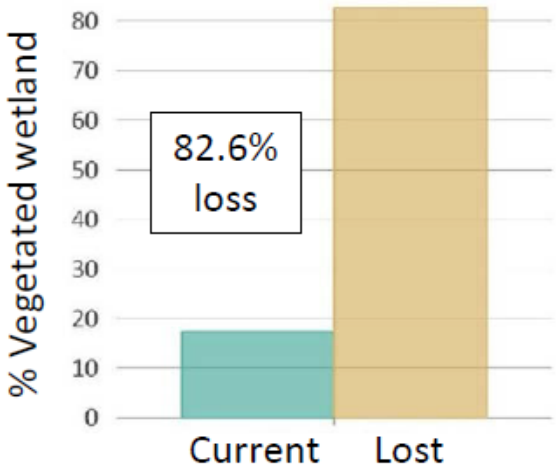
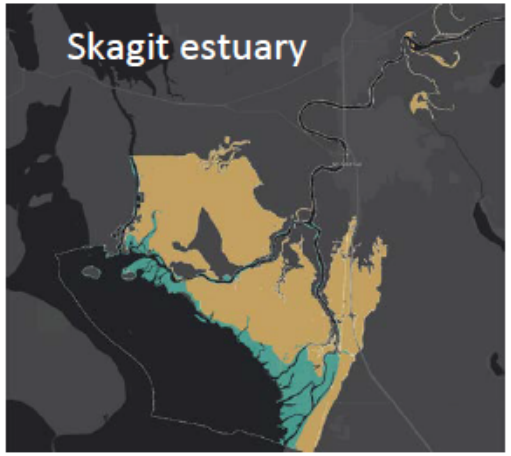
NWFSC & SWFSC salmon habitat research



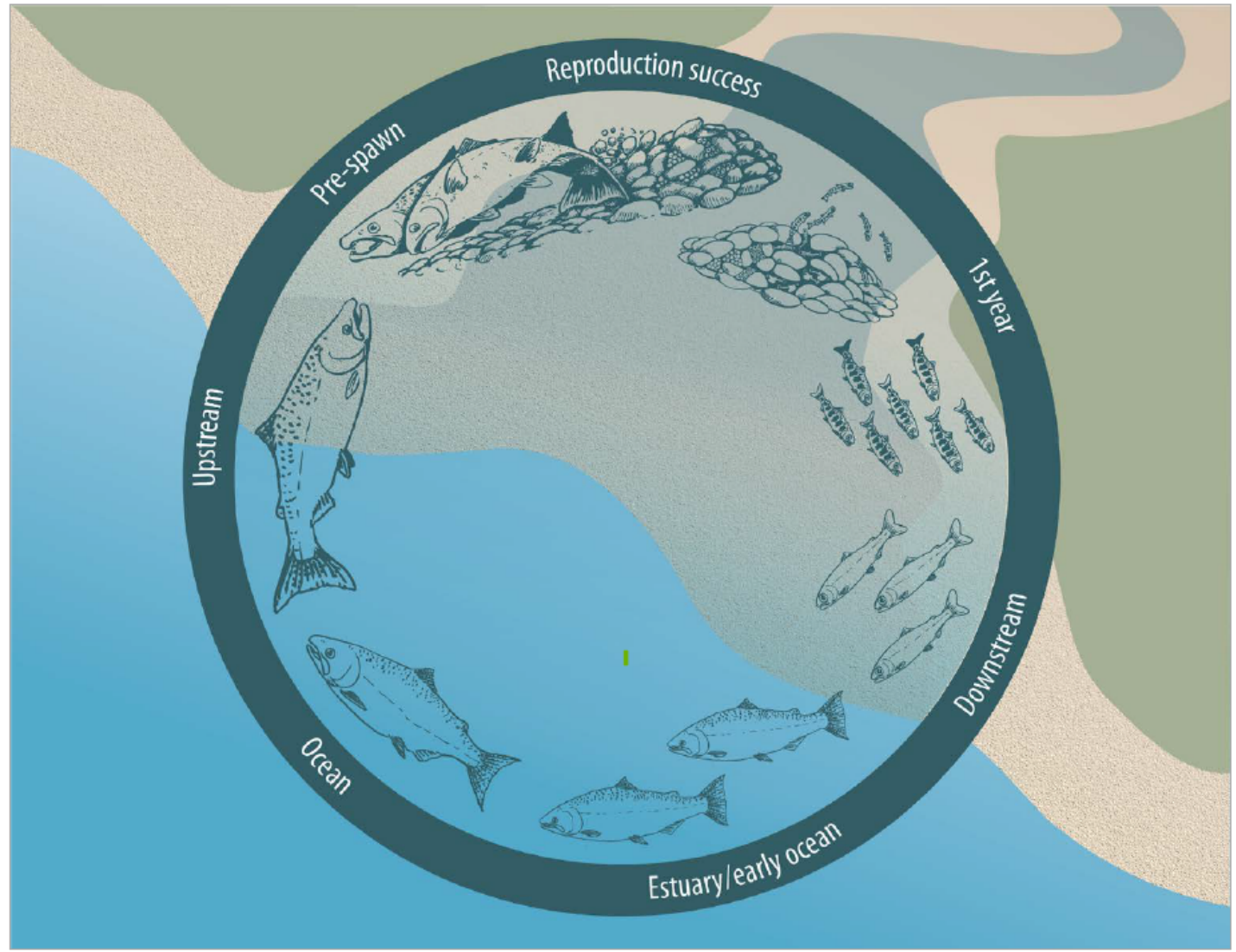


Freshwater rearing

Estuary rearing

Early ocean entry

Life cycle integration

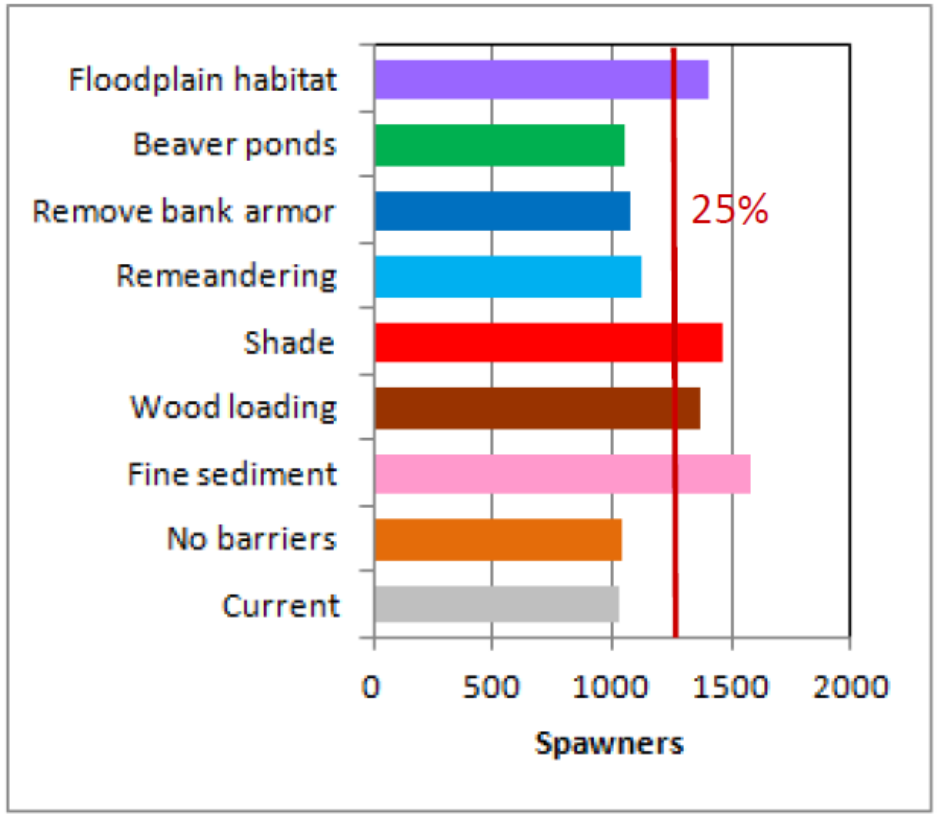


Large-scale watershed assessment in the Chehalis River

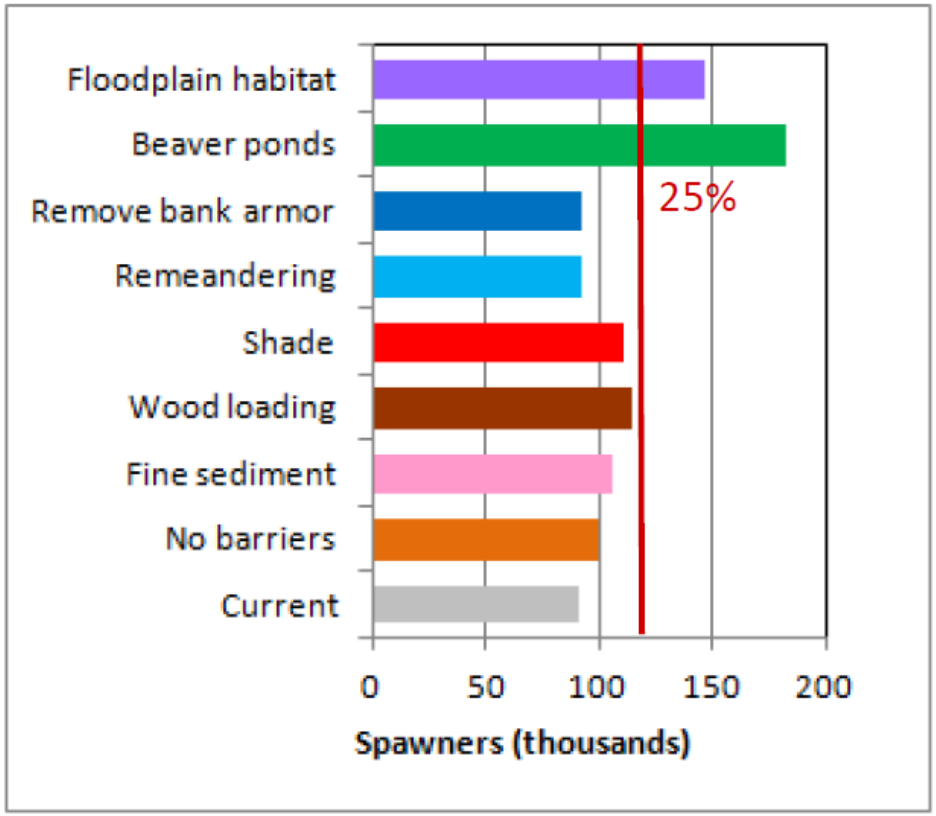
- Examine how change due to land use management and habitat restoration actions effects potential salmonid production
- Quantify historical & current habitat area
  - Delta/bay habitats
  - Mainstem river
  - Floodplain habitats
  - Tributaries
  - Beaver ponds and lake
- Estimate historical & current salmon production

Large-scale watershed assessment in the Chehalis River

Spring Chinook salmon



Coho salmon



Beechie et al. 2020

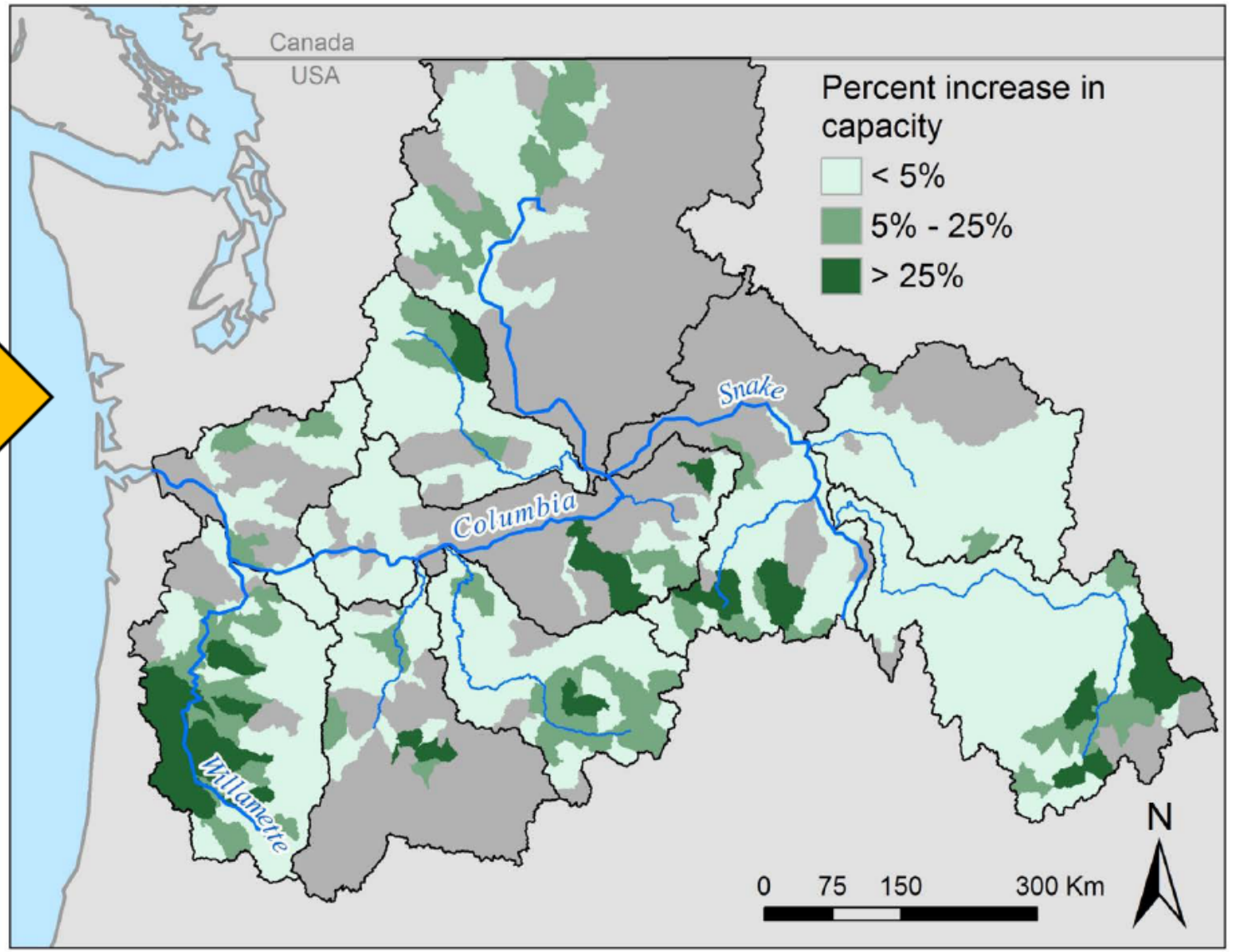
Columbia River basin-wide habitat models

Estimates of spring Chinook rearing capacity by increasing floodplain width in:

- Cropland
- Rangeland
- Unimproved roads

Drawbacks to approach:

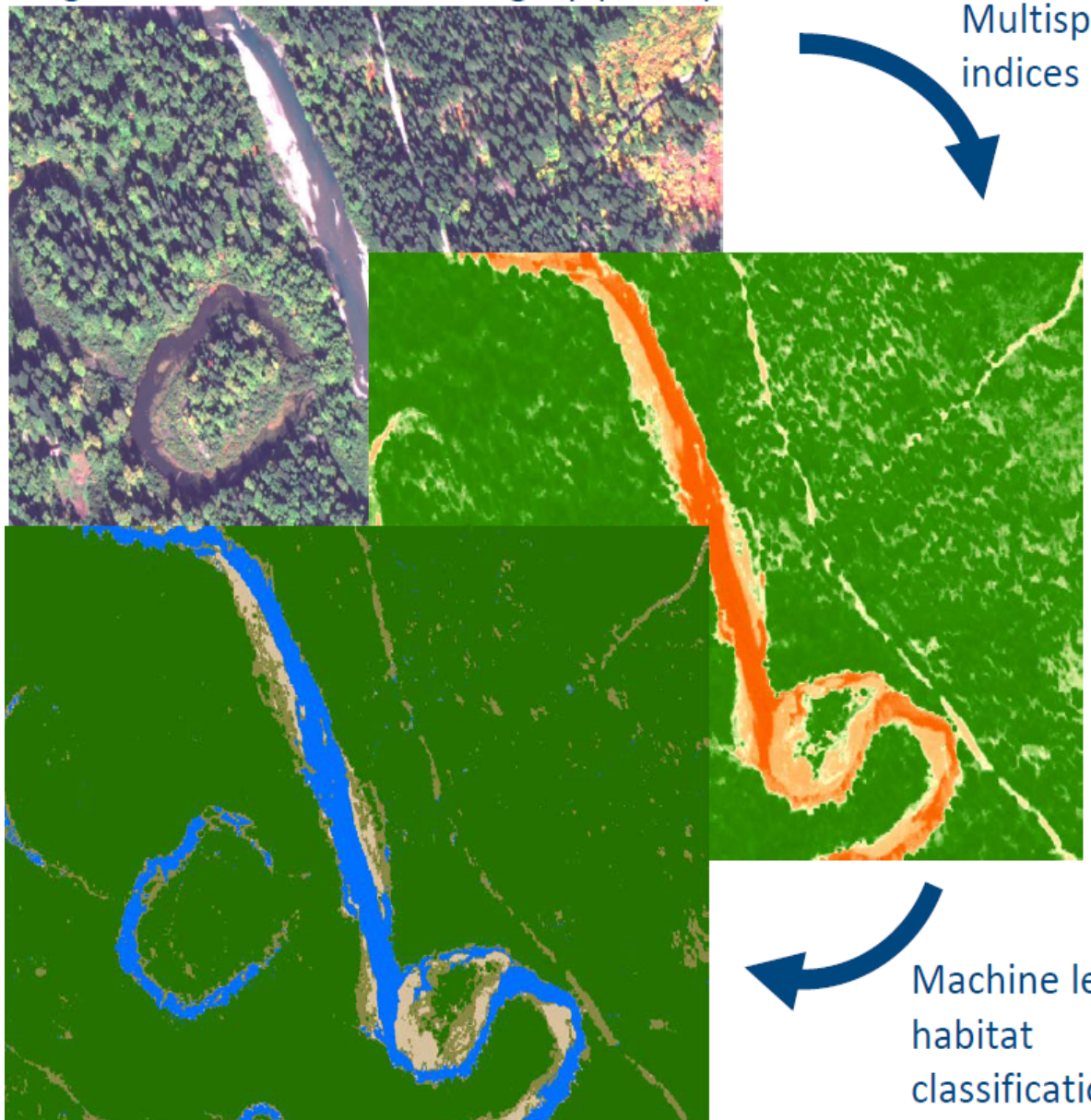
- Insensitive to other restoration actions
- “Static” model



Bond, M.H., Nodine, T.G., Beechie, T.J., and Zabel, R.W. 2018. Canadian Journal of Fisheries and Aquatic Sciences

Matching estimates of habitat and streamflow

High resolution satellite imagery (< 1 m)

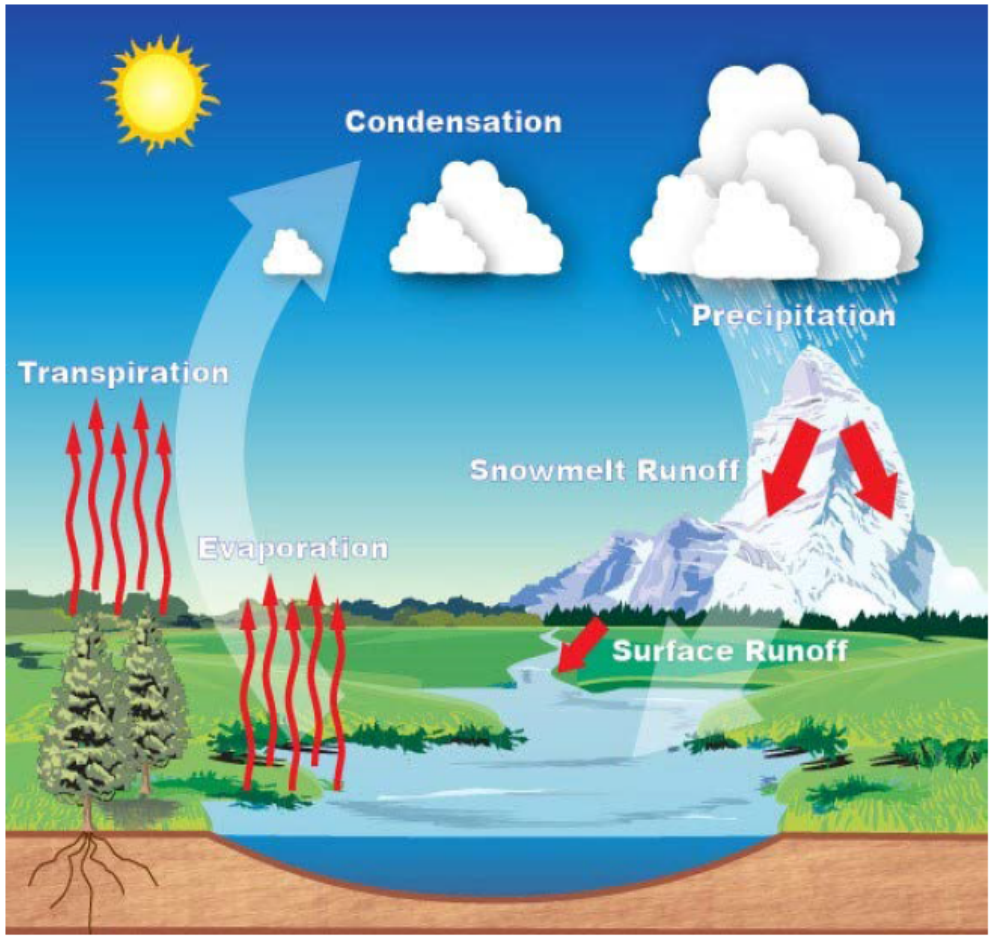


Multispectral indices

Machine learning habitat classification models

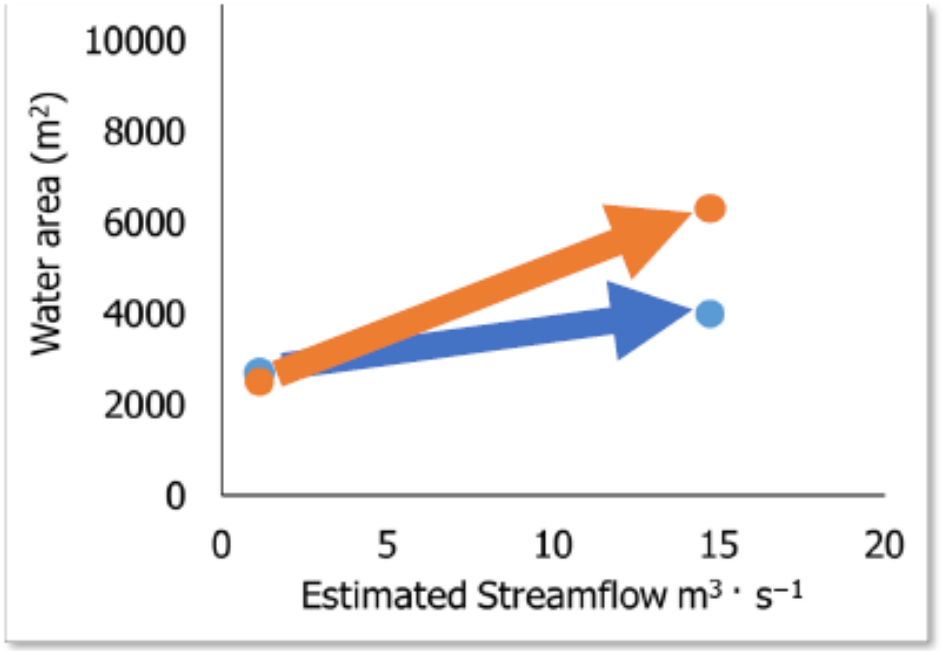
+

National Water Model streamflow estimates 1993-2018+



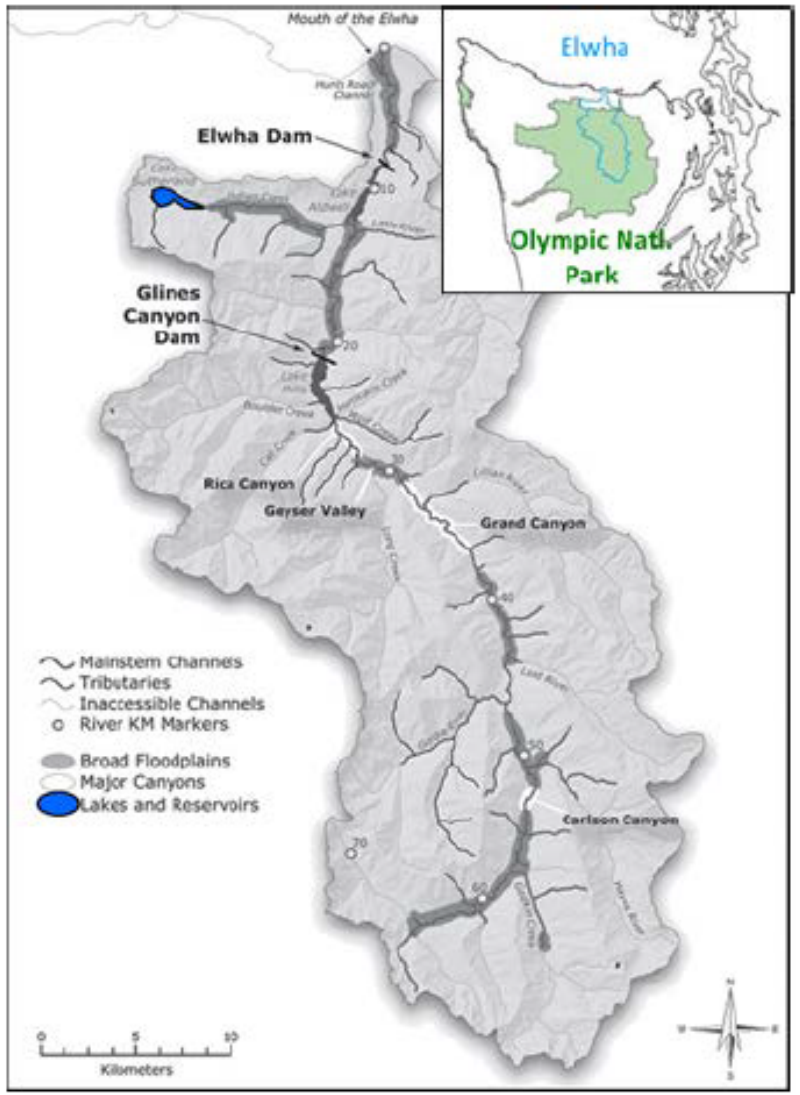
NOAA, Office of Water Prediction

Reach-specific response to flow

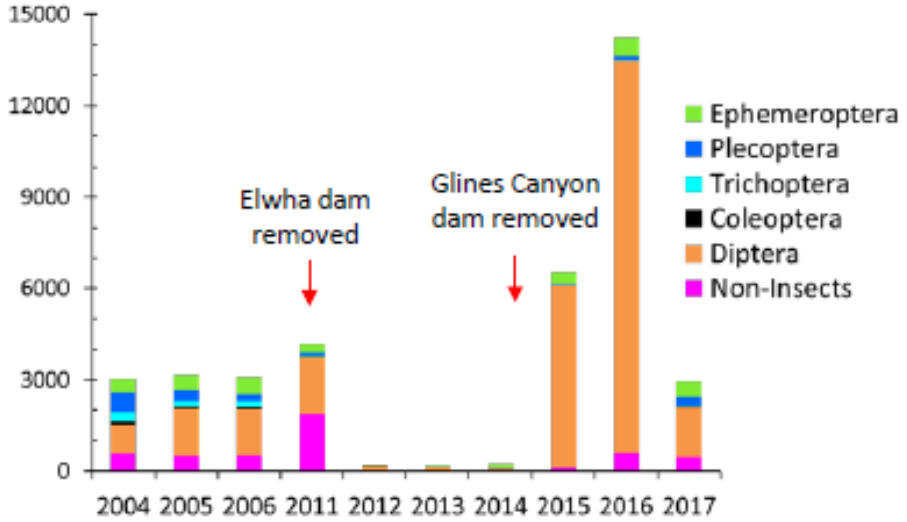


- Constructing flow-habitat curves for all stream reaches.
- Continually updated as new imagery is available.
- Addresses multiple scenarios simultaneously:
  - How much flow is needed to activate floodplain?
  - How much habitat gained from flow addition?
  - How much habitat is available for the population on at any date (flow)?

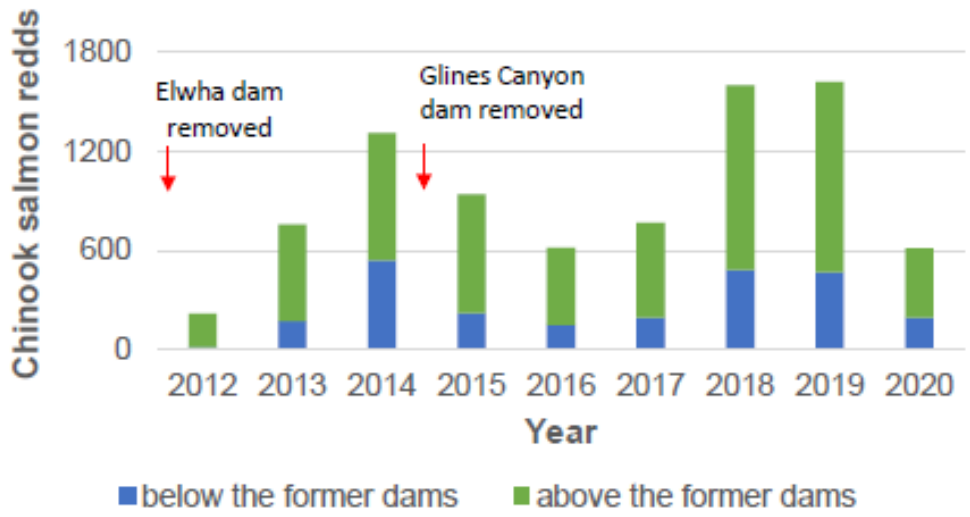
Elwha River dam removal and ecosystem response

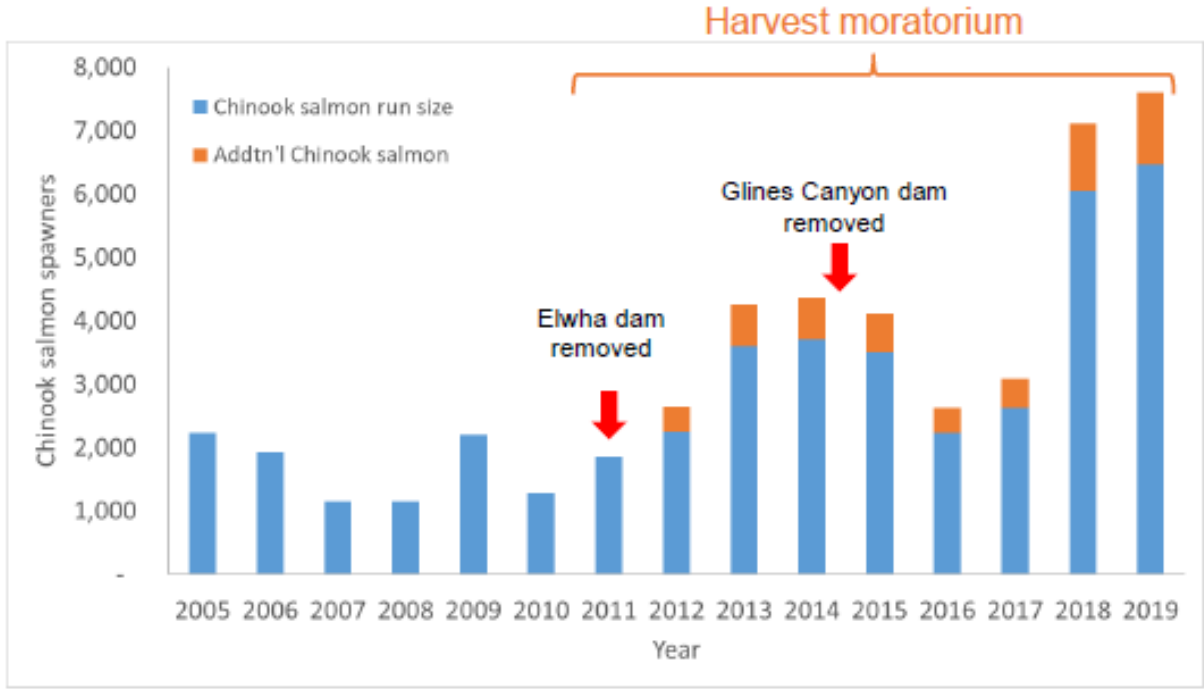


Elwha River dam removal and ecosystem response



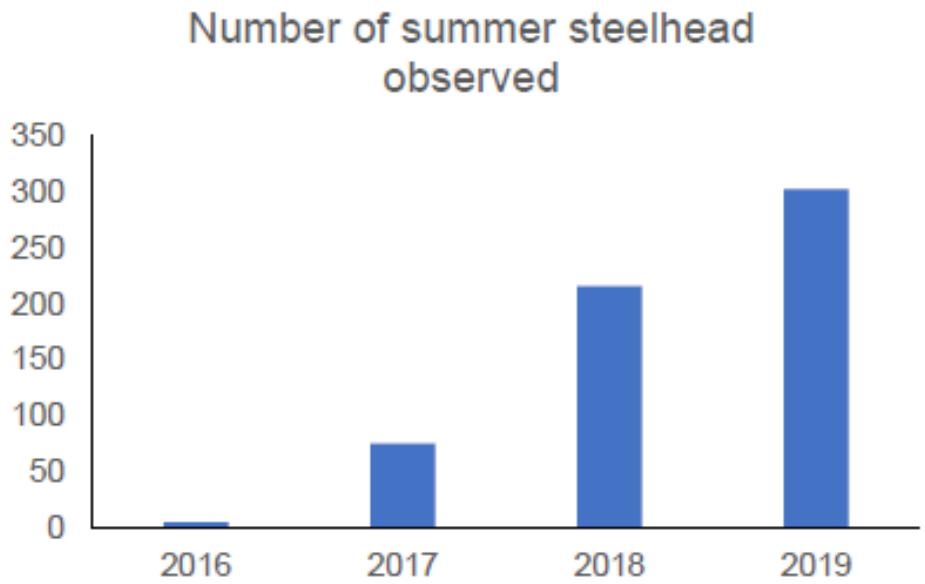
Recolonization and Elwha River harvest moratorium



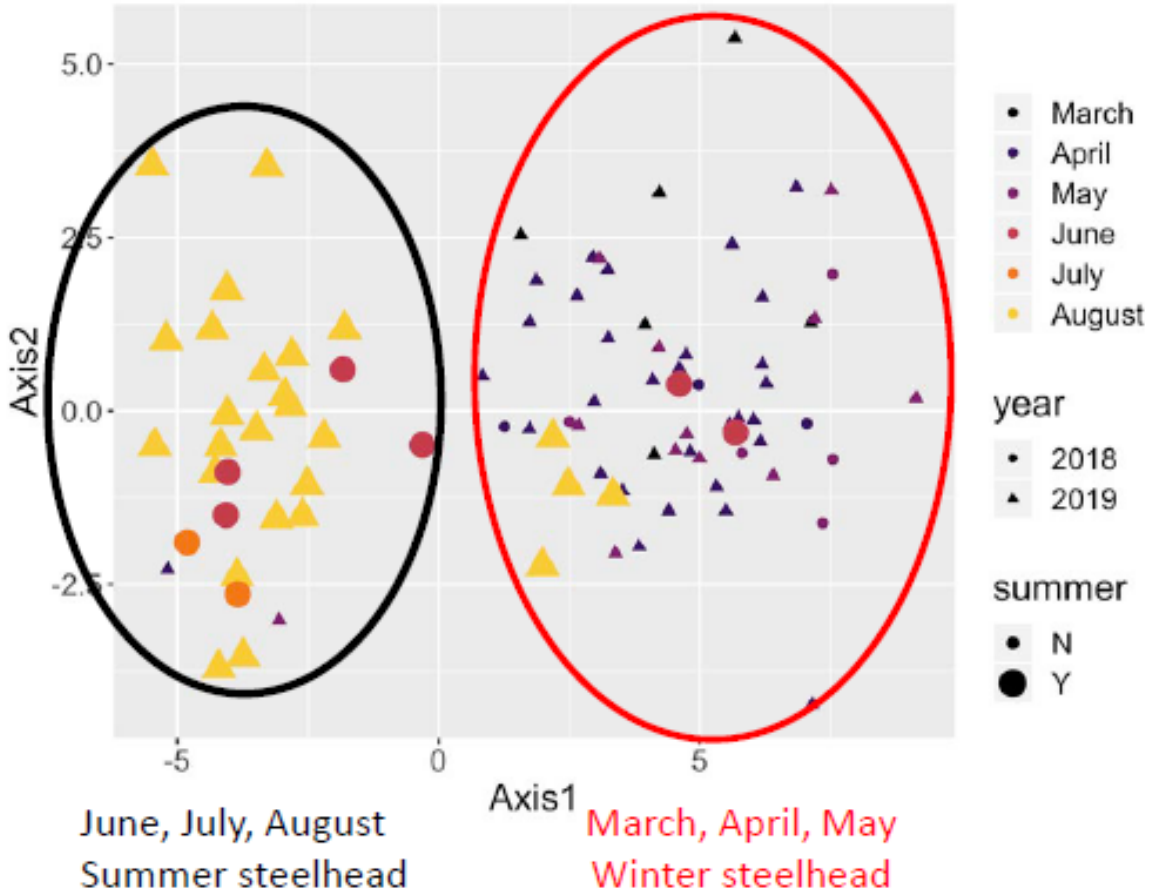


- Recreational and commercial fishing closure since 2011
- Implemented to facilitate recolonization of Elwha
- Reduced exploitation by ~50% compared to other Puget Sound stocks
- Since 2011, moratorium resulted in >3,700 spawners (orange)

The ‘re-awakening’ of summer steelhead (*O. mykiss*)



First documented summer steelhead Oct 2013



June, July, August
Summer steelhead

March, April, May
Winter steelhead

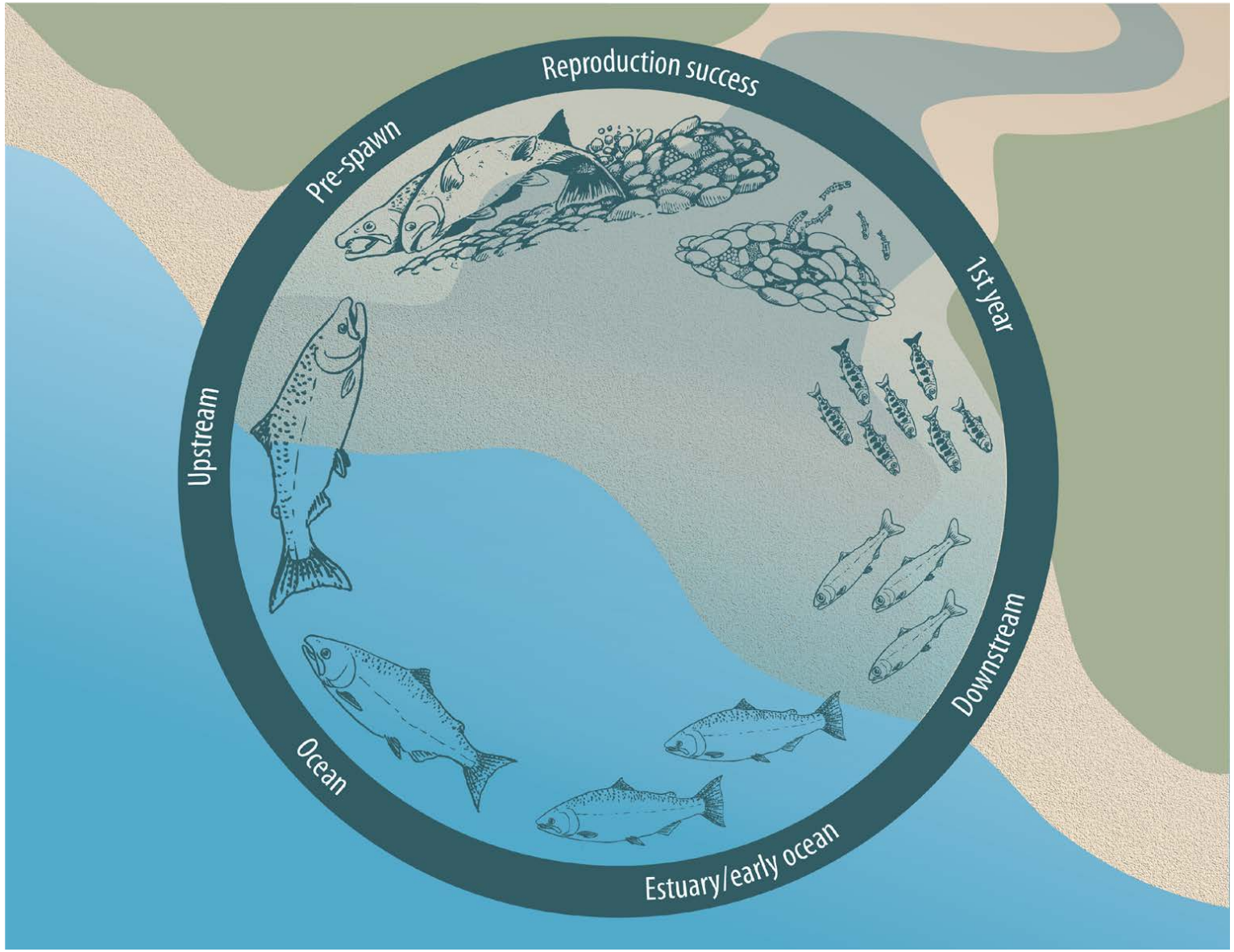
- The *GREB1L* pre-migration marker is evident in Elwha summer steelhead, but not Elwha winter steelhead
- ‘Re-awakening’ of summer steelhead, likely owing to the harboring of alleles for run timing in up-river resident *O. mykiss* populations

Freshwater rearing

Estuary rearing

Early ocean entry

Life cycle integration



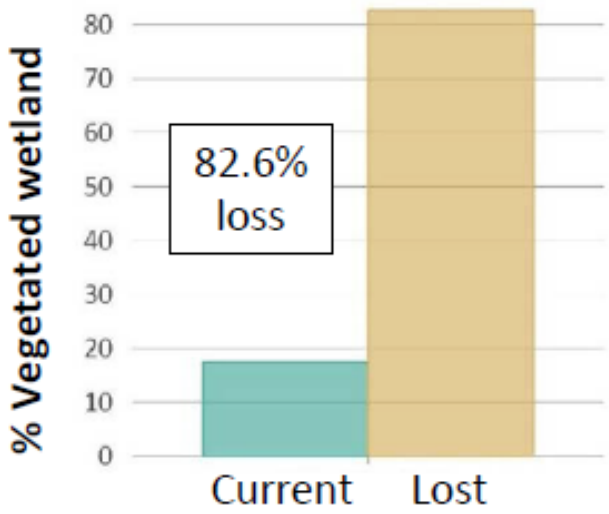
Historical extent and loss of vegetated tidal wetlands

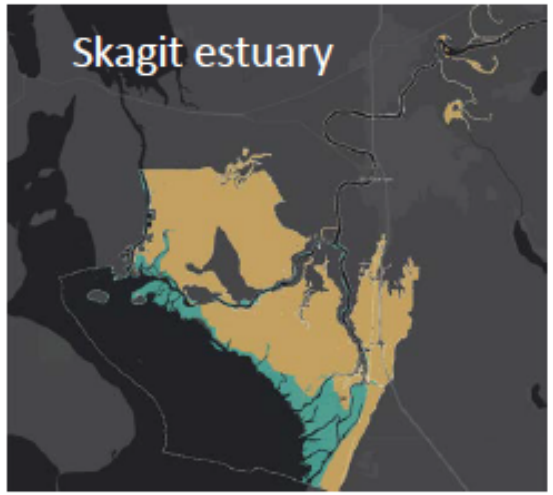
1) Map historical extents of Pacific Coast estuaries using elevation based maps

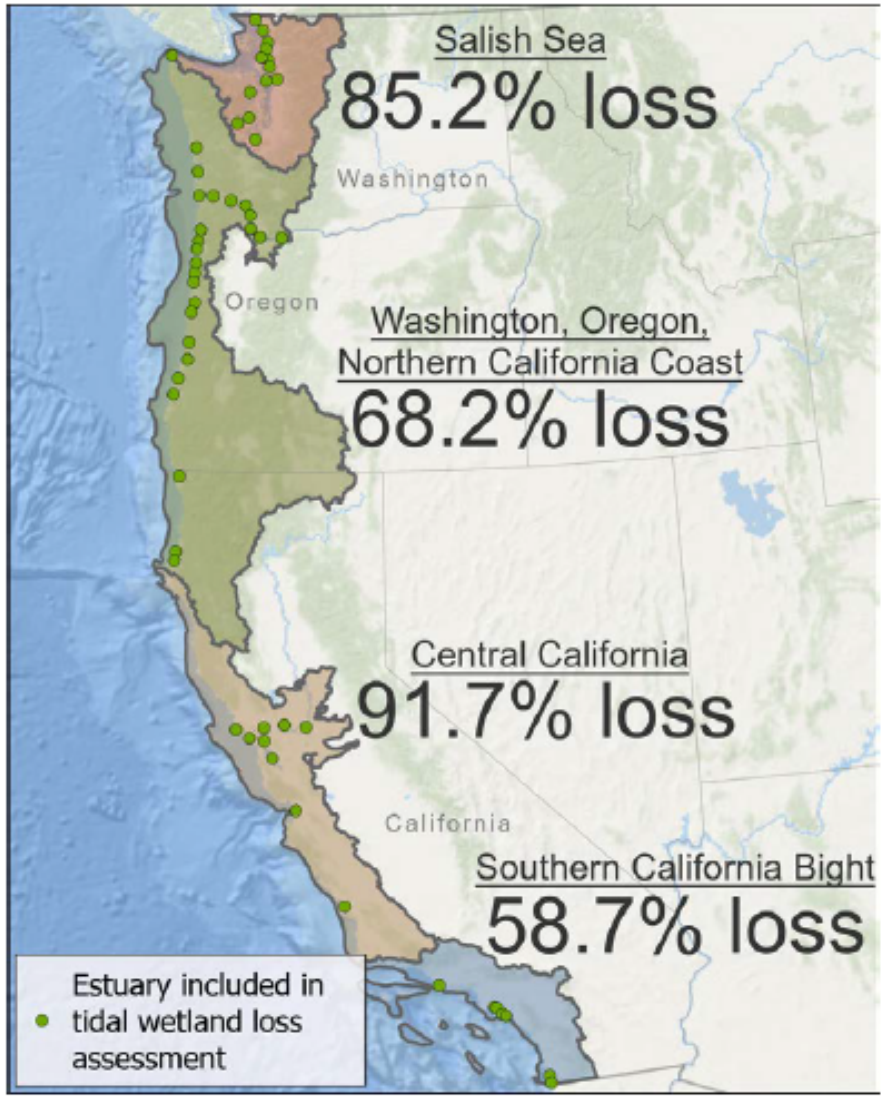
2) Map current vegetated wetlands using National Wetlands Inventory

3) Historical – Current = Lost

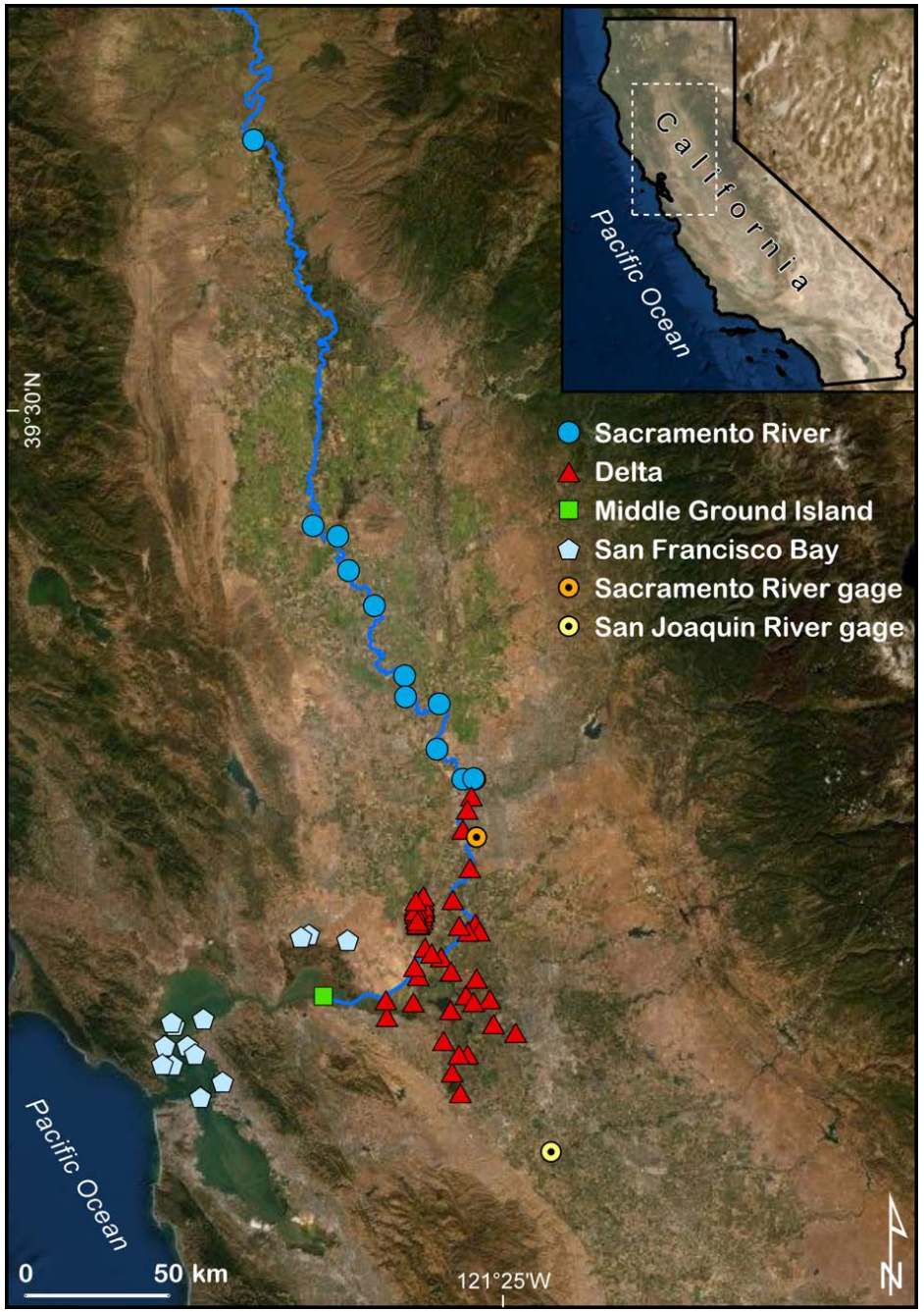
Result:
85% of tidal wetlands have been lost from the U.S. West Coast







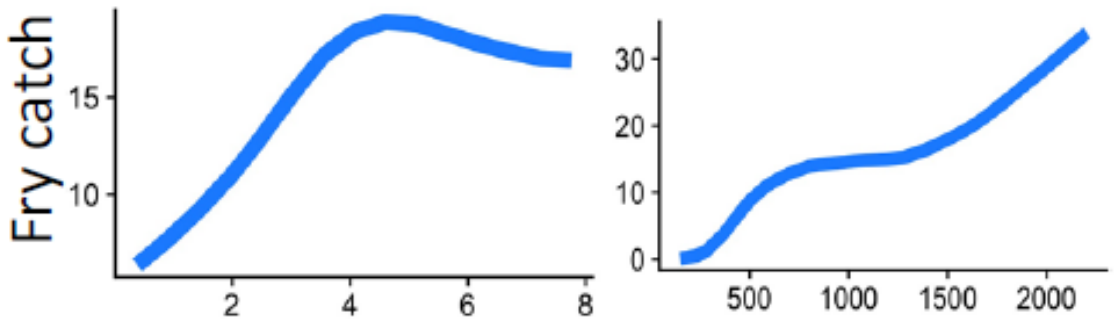
Brophy et al. 2019



Effects of spawners, flow, landscape context, & climate on juvenile Chinook salmon habitat use

1. How does climate constrain annual rearing windows?
2. How are escapement and flow likely to contribute to occupancy of restoration sites?

Effects of spawners, flow, & landscape context on habitat occupancy of naturally spawned Chinook salmon fry in the Central Valley



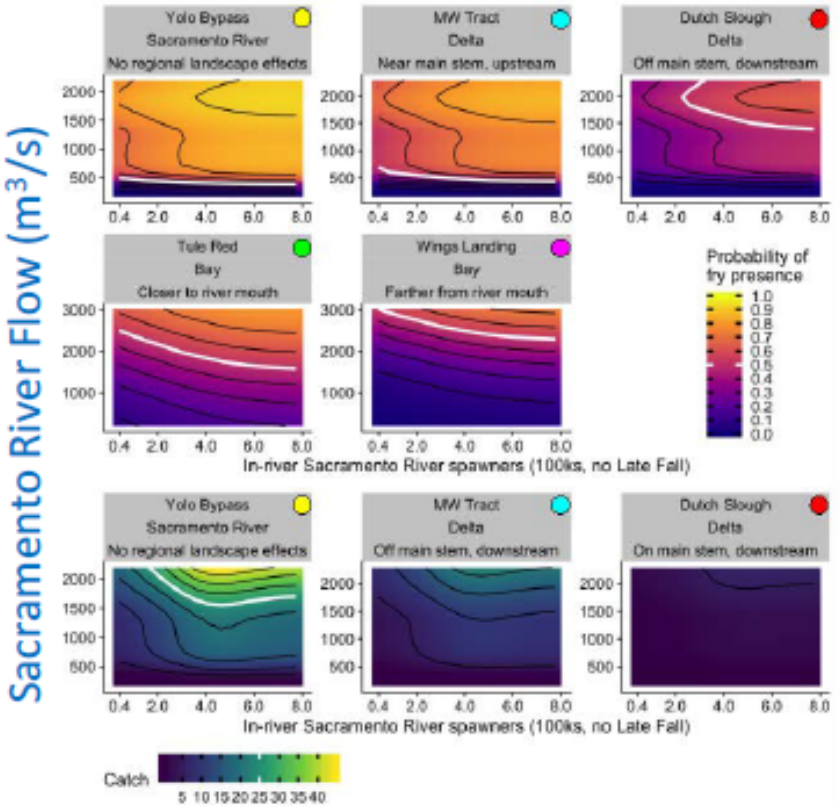
In-River Spawners (100ks, no late fall)

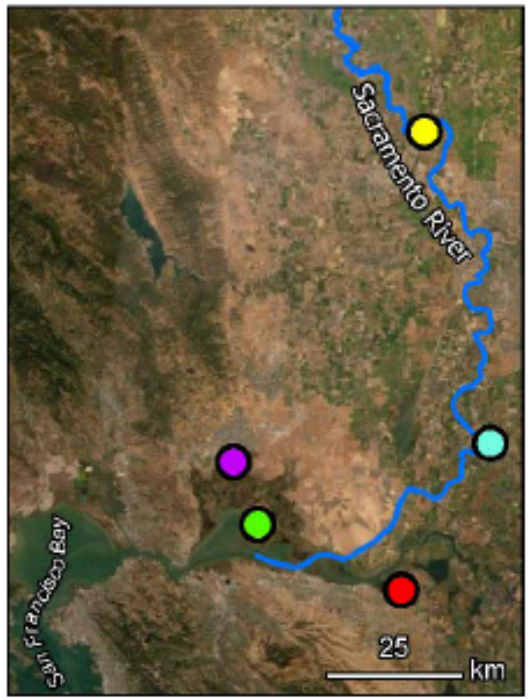
SR Flow (m^3/s)

Dec – May Median flow = 515 (m^3/s)

PFMC Target: 112,000
(hatchery + in-river fall run spawners)

Inferring restoration site occupancy





Munsch et al. 2020

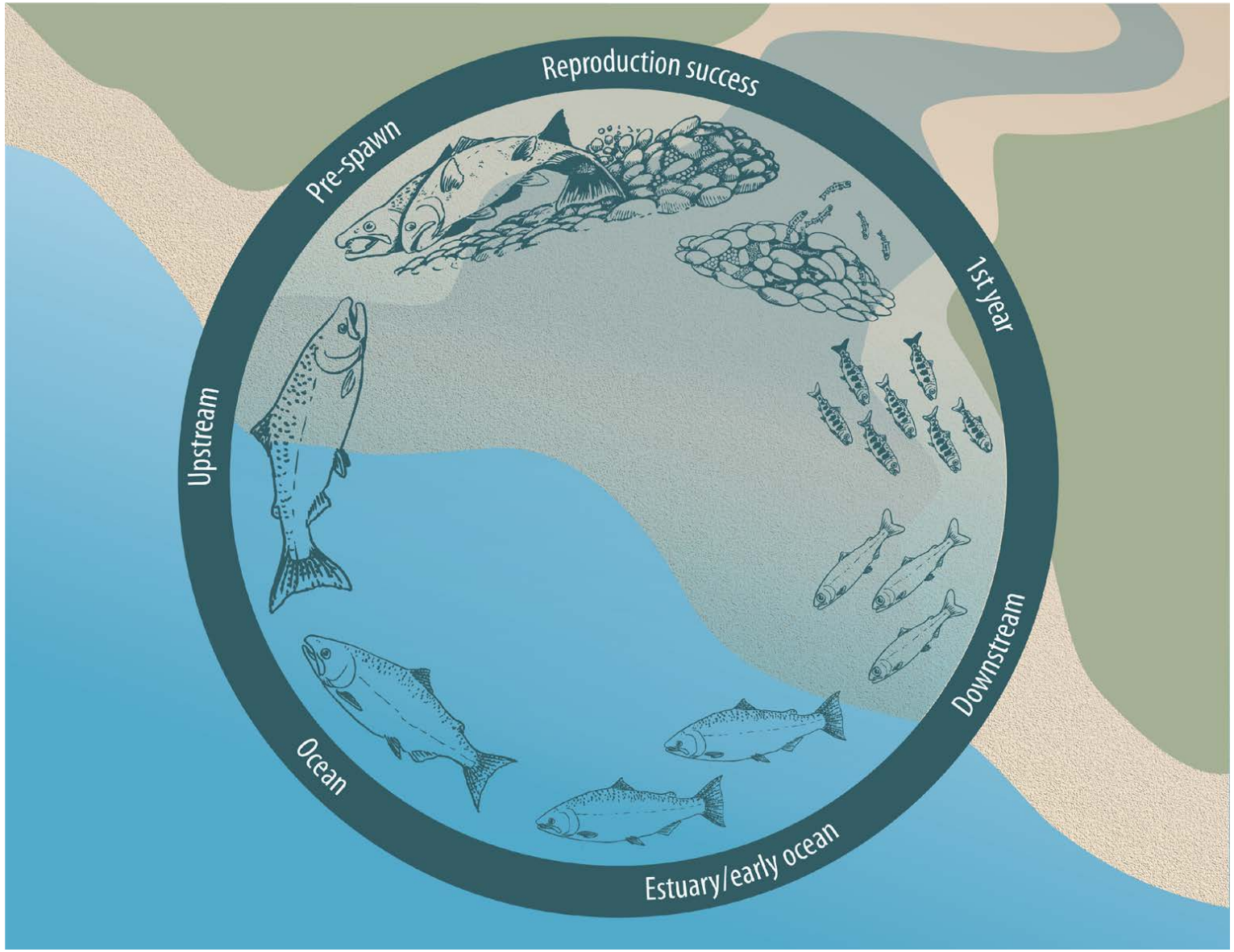
In-river spawners (100ks, no late fall)

Freshwater rearing

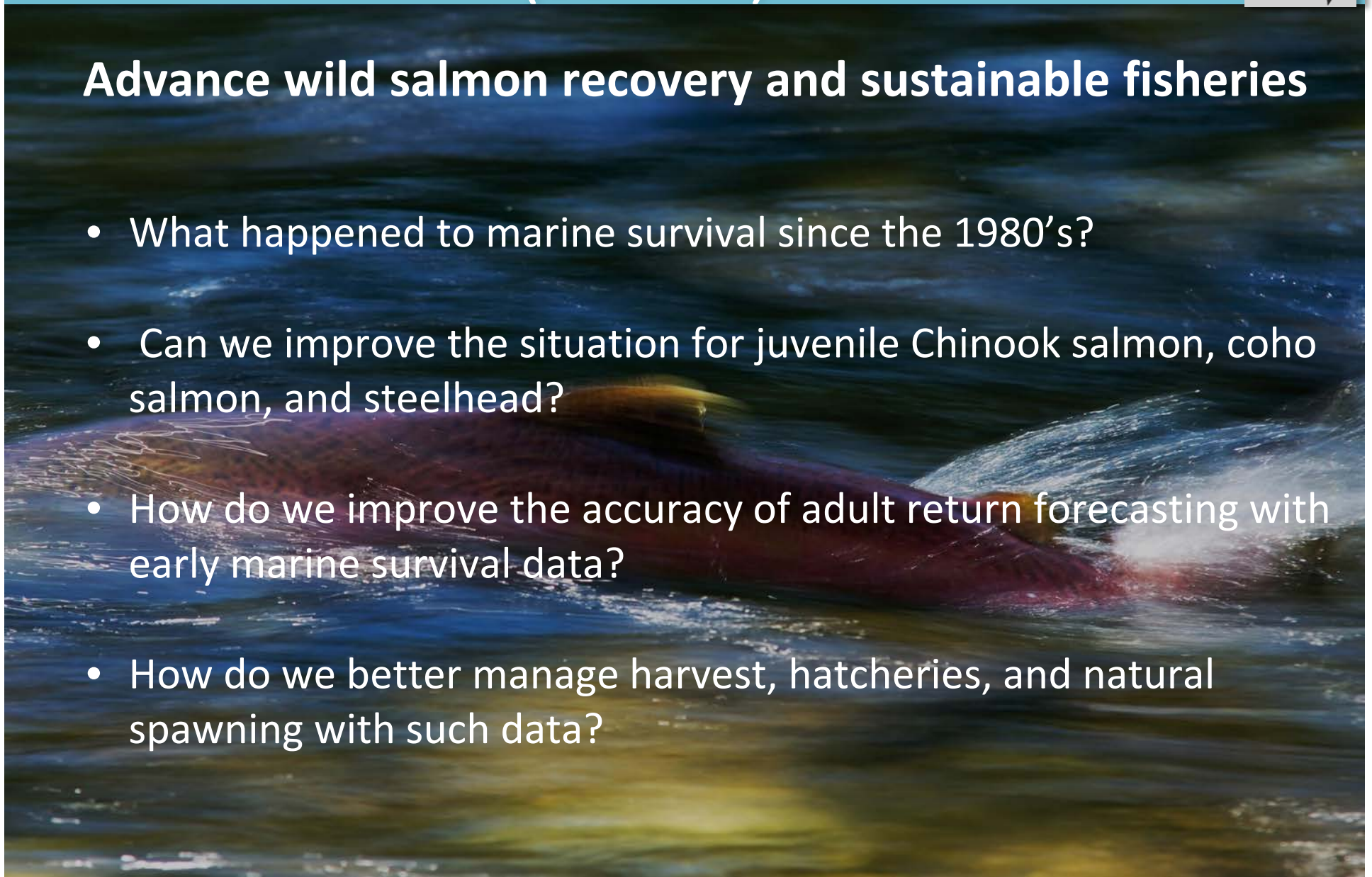
Estuary rearing

Early ocean entry

Life cycle integration



Salish Sea Marine Survival Project (SSMSP)

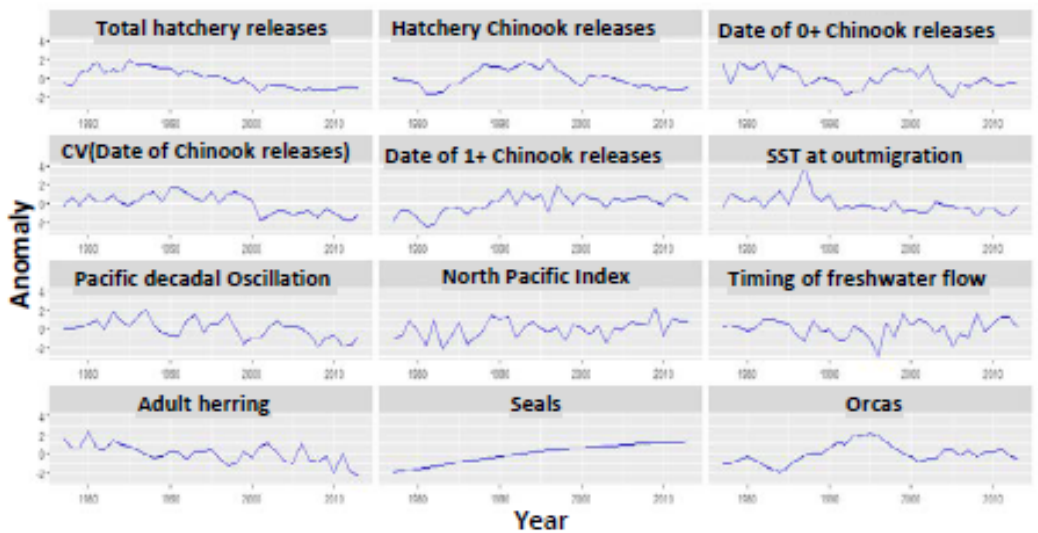


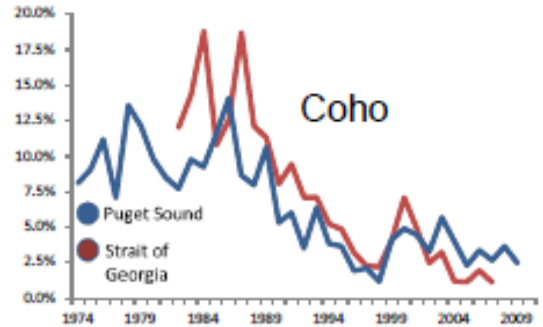
Advance wild salmon recovery and sustainable fisheries

- What happened to marine survival since the 1980's?
- Can we improve the situation for juvenile Chinook salmon, coho salmon, and steelhead?
- How do we improve the accuracy of adult return forecasting with early marine survival data?
- How do we better manage harvest, hatcheries, and natural spawning with such data?

Salish Sea Marine Survival Project

- **Understanding causes of current low survival**
  - Bottom-up hypotheses (e.g., impacts on growth)
  - Top-down hypotheses (e.g., predation)
  - Anthropogenic impacts (e.g., habitat loss)
  - Field studies in Puget Sound
- **Reconstructing historical patterns**
  - Geoduck growth as indicators of primary production
  - Forage fish and jellyfish trends
  - Assessing importance of multiple stressors
- **Ecosystem modeling using Atlantis** (with CB Division)
- **Ecosystem indicators for forecasting returns**



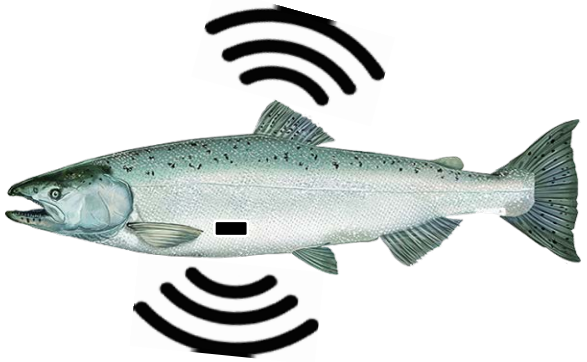


Salmon Ocean Behavior and Distribution (SOBaD)

Northwest Fisheries Science Center
Fish Ecology Division
Estuary and Ocean Ecology Program
David Huff and Joe Smith

Seattle

Implanting salmon with acoustic tags



Tagged in 2019

Chinook

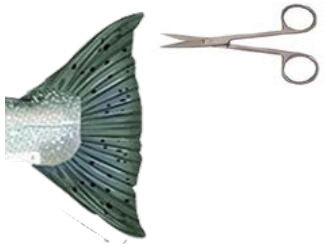
NOAA= 142

DFO = 100

UBC = 100

Coho

NOAA = 35



Fish Ecology (FE)

- Rich Zabel

Estuary and Ocean Ecology

- Joe Smith
- David Huff
- Brian Burke
- Brian Wells

Migrational Behavior

- Steve Corbett

Watershed

- Josh Chamberlin

Conservation Biology (CB)

Ecosystem Science

- Brad Hanson
- Candice Emmons
- Kelly Andrews

Genetics and Evolution

- Krista Nichols
- Don Van Doornik

Environmental and Fisheries Sciences (EFS)

Environmental Physiology

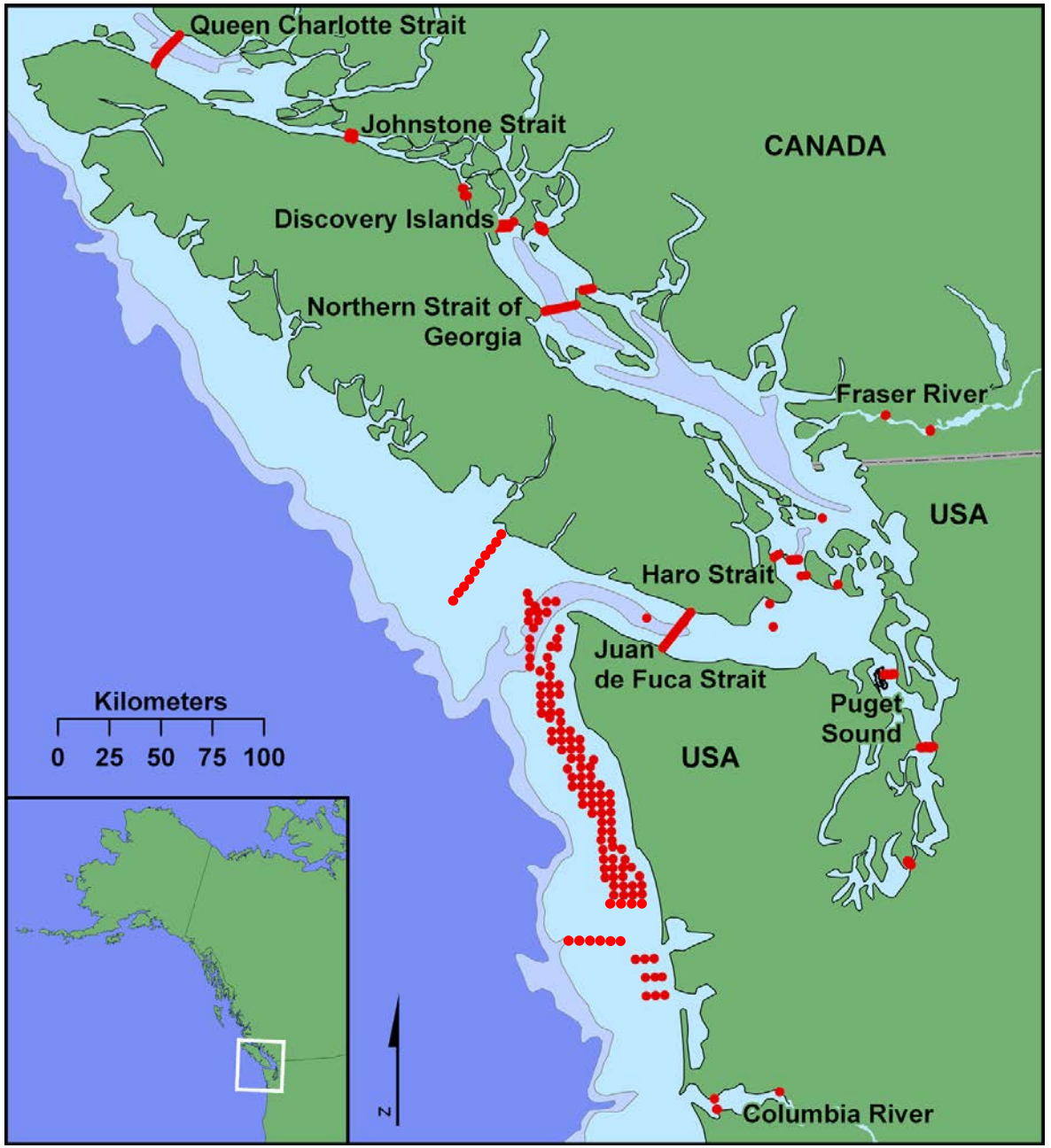
- Brian Beckman

Marine Fish and Shellfish Biology

- Rick Goetz

Hatchery Reform Science

- Barry Berejikian
- Megan Moore



Map created by Kintama

Department of Fisheries and Oceans

- Jackie King
- Cameron Freshwater

University of Victoria

- Will Duguid
- Frances Juanes

University of British Columbia

- Scott Hinch

WDFW

- Sandie O'Neill

University of Washington - SAFS

- Tom Quinn

University of Washington – APL

- Justin Shapiro

University of Alaska – Fairbanks

- Andy Seitz

Oregon State University

- Jack Barth
- Anatoli Erofeev
- Steve Pierce

Makah Tribe

- Jonathan Scordino

NRC Postdoc

- Bill Matsubu

Lynker

- Wayne Haimes

JISAO

- Andy Jasonowicz

Hollings Scholar

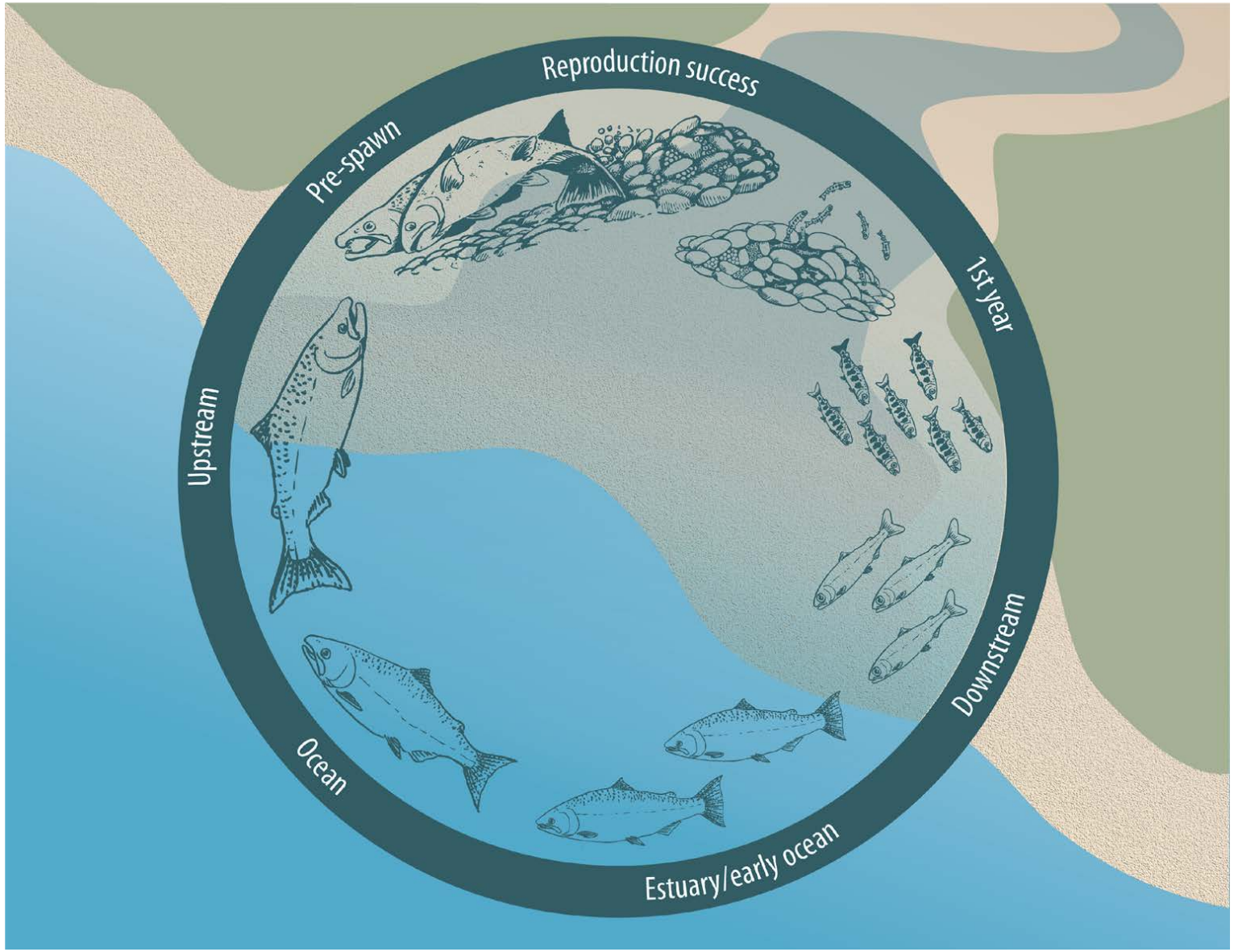
- Raien Emery

Freshwater rearing

Estuary rearing

Early ocean entry

Life cycle integration



ICES Journal of
Marine Science

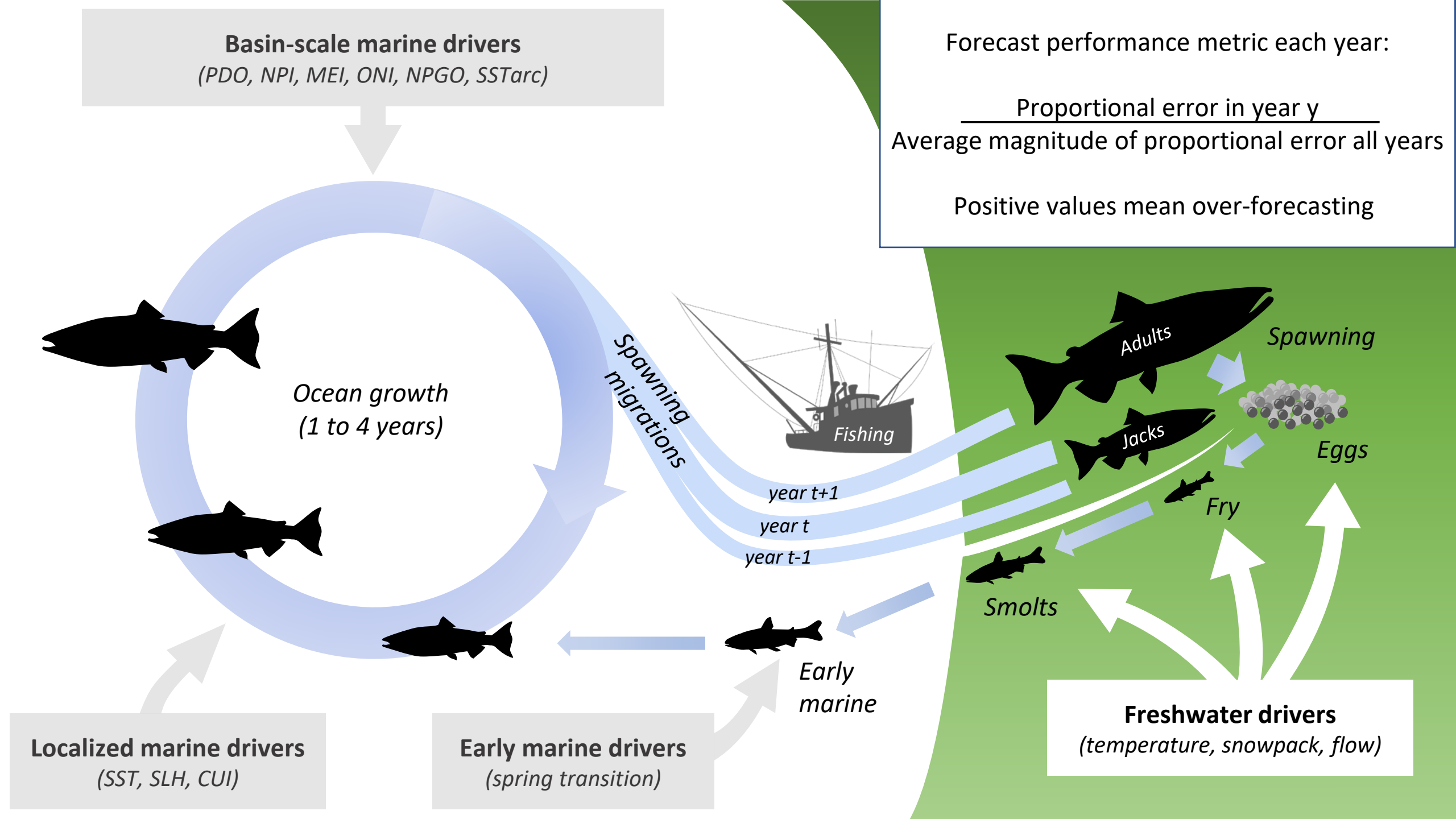
ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2019), doi:10.1093/icesjms/fsz189

Contribution to the Themed Section: *'Science in support of a nonlinear non-equilibrium world'*

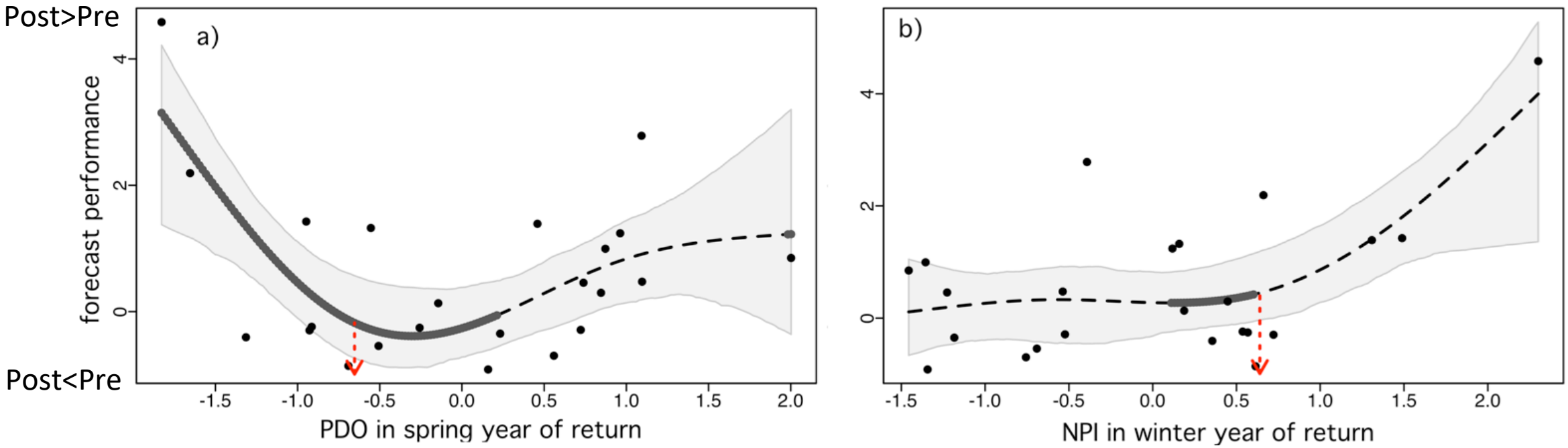
Ecological thresholds in forecast performance for key United States West Coast Chinook salmon stocks

William H. Satterthwaite [1]*, Kelly S. Andrews[2], Brian J. Burke[3], Jennifer L. Gosselin[4], Correigh M. Greene[3], Chris J. Harvey[2], Stuart H. Munsch[5], Michael R. O'Farrell[1], Jameal F. Samhouri[2], and Kathryn L. Sobocinski[3,6]


Basin-scale marine drivers
(PDO, NPI, MEI, ONI, NPGO, SSTarc)
Forecast performance metric each year:
Proportional error in year y
Average magnitude of proportional error all years
Positive values mean over-forecasting
Ocean growth
(1 to 4 years)
Spawning migrations
Fishing
year t+1
year t
year t-1
Adults
Spawning
Jacks
Eggs
Fry
Smolts
Early marine
Localized marine drivers
(SST, SLH, CUI)
Early marine drivers
(spring transition)
Freshwater drivers
(temperature, snowpack, flow)

Ecological thresholds

- Klamath River Fall Chinook: no clear relationships
- Sacramento River Fall Chinook: two well-supported models were nonlinear with thresholds



- Puget Sound Chinook stocks: support for nonlinear models with thresholds for multiple stock-driver-lag combinations

Habitat indicators for stocks in rebuilding plans

- Sacramento and Klamath stocks in rebuilding plans after poor productivity from brood years 2012-2014
- Rebuilding plans suggested multiple possible habitat impacts
- Habitat Committee review: track life-stage specific habitat change using indicators
- Goals:
  1) highlight poor habitat conditions in critical years of rebuilding plan

  2) document how habitat impacts have changed in years after the rebuilding plan

  3) identify cumulative impacts at different life stages

  4) identify habitat actions for potential Council engagement

SACRAMENTO RIVER FALL CHINOOK

(JULY 2019)

**SALMON REBUILDING PLAN,
ENVIRONMENTAL ASSESSMENT*,
MAGNUSON-STEVENS FISHERY CONSERVATION AND
MANAGEMENT ACT ANALYSIS*,
REGULATORY IMPACT REVIEW*, AND
INITIAL REGULATORY FLEXIBILITY ANALYSIS***

KLAMATH RIVER FALL CHINOOK

(JULY, 2019)

**SALMON REBUILDING PLAN,
ENVIRONMENTAL ASSESSMENT*,
MAGNUSON-STEVENS FISHERY CONSERVATION AND
MANAGEMENT ACT ANALYSIS*,
REGULATORY IMPACT REVIEW*, AND
INITIAL REGULATORY FLEXIBILITY ANALYSIS***

Habitat indicators for stocks in rebuilding plans

- Life stages

	Freshwater conditions																Marine conditions				
	Adult spawners				Incubation			Freshwater/delta residence							Hatchery releases			Marine residence				
Brood year	Spawners	CChannel.F	Flows.F	Temp.F	Flows.W	Temp.W	FW.surv	Flows.S	Delta	SDFlow.S	Precip	Temp.S	CChannel.S	Yolo	Releases	Net.pen	FW.timing	Mar.timing	SSTarc	NPH	NPGO	Predation
1983	-0.54	-0.48	2.96	0.82	1.92	2.68	NA	0.56	-0.47	0.91	2.10	0.05	0.06	0.60	-1.30	-0.58	0.61	-0.39	-0.31	0.99	0.95	0.11
1984	-0.20	-0.48	3.44	-0.32	2.31	1.50	NA	-0.60	-0.82	-0.94	0.24	-0.97	-0.82	-0.74	0.49	-0.81	0.58	1.35	0.35	-0.57	0.24	2.91
1985	0.50	-0.09	0.74	NA	0.88	0.89	NA	0.48	1.18	1.54	-0.74	0.33	-0.35	0.58	0.34	-1.16	1.02	1.52	-0.39	-0.13	-0.65	0.42
1986	0.55	1.07	-0.53	0.15	-0.76	-0.28	NA	-0.73	-0.73	-1.09	0.91	-0.57	-1.04	-0.74	-0.05	-1.06	0.53	-0.17	-0.28	0.19	0.34	2.91
1987	0.28	0.23	0.33	0.15	0.49	0.17	NA	-0.65	-0.86	-0.85	-1.33	0.11	-2.46	-0.74	-0.27	-0.98	-0.11	0.17	0.06	0.75	1.44	0.41
1988	0.45	-0.48	-0.86	1.58	-1.40	0.01	NA	-0.68	-0.50	-0.66	-0.83	-0.01	-2.19	-0.55	-1.88	-1.29	1.12	1.72	-0.06	-0.33	0.76	2.91
1989	-0.12	-0.48	-0.64	-1.75	-0.93	0.05	NA	-1.04	-0.89	-1.42	-0.14	0.05	-2.86	-0.74	-0.12	0.18	-1.39	-0.59	-0.04	0.64	0.26	-0.42
1990	-0.66	-0.48	0.79	1.58	-1.03	-0.58	NA	-1.06	-0.75	-1.06	-0.92	1.52	-2.39	-0.74	0.37	-0.14	-0.32	0.79	0.11	0.74	-0.36	-0.23
1991	-0.52	-0.48	-1.07	-0.32	-1.33	-1.76	NA	-0.84	-0.84	-0.40	-0.96	-0.97	-1.05	-0.74	0.82	-1.28	-0.34	-0.64	-0.49	-0.64	-1.35	0.40
1992	-1.07	-0.48	-1.04	-1.27	-0.96	-1.03	NA	0.57	0.23	0.96	-0.88	1.35	0.04	0.38	-1.34	-1.26	0.32	-0.37	-0.45	1.74	-1.20	0.27
1993	-0.28	-0.23	-1.47	-1.75	-1.74	-0.44	NA	-1.00	-0.80	-1.37	0.95	-0.12	-0.17	-0.74	-0.64	-1.06	1.25	-1.77	-0.36	0.96	-1.20	0.16
1994	-0.05	-0.48	0.20	-0.80	0.04	0.36	NA	1.74	2.71	1.43	-1.09	1.86	0.22	2.28	-0.25	-1.07	1.02	0.52	-0.18	0.05	-1.79	-0.40
1995	0.74	-0.20	-0.76	-0.32	-1.11	-1.33	NA	0.58	0.65	0.38	2.03	-0.18	0.53	1.02	0.41	-1.11	-3.52	-2.60	-0.66	1.00	-0.95	-0.68
1996	0.81	-0.48	0.25	0.15	-0.14	-1.19	NA	0.65	-0.48	1.33	0.59	-0.29	0.52	1.12	-1.15	-1.20	1.09	0.07	-0.52	0.94	-0.67	-0.17
1997	0.87	0.36	0.47	2.05	0.32	-0.60	NA	2.04	1.45	1.19	0.60	2.26	0.75	1.70	1.01	-0.58	0.20	0.61	-0.27	0.84	0.56	-0.38
1998	0.28	4.72	0.28	0.15	-0.43	0.09	NA	0.87	0.16	0.45	1.92	1.35	0.68	0.67	-0.84	-1.17	0.07	-0.39	0.90	-0.46	1.74	0.37
1999	1.17	-0.48	1.14	1.10	1.33	0.36	NA	0.53	0.27	0.88	-0.15	-0.12	-0.05	0.31	-1.07	-1.19	-0.01	-1.25	0.23	-1.04	2.25	-0.11
2000	1.21	1.60	0.57	0.15	0.73	-0.09	NA	-0.74	-0.62	-0.67	0.05	-0.40	-0.25	-0.74	-0.06	0.00	-0.19	-0.71	0.33	0.09	2.18	0.08
2001	1.69	-0.10	0.09	0.63	0.53	-0.30	NA	-0.26	-0.65	-0.09	-1.03	-0.46	0.58	-0.58	-0.90	-0.71	-0.24	-0.76	0.34	-0.37	1.30	-0.10
2002	1.99	-0.19	-0.60	-0.80	0.26	-0.07	NA	0.92	-0.29	0.74	-0.42	0.28	0.55	-0.29	1.12	0.57	-1.06	1.20	-0.34	0.00	1.17	-0.29
2003	1.36	-0.48	-0.34	0.63	0.22	0.17	-0.83	0.63	-0.18	0.95	0.30	-0.52	0.68	0.09	0.29	0.21	-0.11	-1.15	-0.40	0.13	0.24	-0.61
2004	0.48	-0.48	0.04	2.29	0.42	-0.49	-0.40	0.09	0.09	0.14	-0.28	0.90	0.63	-0.61	0.92	0.89	-1.44	-0.02	-0.64	0.12	-1.32	-1.31
2005	0.53	-0.48	0.17	0.63	-0.49	-0.39	-0.38	2.21	2.55	1.10	0.37	-0.86	0.70	2.44	1.32	0.75	-0.73	-0.56	0.17	0.49	-0.47	-1.26
2006	0.42	-0.48	0.39	0.15	0.78	0.62	-0.68	-0.82	-0.73	-1.14	1.32	-0.46	0.34	-0.74	1.23	0.99	0.02	-1.72	0.49	0.27	0.13	-0.95
2007	-0.88	-0.48	0.17	-0.04	0.54	-0.41	-0.06	-0.71	-0.77	-0.64	-1.07	-0.01	0.35	-0.74	1.32	1.20	0.30	1.01	0.78	-0.41	1.50	-0.81
2008	-1.37	-0.48	-0.34	-0.51	0.44	-1.01	-0.45	-0.83	-0.60	-0.49	-0.92	-0.35	0.28	-0.74	0.80	0.98	0.53	1.08	0.67	-0.98	0.43	-0.59
2009	-2.17	-0.10	-0.93	-0.51	-1.27	-0.23	1.13	-0.32	-0.46	-0.10	-0.61	1.75	0.39	-0.61	0.87	0.84	0.73	-0.10	0.18	-0.09	1.57	-0.51
2010	-0.55	-0.29	-0.64	-0.42	-1.00	0.44	1.21	0.57	1.22	0.72	-0.01	2.14	0.75	0.48	1.17	0.90	0.22	0.07	0.25	-0.45	1.06	-0.65
2011	-0.74	0.49	0.09	-0.04	0.27	1.14	-0.31	-0.87	-0.48	-1.13	0.76	0.33	0.67	-0.74	1.18	0.53	0.30	1.45	0.58	-0.88	1.56	-0.39
2012	0.21	-0.48	0.57	NA	2.11	0.49	-0.01	-0.54	-0.75	-0.27	-0.79	-1.20	0.66	-0.39	0.32	0.13	-2.83	-0.02	0.21	-0.33	0.66	0.02
2013	0.97	0.80	-0.20	-0.42	0.69	0.38	0.13	-1.22	-0.82	-1.26	-0.51	-1.48	0.48	-0.74	0.31	1.51	0.53	1.30	-0.81	-0.23	-0.28	0.49
2014	0.23	-0.29	-0.85	-1.37	-1.25	-2.82	-1.38	-0.78	-0.88	-0.03	-1.26	-1.14	0.52	-0.71	-0.21	0.68	0.48	-0.44	-1.32	0.32	-1.16	0.87
2015	-0.80	-0.39	-1.18	-0.61	-0.34	-0.58	0.26	-0.16	-0.12	0.58	-0.72	-0.97	0.44	-0.32	0.69	0.40	0.20	0.34	-1.12	0.09	-0.20	-0.51
2016	-1.15	-0.48	-1.37	-1.56	-0.84	0.86	2.82	2.21	1.80	1.47	0.14	-0.91	0.75	2.70	-0.92	-0.01	0.58	-0.47	-0.50	0.23	-0.49	NA
2017	-2.59	2.00	0.21	-0.51	0.25	0.86	-0.65	-1.01	-0.27	-1.10	1.92	-1.03	0.67	-0.61	-0.26	1.10	-0.14	-0.49	-0.62	-0.10	-2.01	NA
2018	-0.85	-0.48	0.23	0.25	0.61	0.98	-0.41	1.17	1.41	1.54	-0.66	-0.35	0.75	0.64	-0.78	0.90	0.68	0.79	-0.84	0.29	-2.09	NA
2019	-0.20	-0.19	-0.36	-0.51	-0.62	1.55	NA	-0.97	1.05	-1.59	1.08	-0.91	0.64	-0.74	-2.92	2.62	0.04	0.61	-0.39	0.33	-1.57	NA

Habitat indicators for stocks in rebuilding plans

- Life stages
- Multiple indicators

	Freshwater conditions																Marine conditions				
	Adult spawners				Incubation			Freshwater/delta residence							Hatchery releases			Marine residence				
Brood year	Spawners	CChannel.F	Flows.F	Temp.F	Flows.W	Temp.W	FW.surv	Flows.S	Delta	SDFlow.S	Precip	Temp.S	CChannel.S	Yolo	Releases	Net.pen	FW.timing	Mar.timing	SSTarc	NPH	NPGO	Predation
1983	-0.54	-0.48	2.96	0.82	1.92	2.68	NA	0.56	-0.47	0.91	2.10	0.05	0.06	0.60	-1.30	-0.58	0.61	-0.39	-0.31	0.99	0.95	0.11
1984	-0.20	-0.48	3.44	-0.32	2.31	1.50	NA	-0.60	-0.82	-0.94	0.24	-0.97	-0.82	-0.74	0.49	-0.81	0.58	1.35	0.35	-0.57	0.24	2.91
1985	0.50	-0.09	0.74	NA	0.88	0.89	NA	0.48	1.18	1.54	-0.74	0.33	-0.35	0.58	0.34	-1.16	1.02	1.52	-0.39	-0.13	-0.65	0.42
1986	0.55	1.07	-0.53	0.15	-0.76	-0.28	NA	-0.73	-0.73	-1.09	0.91	-0.57	-1.04	-0.74	-0.05	-1.06	0.53	-0.17	-0.28	0.19	0.34	2.91
1987	0.28	0.23	0.33	0.15	0.49	0.17	NA	-0.65	-0.86	-0.85	-1.33	0.11	-2.46	-0.74	-0.27	-0.98	-0.11	0.17	0.06	0.75	1.44	0.41
1988	0.45	-0.48	-0.86	1.58	-1.40	0.01	NA	-0.68	-0.50	-0.66	-0.83	-0.01	-2.19	-0.55	-1.88	-1.29	1.12	1.72	-0.06	-0.33	0.76	2.91
1989	-0.12	-0.48	-0.64	-1.75	-0.93	0.05	NA	-1.04	-0.89	-1.42	-0.14	0.05	-2.86	-0.74	-0.12	0.18	-1.39	-0.59	-0.04	0.64	0.26	-0.42
1990	-0.66	-0.48	0.79	1.58	-1.03	-0.58	NA	-1.06	-0.75	-1.06	-0.92	1.52	-2.39	-0.74	0.37	-0.14	-0.32	0.79	0.11	0.74	-0.36	-0.23
1991	-0.52	-0.48	-1.07	-0.32	-1.33	-1.76	NA	-0.84	-0.84	-0.40	-0.96	-0.97	-1.05	-0.74	0.82	-1.28	-0.34	-0.64	-0.49	-0.64	-1.35	0.40
1992	-1.07	-0.48	-1.04	-1.27	-0.96	-1.03	NA	0.57	0.23	0.96	-0.88	1.35	0.04	0.38	-1.34	-1.26	0.32	-0.37	-0.45	1.74	-1.20	0.27
1993	-0.28	-0.23	-1.47	-1.75	-1.74	-0.44	NA	-1.00	-0.80	-1.37	0.95	-0.12	-0.17	-0.74	-0.64	-1.06	1.25	-1.77	-0.36	0.96	-1.20	0.16
1994	-0.05	-0.48	0.20	-0.80	0.04	0.36	NA	1.74	2.71	1.43	-1.09	1.86	0.22	2.28	-0.25	-1.07	1.02	0.52	-0.18	0.05	-1.79	-0.40
1995	0.74	-0.20	-0.76	-0.32	-1.11	-1.33	NA	0.58	0.65	0.38	2.03	-0.18	0.53	1.02	0.41	-1.11	-3.52	-2.60	-0.66	1.00	-0.95	-0.68
1996	0.81	-0.48	0.25	0.15	-0.14	-1.19	NA	0.65	-0.48	1.33	0.59	-0.29	0.52	1.12	-1.15	-1.20	1.09	0.07	-0.52	0.94	-0.67	-0.17
1997	0.87	0.36	0.47	2.05	0.32	-0.60	NA	2.04	1.45	1.19	0.60	2.26	0.75	1.70	1.01	-0.58	0.20	0.61	-0.27	0.84	0.56	-0.38
1998	0.28	4.72	0.28	0.15	-0.43	0.09	NA	0.87	0.16	0.45	1.92	1.35	0.68	0.67	-0.84	-1.17	0.07	-0.39	0.90	-0.46	1.74	0.37
1999	1.17	-0.48	1.14	1.10	1.33	0.36	NA	0.53	0.27	0.88	-0.15	-0.12	-0.05	0.31	-1.07	-1.19	-0.01	-1.25	0.23	-1.04	2.25	-0.11
2000	1.21	1.60	0.57	0.15	0.73	-0.09	NA	-0.74	-0.62	-0.67	0.05	-0.40	-0.25	-0.74	-0.06	0.00	-0.19	-0.71	0.33	0.09	2.18	0.08
2001	1.69	-0.10	0.09	0.63	0.53	-0.30	NA	-0.26	-0.65	-0.09	-1.03	-0.46	0.58	-0.58	-0.90	-0.71	-0.24	-0.76	0.34	-0.37	1.30	-0.10
2002	1.99	-0.19	-0.60	-0.80	0.26	-0.07	NA	0.92	-0.29	0.74	-0.42	0.28	0.55	-0.29	1.12	0.57	-1.06	1.20	-0.34	0.00	1.17	-0.29
2003	1.36	-0.48	-0.34	0.63	0.22	0.17	-0.83	0.63	-0.18	0.95	0.30	-0.52	0.68	0.09	0.29	0.21	-0.11	-1.15	-0.40	0.13	0.24	-0.61
2004	0.48	-0.48	0.04	2.29	0.42	-0.49	-0.40	0.09	0.09	0.14	-0.28	0.90	0.63	-0.61	0.92	0.89	-1.44	-0.02	-0.64	0.12	-1.32	-1.31
2005	0.53	-0.48	0.17	0.63	-0.49	-0.39	-0.38	2.21	2.55	1.10	0.37	-0.86	0.70	2.44	1.32	0.75	-0.73	-0.56	0.17	0.49	-0.47	-1.26
2006	0.42	-0.48	0.39	0.15	0.78	0.62	-0.68	-0.82	-0.73	-1.14	1.32	-0.46	0.34	-0.74	1.23	0.99	0.02	-1.72	0.49	0.27	0.13	-0.95
2007	-0.88	-0.48	0.17	-0.04	0.54	-0.41	-0.06	-0.71	-0.77	-0.64	-1.07	-0.01	0.35	-0.74	1.32	1.20	0.30	1.01	0.78	-0.41	1.50	-0.81
2008	-1.37	-0.48	-0.34	-0.51	0.44	-1.01	-0.45	-0.83	-0.60	-0.49	-0.92	-0.35	0.28	-0.74	0.80	0.98	0.53	1.08	0.67	-0.98	0.43	-0.59
2009	-2.17	-0.10	-0.93	-0.51	-1.27	-0.23	1.13	-0.32	-0.46	-0.10	-0.61	1.75	0.39	-0.61	0.87	0.84	0.73	-0.10	0.18	-0.09	1.57	-0.51
2010	-0.55	-0.29	-0.64	-0.42	-1.00	0.44	1.21	0.57	1.22	0.72	-0.01	2.14	0.75	0.48	1.17	0.90	0.22	0.07	0.25	-0.45	1.06	-0.65
2011	-0.74	0.49	0.09	-0.04	0.27	1.14	-0.31	-0.87	-0.48	-1.13	0.76	0.33	0.67	-0.74	1.18	0.53	0.30	1.45	0.58	-0.88	1.56	-0.39
2012	0.21	-0.48	0.57	NA	2.11	0.49	-0.01	-0.54	-0.75	-0.27	-0.79	-1.20	0.66	-0.39	0.32	0.13	-2.83	-0.02	0.21	-0.33	0.66	0.02
2013	0.97	0.80	-0.20	-0.42	0.69	0.38	0.13	-1.22	-0.82	-1.26	-0.51	-1.48	0.48	-0.74	0.31	1.51	0.53	1.30	-0.81	-0.23	-0.28	0.49
2014	0.23	-0.29	-0.85	-1.37	-1.25	-2.82	-1.38	-0.78	-0.88	-0.03	-1.26	-1.14	0.52	-0.71	-0.21	0.68	0.48	-0.44	-1.32	0.32	-1.16	0.87
2015	-0.80	-0.39	-1.18	-0.61	-0.34	-0.58	0.26	-0.16	-0.12	0.58	-0.72	-0.97	0.44	-0.32	0.69	0.40	0.20	0.34	-1.12	0.09	-0.20	-0.51
2016	-1.15	-0.48	-1.37	-1.56	-0.84	0.86	2.82	2.21	1.80	1.47	0.14	-0.91	0.75	2.70	-0.92	-0.01	0.58	-0.47	-0.50	0.23	-0.49	NA
2017	-2.59	2.00	0.21	-0.51	0.25	0.86	-0.65	-1.01	-0.27	-1.10	1.92	-1.03	0.67	-0.61	-0.26	1.10	-0.14	-0.49	-0.62	-0.10	-2.01	NA
2018	-0.85	-0.48	0.23	0.25	0.61	0.98	-0.41	1.17	1.41	1.54	-0.66	-0.35	0.75	0.64	-0.78	0.90	0.68	0.79	-0.84	0.29	-2.09	NA
2019	-0.20	-0.19	-0.36	-0.51	-0.62	1.55	NA	-0.97	1.05	-1.59	1.08	-0.91	0.64	-0.74	-2.92	2.62	0.04	0.61	-0.39	0.33	-1.57	NA

Habitat indicators for stocks in rebuilding plans

- Life stages
- Multiple indicators
- Indicators by brood year
- Each indicator is reported as anomaly in direction of positive effect on productivity
- Green = Top 33%
- Red = Bottom 33%
- Critical brood years

	Freshwater conditions																		Marine conditions				
	Adult spawners				Incubation			Freshwater/delta residence							Hatchery releases			Marine residence				
Brood year	Spawners	CChannel.F	Flows.F	Temp.F	Flows.W	Temp.W	FW.surv	Flows.S	Delta	SDFlow.S	Precip	Temp.S	CChannel.S	Yolo	Releases	Net.pen	FW.timing	Mar.timing	SSTarc	NPH	NPGO	Predation
1983	-0.54	-0.48	2.96	0.82	1.92	2.68	NA	0.56	-0.47	0.91	2.10	0.05	0.06	0.60	-1.30	-0.58	0.61	-0.39	-0.31	0.99	0.95	0.11
1984	-0.20	-0.48	3.44	-0.32	2.31	1.50	NA	-0.60	-0.82	-0.94	0.24	-0.97	-0.82	-0.74	0.49	-0.81	0.58	1.35	0.35	-0.57	0.24	2.91
1985	0.50	-0.09	0.74	NA	0.88	0.89	NA	0.48	1.18	1.54	-0.74	0.33	-0.35	0.58	0.34	-1.16	1.02	1.52	-0.39	-0.13	-0.65	0.42
1986	0.55	1.07	-0.53	0.15	-0.76	-0.28	NA	-0.73	-0.73	-1.09	0.91	-0.57	-1.04	-0.74	-0.05	-1.06	0.53	-0.17	-0.28	0.19	0.34	2.91
1987	0.28	0.23	0.33	0.15	0.49	0.17	NA	-0.65	-0.86	-0.85	-1.33	0.11	-2.46	-0.74	-0.27	-0.98	-0.11	0.17	0.06	0.75	1.44	0.41
1988	0.45	-0.48	-0.86	1.58	-1.40	0.01	NA	-0.68	-0.50	-0.66	-0.83	-0.01	-2.19	-0.55	-1.88	-1.29	1.12	1.72	-0.06	-0.33	0.76	2.91
1989	-0.12	-0.48	-0.64	-1.75	-0.93	0.05	NA	-1.04	-0.89	-1.42	-0.14	0.05	-2.86	-0.74	-0.12	0.18	-1.39	-0.59	-0.04	0.64	0.26	-0.42
1990	-0.66	-0.48	0.79	1.58	-1.03	-0.58	NA	-1.06	-0.75	-1.06	-0.92	1.52	-2.39	-0.74	0.37	-0.14	-0.32	0.79	0.11	0.74	-0.36	-0.23
1991	-0.52	-0.48	-1.07	-0.32	-1.33	-1.76	NA	-0.84	-0.84	-0.40	-0.96	-0.97	-1.05	-0.74	0.82	-1.28	-0.34	-0.64	-0.49	-0.64	-1.35	0.40
1992	-1.07	-0.48	-1.04	-1.27	-0.96	-1.03	NA	0.57	0.23	0.96	-0.88	1.35	0.04	0.38	-1.34	-1.26	0.32	-0.37	-0.45	1.74	-1.20	0.27
1993	-0.28	-0.23	-1.47	-1.75	-1.74	-0.44	NA	-1.00	-0.80	-1.37	0.95	-0.12	-0.17	-0.74	-0.64	-1.06	1.25	-1.77	-0.36	0.96	-1.20	0.16
1994	-0.05	-0.48	0.20	-0.80	0.04	0.36	NA	1.74	2.71	1.43	-1.09	1.86	0.22	2.28	-0.25	-1.07	1.02	0.52	-0.18	0.05	-1.79	-0.40
1995	0.74	-0.20	-0.76	-0.32	-1.11	-1.33	NA	0.58	0.65	0.38	2.03	-0.18	0.53	1.02	0.41	-1.11	-3.52	-2.60	-0.66	1.00	-0.95	-0.68
1996	0.81	-0.48	0.25	0.15	-0.14	-1.19	NA	0.65	-0.48	1.33	0.59	-0.29	0.52	1.12	-1.15	-1.20	1.09	0.07	-0.52	0.94	-0.67	-0.17
1997	0.87	0.36	0.47	2.05	0.32	-0.60	NA	2.04	1.45	1.19	0.60	2.26	0.75	1.70	1.01	-0.58	0.20	0.61	-0.27	0.84	0.56	-0.38
1998	0.28	4.72	0.28	0.15	-0.43	0.09	NA	0.87	0.16	0.45	1.92	1.35	0.68	0.67	-0.84	-1.17	0.07	-0.39	0.90	-0.46	1.74	0.37
1999	1.17	-0.48	1.14	1.10	1.33	0.36	NA	0.53	0.27	0.88	-0.15	-0.12	-0.05	0.31	-1.07	-1.19	-0.01	-1.25	0.23	-1.04	2.25	-0.11
2000	1.21	1.60	0.57	0.15	0.73	-0.09	NA	-0.74	-0.62	-0.67	0.05	-0.40	-0.25	-0.74	-0.06	0.00	-0.19	-0.71	0.33	0.09	2.18	0.08
2001	1.69	-0.10	0.09	0.63	0.53	-0.30	NA	-0.26	-0.65	-0.09	-1.03	-0.46	0.58	-0.58	-0.90	-0.71	-0.24	-0.76	0.34	-0.37	1.30	-0.10
2002	1.99	-0.19	-0.60	-0.80	0.26	-0.07	NA	0.92	-0.29	0.74	-0.42	0.28	0.55	-0.29	1.12	0.57	-1.06	1.20	-0.34	0.00	1.17	-0.29
2003	1.36	-0.48	-0.34	0.63	0.22	0.17	-0.83	0.63	-0.18	0.95	0.30	-0.52	0.68	0.09	0.29	0.21	-0.11	-1.15	-0.40	0.13	0.24	-0.61
2004	0.48	-0.48	0.04	2.29	0.42	-0.49	-0.40	0.09	0.09	0.14	-0.28	0.90	0.63	-0.61	0.92	0.89	-1.44	-0.02	-0.64	0.12	-1.32	-1.31
2005	0.53	-0.48	0.17	0.63	-0.49	-0.39	-0.38	2.21	2.55	1.10	0.37	-0.86	0.70	2.44	1.32	0.75	-0.73	-0.56	0.17	0.49	-0.47	-1.26
2006	0.42	-0.48	0.39	0.15	0.78	0.62	-0.68	-0.82	-0.73	-1.14	1.32	-0.46	0.34	-0.74	1.23	0.99	0.02	-1.72	0.49	0.27	0.13	-0.95
2007	-0.88	-0.48	0.17	-0.04	0.54	-0.41	-0.06	-0.71	-0.77	-0.64	-1.07	-0.01	0.35	-0.74	1.32	1.20	0.30	1.01	0.78	-0.41	1.50	-0.81
2008	-1.37	-0.48	-0.34	-0.51	0.44	-1.01	-0.45	-0.83	-0.60	-0.49	-0.92	-0.35	0.28	-0.74	0.80	0.98	0.53	1.08	0.67	-0.98	0.43	-0.59
2009	-2.17	-0.10	-0.93	-0.51	-1.27	-0.23	1.13	-0.32	-0.46	-0.10	-0.61	1.75	0.39	-0.61	0.87	0.84	0.73	-0.10	0.18	-0.09	1.57	-0.51
2010	-0.55	-0.29	-0.64	-0.42	-1.00	0.44	1.21	0.57	1.22	0.72	-0.01	2.14	0.75	0.48	1.17	0.90	0.22	0.07	0.25	-0.45	1.06	-0.65
2011	-0.74	0.49	0.09	-0.04	0.27	1.14	-0.31	-0.87	-0.48	-1.13	0.76	0.33	0.67	-0.74	1.18	0.53	0.30	1.45	0.58	-0.88	1.56	-0.39
2012	0.21	-0.48	0.57	NA	2.11	0.49	-0.01	-0.54	-0.75	-0.27	-0.79	-1.20	0.66	-0.39	0.32	0.13	-2.83	-0.02	0.21	-0.33	0.66	0.02
2013	0.97	0.80	-0.20	-0.42	0.69	0.38	0.13	-1.22	-0.82	-1.26	-0.51	-1.48	0.48	-0.74	0.31	1.51	0.53	1.30	-0.81	-0.23	-0.28	0.49
2014	0.23	-0.29	-0.85	-1.37	-1.25	-2.82	-1.38	-0.78	-0.88	-0.03	-1.26	-1.14	0.52	-0.71	-0.21	0.68	0.48	-0.44	-1.32	0.32	-1.16	0.87
2015	-0.80	-0.39	-1.18	-0.61	-0.34	-0.58	0.26	-0.16	-0.12	0.58	-0.72	-0.97	0.44	-0.32	0.69	0.40	0.20	0.34	-1.12	0.09	-0.20	-0.51
2016	-1.15	-0.48	-1.37	-1.56	-0.84	0.86	2.82	2.21	1.80	1.47	0.14	-0.91	0.75	2.70	-0.92	-0.01	0.58	-0.47	-0.50	0.23	-0.49	NA
2017	-2.59	2.00	0.21	-0.51	0.25	0.86	-0.65	-1.01	-0.27	-1.10	1.92	-1.03	0.67	-0.61	-0.26	1.10	-0.14	-0.49	-0.62	-0.10	-2.01	NA
2018	-0.85	-0.48	0.23	0.25	0.61	0.98	-0.41	1.17	1.41	1.54	-0.66	-0.35	0.75	0.64	-0.78	0.90	0.68	0.79	-0.84	0.29	-2.09	NA
2019	-0.20	-0.19	-0.36	-0.51	-0.62	1.55	NA	-0.97	1.05	-1.59	1.08	-0.91	0.64	-0.74	-2.92	2.62	0.04	0.61	-0.39	0.33	-1.57	NA

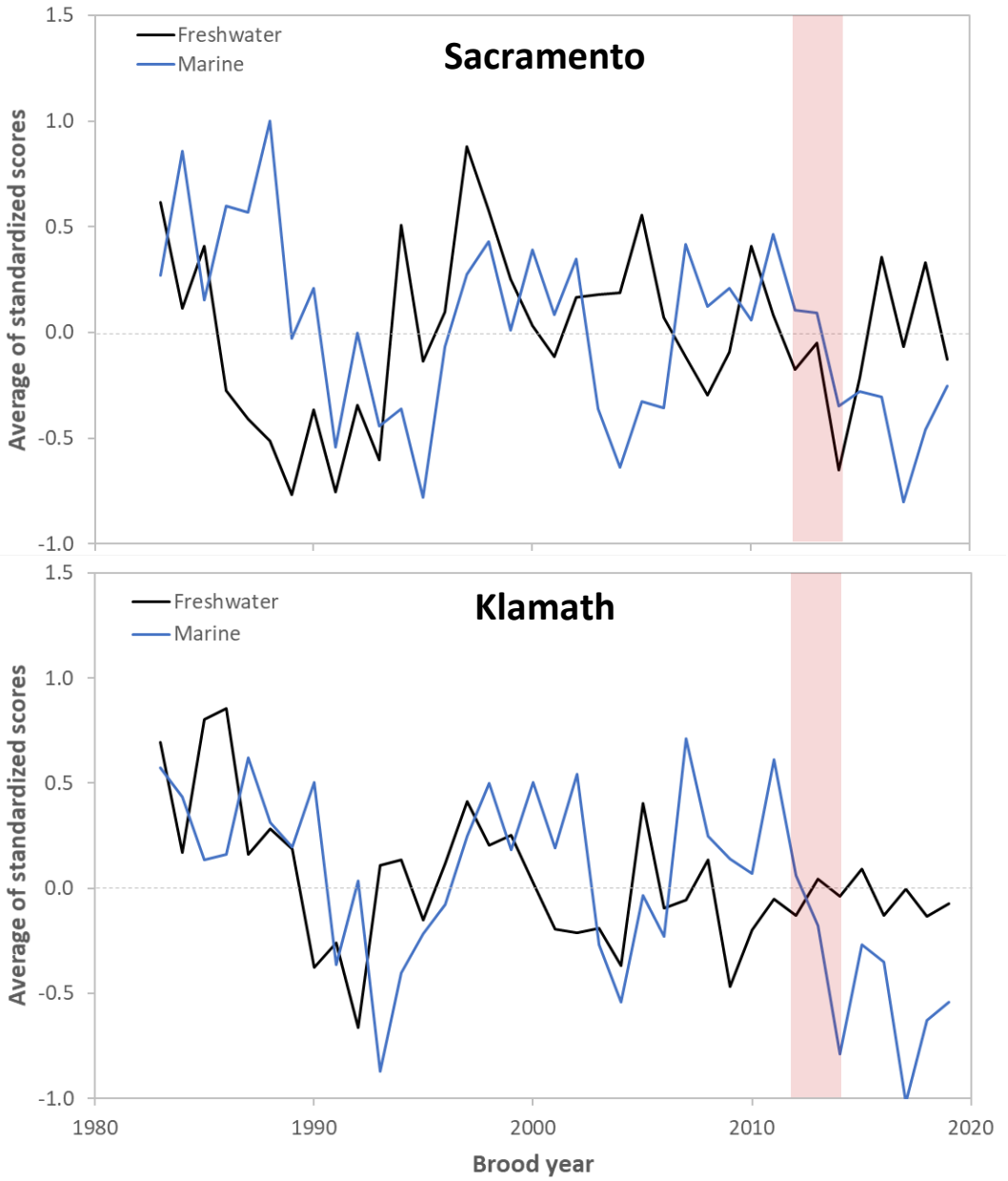
Habitat indicators for stocks in rebuilding plans

- Life stages
- Multiple indicators
- Indicators by brood year
- Each indicator is reported as anomaly in direction of positive effect on productivity
- Green = Top 33%
- Red = Bottom 33%
- More information in Ecosystem Status Report

	Freshwater conditions																Marine conditions				
	Adult spawners				Incubation			Freshwater/delta residence							Hatchery releases			Marine residence				
Brood year	Spawners	CChannel.F	Flows.F	Temp.F	Flows.W	Temp.W	FW.surv	Flows.S	Delta	SDFlow.S	Precip	Temp.S	CChannel.S	Yolo	Releases	Net.pen	FW.timing	Mar.timing	SSTarc	NPH	NPGO	Predation
1983	-0.54	-0.48	2.96	0.82	1.92	2.68	NA	0.56	-0.47	0.91	2.10	0.05	0.06	0.60	-1.30	-0.58	0.61	-0.39	-0.31	0.99	0.95	0.11
1984	-0.20	-0.48	3.44	-0.32	2.31	1.50	NA	-0.60	-0.82	-0.94	0.24	-0.97	-0.82	-0.74	0.49	-0.81	0.58	1.35	0.35	-0.57	0.24	2.91
1985	0.50	-0.09	0.74	NA	0.88	0.89	NA	0.48	1.18	1.54	-0.74	0.33	-0.35	0.58	0.34	-1.16	1.02	1.52	-0.39	-0.13	-0.65	0.42
1986	0.55	1.07	-0.53	0.15	-0.76	-0.28	NA	-0.73	-0.73	-1.09	0.91	-0.57	-1.04	-0.74	-0.05	-1.06	0.53	-0.17	-0.28	0.19	0.34	2.91
1987	0.28	0.23	0.33	0.15	0.49	0.17	NA	-0.65	-0.86	-0.85	-1.33	0.11	-2.46	-0.74	-0.27	-0.98	-0.11	0.17	0.06	0.75	1.44	0.41
1988	0.45	-0.48	-0.86	1.58	-1.40	0.01	NA	-0.68	-0.50	-0.66	-0.83	-0.01	-2.19	-0.55	-1.88	-1.29	1.12	1.72	-0.06	-0.33	0.76	2.91
1989	-0.12	-0.48	-0.64	-1.75	-0.93	0.05	NA	-1.04	-0.89	-1.42	-0.14	0.05	-2.86	-0.74	-0.12	0.18	-1.39	-0.59	-0.04	0.64	0.26	-0.42
1990	-0.66	-0.48	0.79	1.58	-1.03	-0.58	NA	-1.06	-0.75	-1.06	-0.92	1.52	-2.39	-0.74	0.37	-0.14	-0.32	0.79	0.11	0.74	-0.36	-0.23
1991	-0.52	-0.48	-1.07	-0.32	-1.33	-1.76	NA	-0.84	-0.84	-0.40	-0.96	-0.97	-1.05	-0.74	0.82	-1.28	-0.34	-0.64	-0.49	-0.64	-1.35	0.40
1992	-1.07	-0.48	-1.04	-1.27	-0.96	-1.03	NA	0.57	0.23	0.96	-0.88	1.35	0.04	0.38	-1.34	-1.26	0.32	-0.37	-0.45	1.74	-1.20	0.27
1993	-0.28	-0.23	-1.47	-1.75	-1.74	-0.44	NA	-1.00	-0.80	-1.37	0.95	-0.12	-0.17	-0.74	-0.64	-1.06	1.25	-1.77	-0.36	0.96	-1.20	0.16
1994	-0.05	-0.48	0.20	-0.80	0.04	0.36	NA	1.74	2.71	1.43	-1.09	1.86	0.22	2.28	-0.25	-1.07	1.02	0.52	-0.18	0.05	-1.79	-0.40
1995	0.74	-0.20	-0.76	-0.32	-1.11	-1.33	NA	0.58	0.65	0.38	2.03	-0.18	0.53	1.02	0.41	-1.11	-3.52	-2.60	-0.66	1.00	-0.95	-0.68
1996	0.81	-0.48	0.25	0.15	-0.14	-1.19	NA	0.65	-0.48	1.33	0.59	-0.29	0.52	1.12	-1.15	-1.20	1.09	0.07	-0.52	0.94	-0.67	-0.17
1997	0.87	0.36	0.47	2.05	0.32	-0.60	NA	2.04	1.45	1.19	0.60	2.26	0.75	1.70	1.01	-0.58	0.20	0.61	-0.27	0.84	0.56	-0.38
1998	0.28	4.72	0.28	0.15	-0.43	0.09	NA	0.87	0.16	0.45	1.92	1.35	0.68	0.67	-0.84	-1.17	0.07	-0.39	0.90	-0.46	1.74	0.37
1999	1.17	-0.48	1.14	1.10	1.33	0.36	NA	0.53	0.27	0.88	-0.15	-0.12	-0.05	0.31	-1.07	-1.19	-0.01	-1.25	0.23	-1.04	2.25	-0.11
2000	1.21	1.60	0.57	0.15	0.73	-0.09	NA	-0.74	-0.62	-0.67	0.05	-0.40	-0.25	-0.74	-0.06	0.00	-0.19	-0.71	0.33	0.09	2.18	0.08
2001	1.69	-0.10	0.09	0.63	0.53	-0.30	NA	-0.26	-0.65	-0.09	-1.03	-0.46	0.58	-0.58	-0.90	-0.71	-0.24	-0.76	0.34	-0.37	1.30	-0.10
2002	1.99	-0.19	-0.60	-0.80	0.26	-0.07	NA	0.92	-0.29	0.74	-0.42	0.28	0.55	-0.29	1.12	0.57	-1.06	1.20	-0.34	0.00	1.17	-0.29
2003	1.36	-0.48	-0.34	0.63	0.22	0.17	-0.83	0.63	-0.18	0.95	0.30	-0.52	0.68	0.09	0.29	0.21	-0.11	-1.15	-0.40	0.13	0.24	-0.61
2004	0.48	-0.48	0.04	2.29	0.42	-0.49	-0.40	0.09	0.09	0.14	-0.28	0.90	0.63	-0.61	0.92	0.89	-1.44	-0.02	-0.64	0.12	-1.32	-1.31
2005	0.53	-0.48	0.17	0.63	-0.49	-0.39	-0.38	2.21	2.55	1.10	0.37	-0.86	0.70	2.44	1.32	0.75	-0.73	-0.56	0.17	0.49	-0.47	-1.26
2006	0.42	-0.48	0.39	0.15	0.78	0.62	-0.68	-0.82	-0.73	-1.14	1.32	-0.46	0.34	-0.74	1.23	0.99	0.02	-1.72	0.49	0.27	0.13	-0.95
2007	-0.88	-0.48	0.17	-0.04	0.54	-0.41	-0.06	-0.71	-0.77	-0.64	-1.07	-0.01	0.35	-0.74	1.32	1.20	0.30	1.01	0.78	-0.41	1.50	-0.81
2008	-1.37	-0.48	-0.34	-0.51	0.44	-1.01	-0.45	-0.83	-0.60	-0.49	-0.92	-0.35	0.28	-0.74	0.80	0.98	0.53	1.08	0.67	-0.98	0.43	-0.59
2009	-2.17	-0.10	-0.93	-0.51	-1.27	-0.23	1.13	-0.32	-0.46	-0.10	-0.61	1.75	0.39	-0.61	0.87	0.84	0.73	-0.10	0.18	-0.09	1.57	-0.51
2010	-0.55	-0.29	-0.64	-0.42	-1.00	0.44	1.21	0.57	1.22	0.72	-0.01	2.14	0.75	0.48	1.17	0.90	0.22	0.07	0.25	-0.45	1.06	-0.65
2011	-0.74	0.49	0.09	-0.04	0.27	1.14	-0.31	-0.87	-0.48	-1.13	0.76	0.33	0.67	-0.74	1.18	0.53	0.30	1.45	0.58	-0.88	1.56	-0.39
2012	0.21	-0.48	0.57	NA	2.11	0.49	-0.01	-0.54	-0.75	-0.27	-0.79	-1.20	0.66	-0.39	0.32	0.13	-2.83	-0.02	0.21	-0.33	0.66	0.02
2013	0.97	0.80	-0.20	-0.42	0.69	0.38	0.13	-1.22	-0.82	-1.26	-0.51	-1.48	0.48	-0.74	0.31	1.51	0.53	1.30	-0.81	-0.23	-0.28	0.49
2014	0.23	-0.29	-0.85	-1.37	-1.25	-2.82	-1.38	-0.78	-0.88	-0.03	-1.26	-1.14	0.52	-0.71	-0.21	0.68	0.48	-0.44	-1.32	0.32	-1.16	0.87
2015	-0.80	-0.39	-1.18	-0.61	-0.34	-0.58	0.26	-0.16	-0.12	0.58	-0.72	-0.97	0.44	-0.32	0.69	0.40	0.20	0.34	-1.12	0.09	-0.20	-0.51
2016	-1.15	-0.48	-1.37	-1.56	-0.84	0.86	2.82	2.21	1.80	1.47	0.14	-0.91	0.75	2.70	-0.92	-0.01	0.58	-0.47	-0.50	0.23	-0.49	NA
2017	-2.59	2.00	0.21	-0.51	0.25	0.86	-0.65	-1.01	-0.27	-1.10	1.92	-1.03	0.67	-0.61	-0.26	1.10	-0.14	-0.49	-0.62	-0.10	-2.01	NA
2018	-0.85	-0.48	0.23	0.25	0.61	0.98	-0.41	1.17	1.41	1.54	-0.66	-0.35	0.75	0.64	-0.78	0.90	0.68	0.79	-0.84	0.29	-2.09	NA
2019	-0.20	-0.19	-0.36	-0.51	-0.62	1.55	NA	-0.97	1.05	-1.59	1.08	-0.91	0.64	-0.74	-2.92	2.62	0.04	0.61	-0.39	0.33	-1.57	NA

Habitat indicators for stocks in rebuilding plans

- Freshwater habitat conditions have tended to **vary inversely** with marine conditions
- During brood years defined by rebuilding plans, **both freshwater and marine conditions were below average**
- Since the rebuilding plan, freshwater habitat conditions have improved somewhat but **marine conditions have declined** to historically low levels.



Summary

Keyword: **integration**

- Across life cycles
- Multiple datasets
- Multiple H’s
- Collaboration of effort

Important to document habitat relationships and successful approaches to restoration and recovery