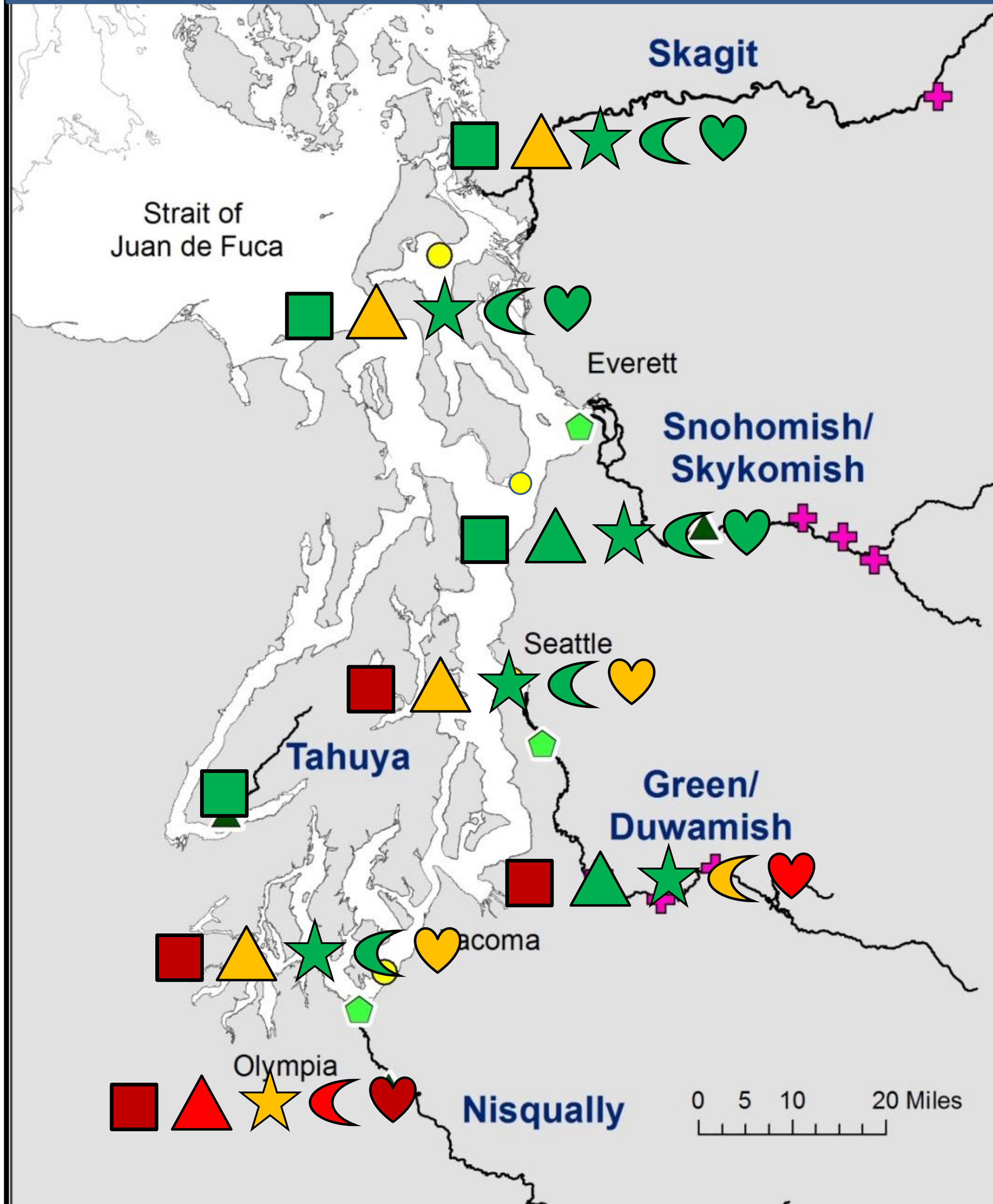
Chen (NWIFC) and Hershberger (USGS)

Fish Health - Disease

Prevalence of other features

Key = 0-20%, 20-40%, 40-60%, >60%

- Nanophyetus
- Kidney Myxosporean
- Sanguinicola
- Gill inflammation
- Heart inflammation



Findings

- ✓ Many fish from Green and Nisqually with Nanophyetus exhibit gill & heart inflammation.
- ✓ Heart & gill inflammation could be indication of compromised swimming performance.

Chen (NWIFC) and Hershberger (USGS)

Genome-Wide Association Study

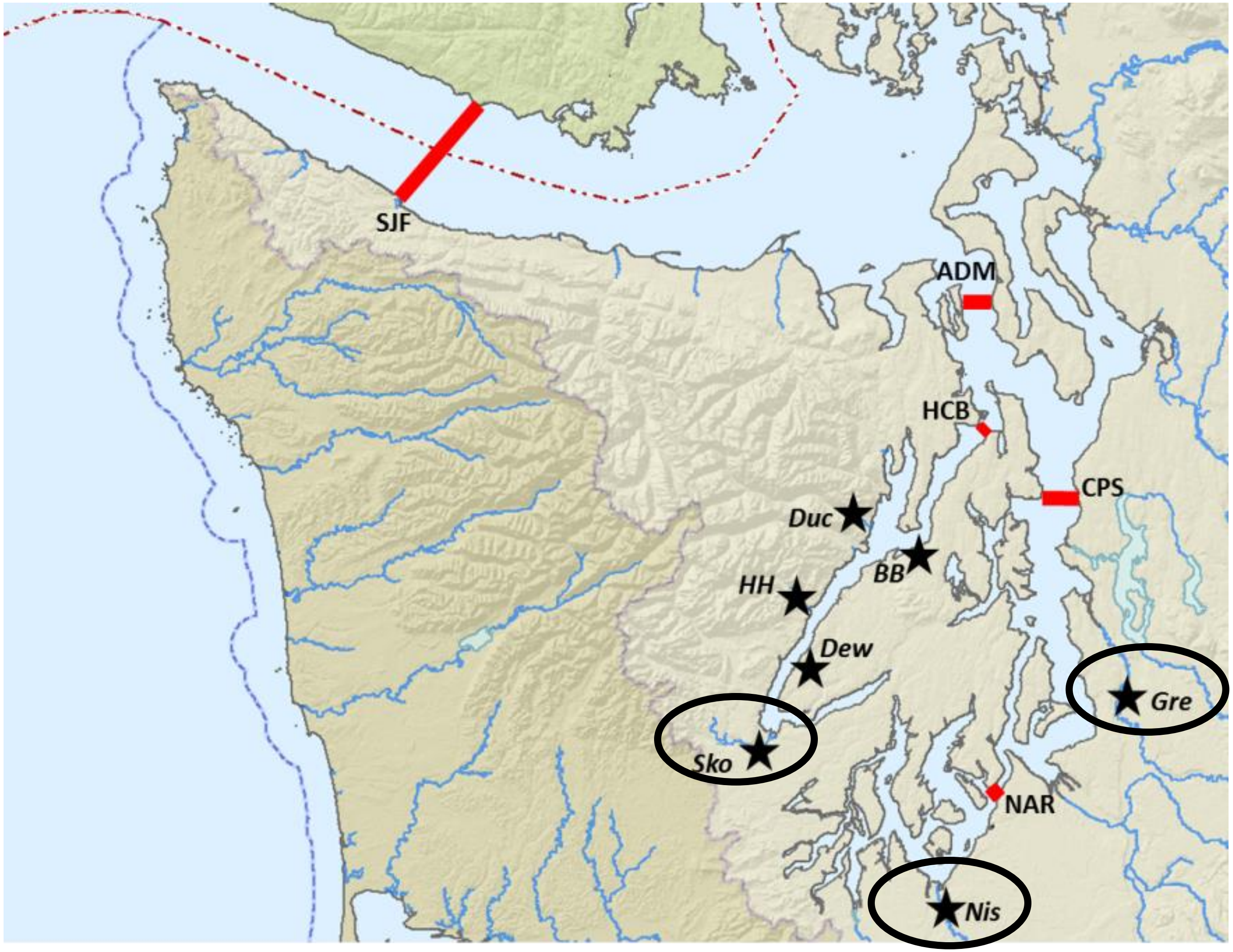
Survivors vs Non-survivors (Methods)

- Genome-wide association studies (GWAS) ask:
  - Is there an significant correlation between genetic “fingerprints” and phenotype, behavior, life history . . . ?
  - For this specific study: between steelhead smolt genotypes and their fate (survival v. mortality) in Puget Sound?
- Acoustically tagged smolts
- Mortality = no detections in Puget Sound
- Survival = detection at last (SJF) array
- Genomic sequencing (~ 5700 “genes”)
- Six analyses with different grouping factors

Warheit (WDFW)

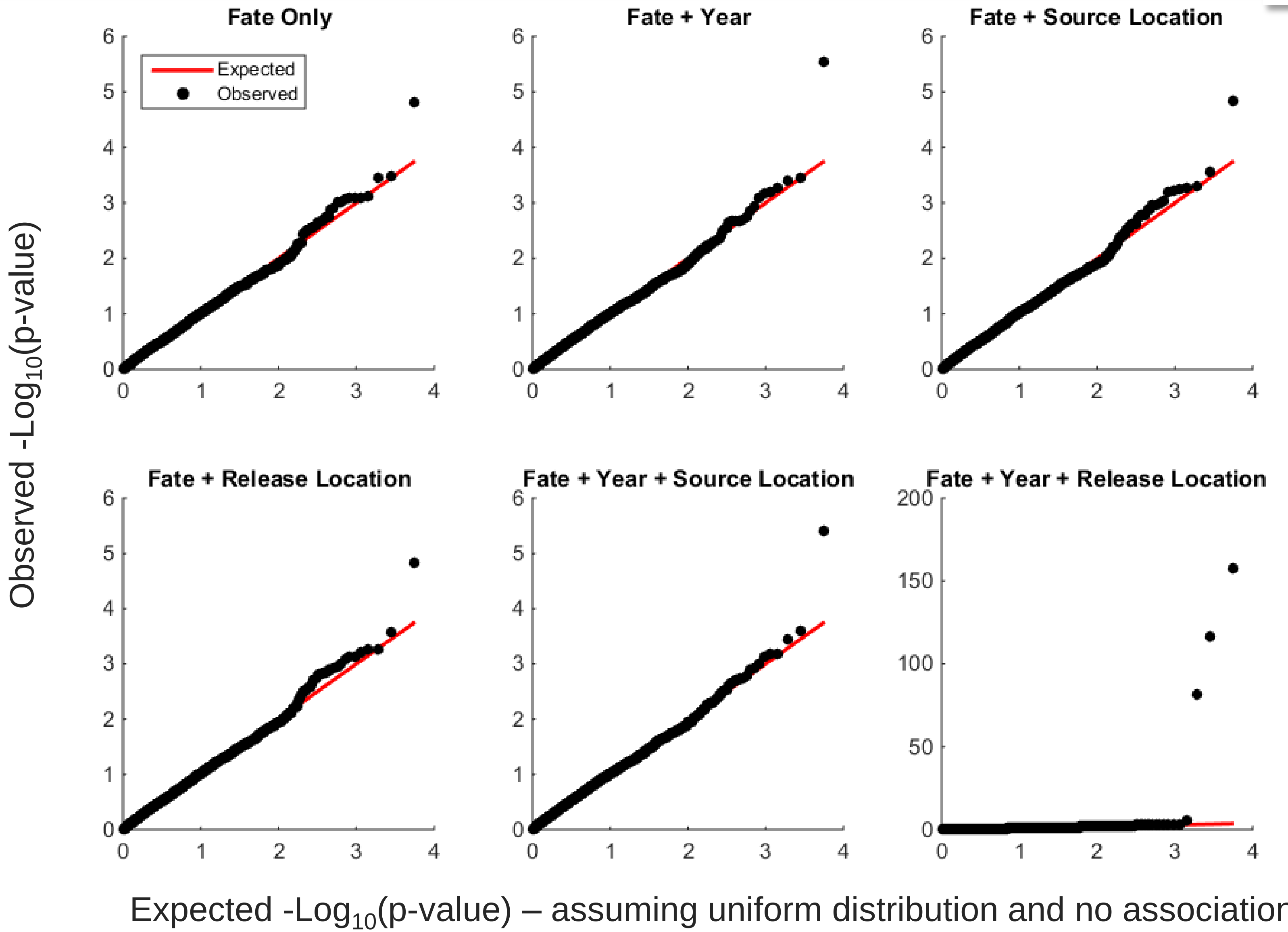
Genome-Wide Association Study

Survivors vs Non-survivors (samples and detection locations)



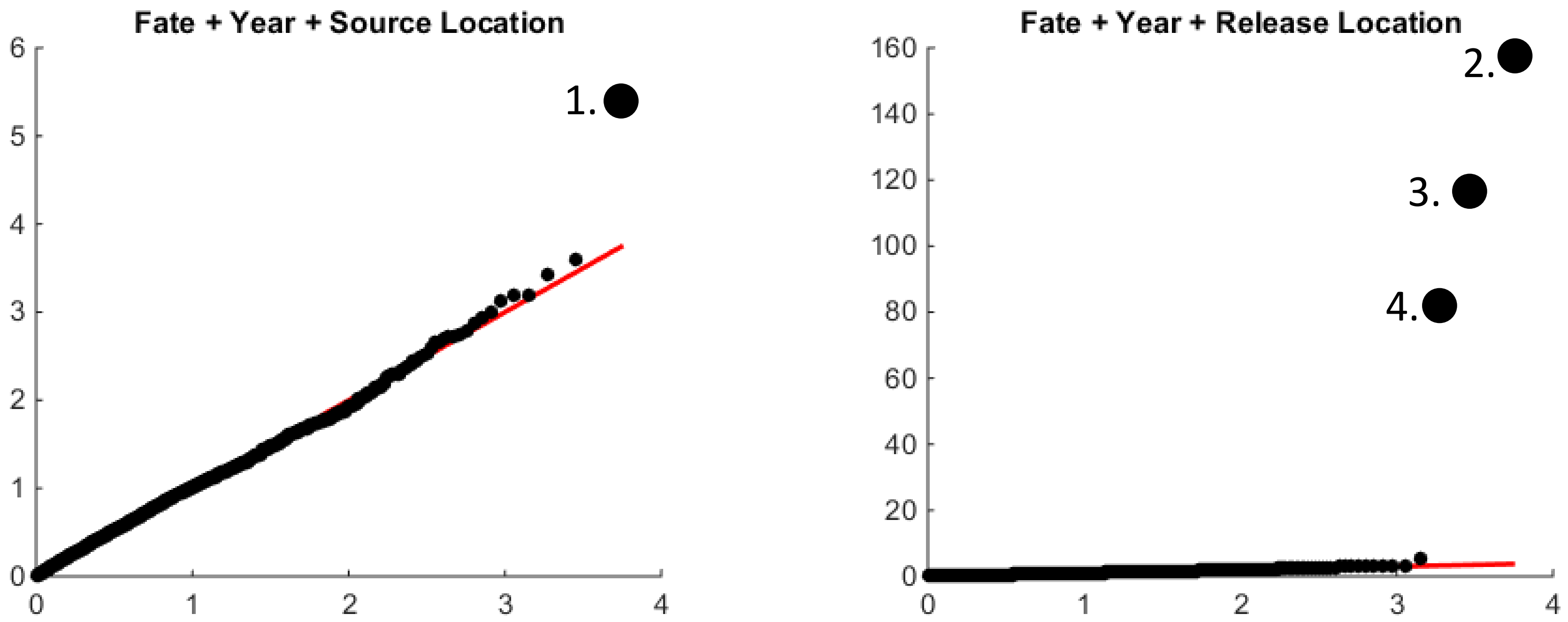
Genome-Wide Association Study

Survivors vs Non-survivors (Are there genetic differences?)



Genome-Wide Association Study

Survivors vs Non-survivors (What are these genes?)



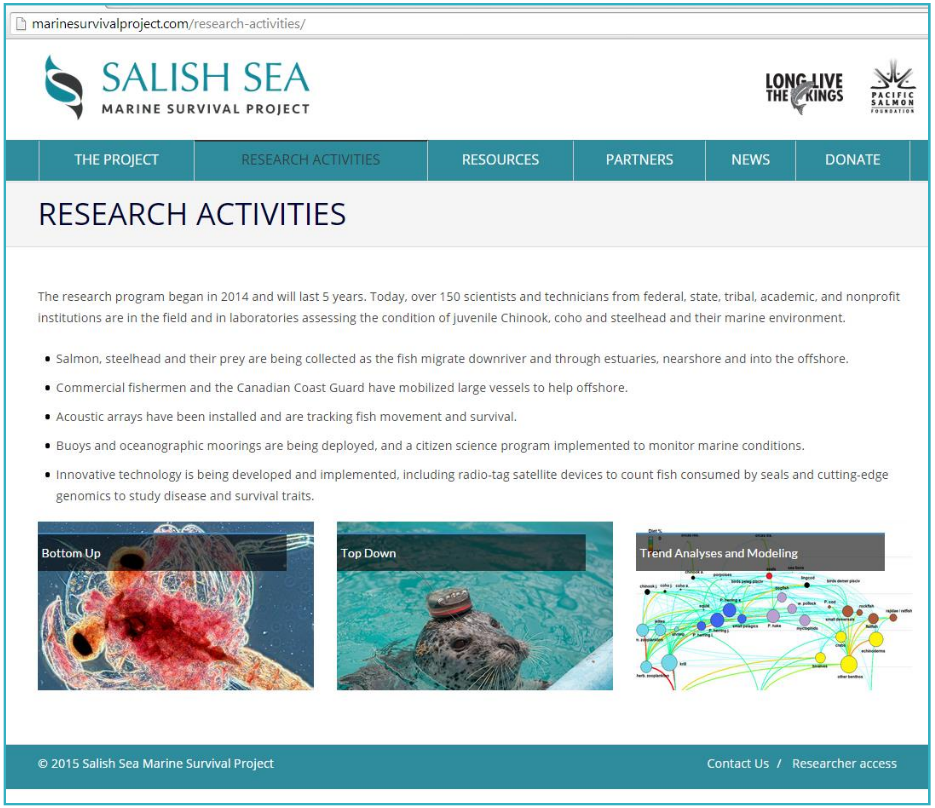
Sequence Alignment with NCBI (NIH) database using BLAST

1. Morphogenesis. Possibly involved with fin development. Swim performance?
2. Possibly immunological
3. No alignment with salmonid sequences in NCBI database
4. Immunological or morphogenesis

Conclusions - Steelhead

- ✓ **Worse South – Better North** abundance (and survival) trends help hone in on mortality drivers.
- ✓ **Reciprocal transplant suggests marine mortality driver** and illustrates increased death by distance traveled through Puget Sound.
- ✓ **Disease prevalence and associated fish condition** (compromised gills, heart) may make South to Central Sound Puget Sound populations more vulnerable to predation. PBDE levels may contribute in Nisqually.
- ✓ Smolts in some populations with particular genetic fingerprints may be **compromised by their morphology (fin development) or immunological responses** making them sick or more vulnerable to predation.
- ✓ **Predation occurring and may include multiple predators.** Pop. increase, distribution, prey range, presence during steelhead outmigration, encounters, abnormal tag behavior, and stationary tag detection locations suggest harbor seals a likely predator. Harbor porpoises, cormorants, loons, common murres not studied. Of those, harbor porpoises w/ significant increase in population presence/distribution in Puget Sound.
- ✓ Correlational relationships may help put current findings in **ecosystem change context** and suggest potential drivers: **+ herring, - hatchery coho releases, + harbor seal.**

Thank You!



Visit marinesurvivalproject.com for more information.