Chehalis basin watershed analysis and life-cycle modeling

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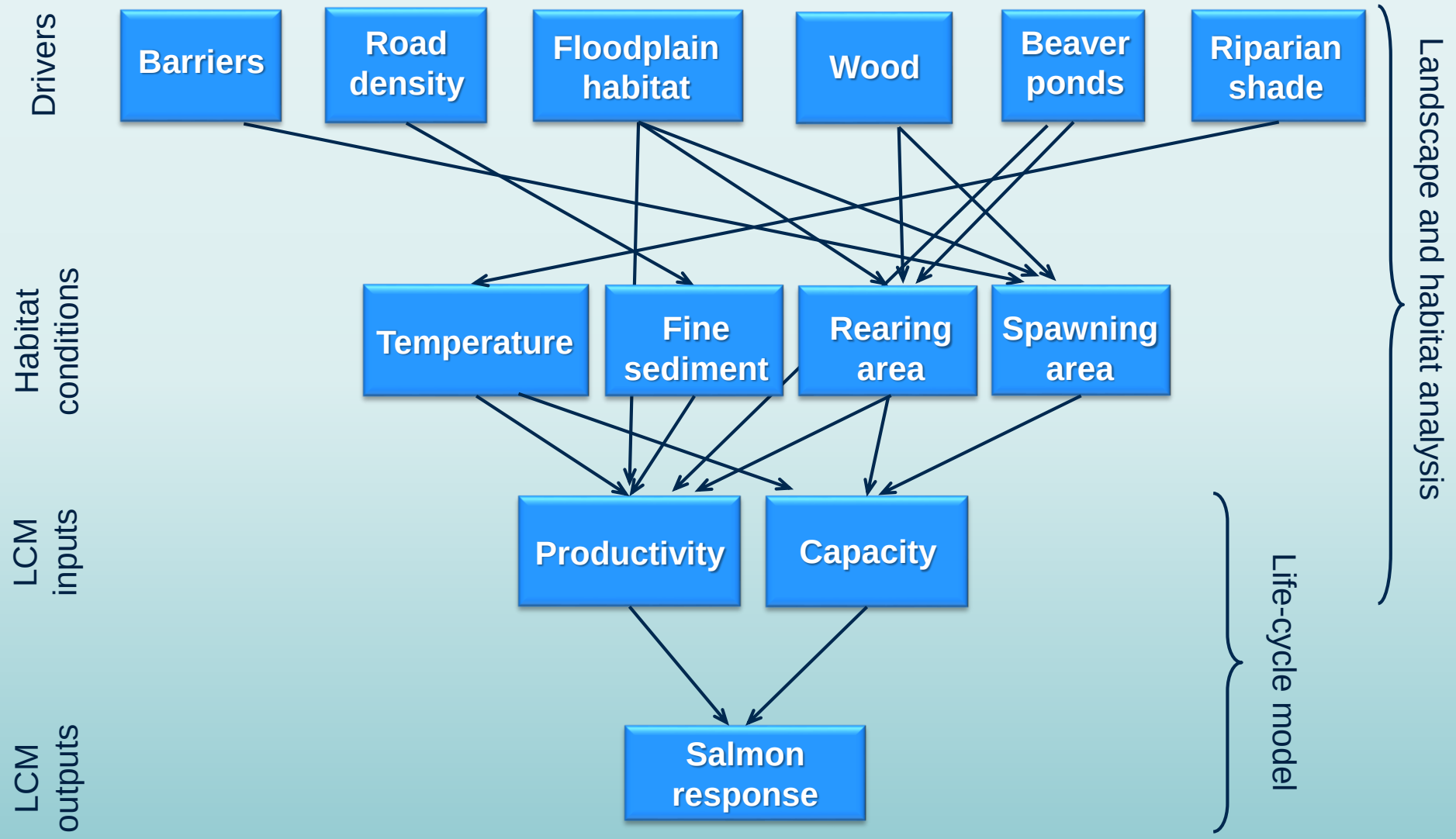
Overview

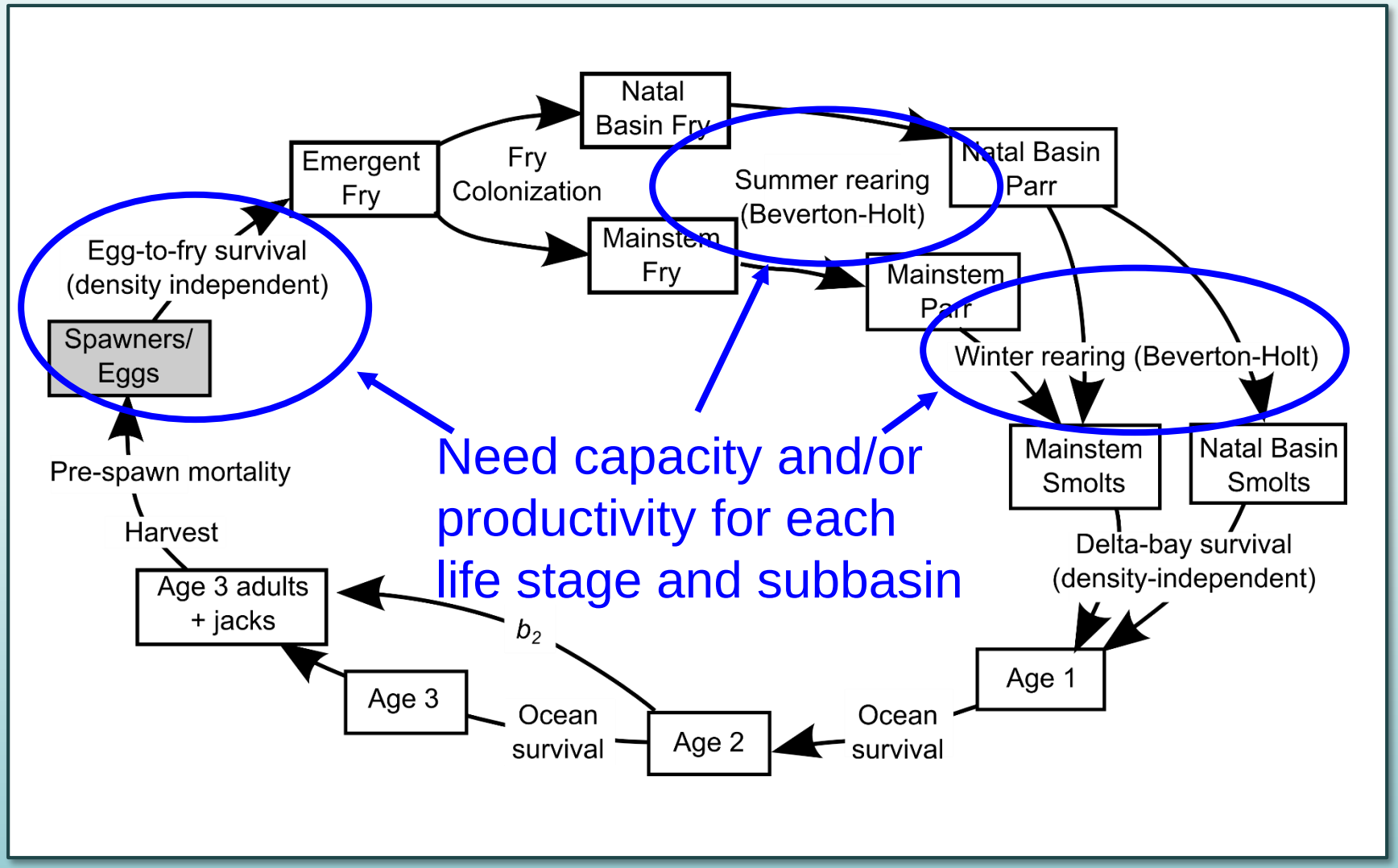
- Overview of the NOAA model
  - Conceptual model
  - Habitat analysis overview
  - Life cycle model overview
- Diagnostic scenarios
  - Assumptions
  - Results
- ASRP scenarios
  - Assumptions
  - Results

Conceptual Model

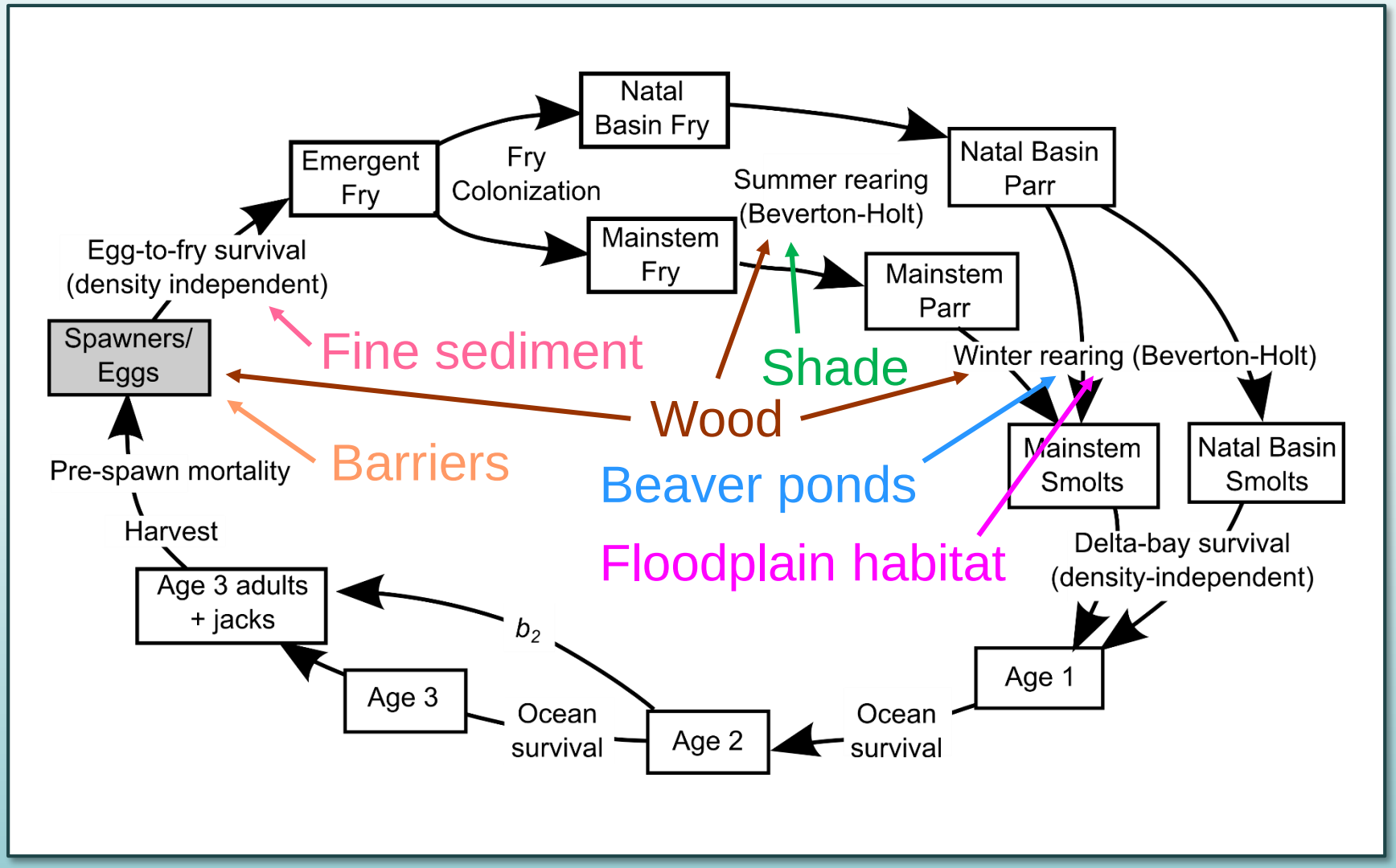


See examples in Bartz et al. 2006, Scheuerell et al. 2006

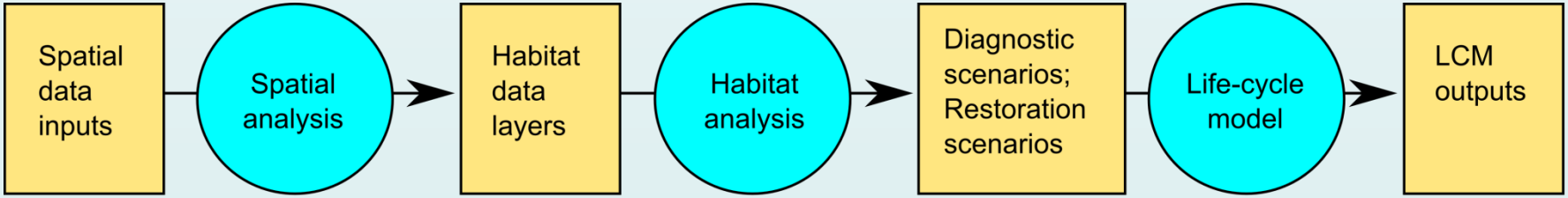
Coho Salmon Life Cycle Model



Influences on Life-Stage Parameters



NOAA Model Structure



Raw data layers:
USGS 10-m DEM
C-CAP land cover raster
PRISM mean annual precip
Washington roads
Ecological Diversity Regions
SWIFD streamlines
WDFW Migration barriers
WDFW Thermalscape
Riparian files
Floodplain habitat polygons
Large river edge habitat
Large river backwaters
Spawning riffles

Final habitat layers:
Large river edge habitat
Large river backwaters
Large river spawning riffles
Floodplain habitats
Attributed streamline

Diagnostic scenarios:
Migration barriers
Fine sediment
Wood loading
Shade (temperature)
Bank armor
Channel straightening
Beaver ponds
Floodplain habitats

Restoration scenarios:
Restoration actions
Climate change effects
Future development

LCM results
-Coho
-Spring Chinook
-Fall Chinook
-Steelhead

Spatial Analysis Steps

- Assign attributes to 200-m stream reaches
  - e.g., slope, wetted width, land cover, fine sediment, temperature
- Generate stream habitat data layers
  - e.g., small stream habitats (<20 m bankfull width), large river habitats (>20 m bankfull width), floodplain habitats

Spatial Analysis Outputs

- Large river bank edge habitat length
- Large river backwater habitat areas
- Large river spawning riffle areas
- Floodplain habitat areas
- Attributed stream lines (slope, land cover, fine sediment, temperature, etc.)

Habitat Analysis Steps

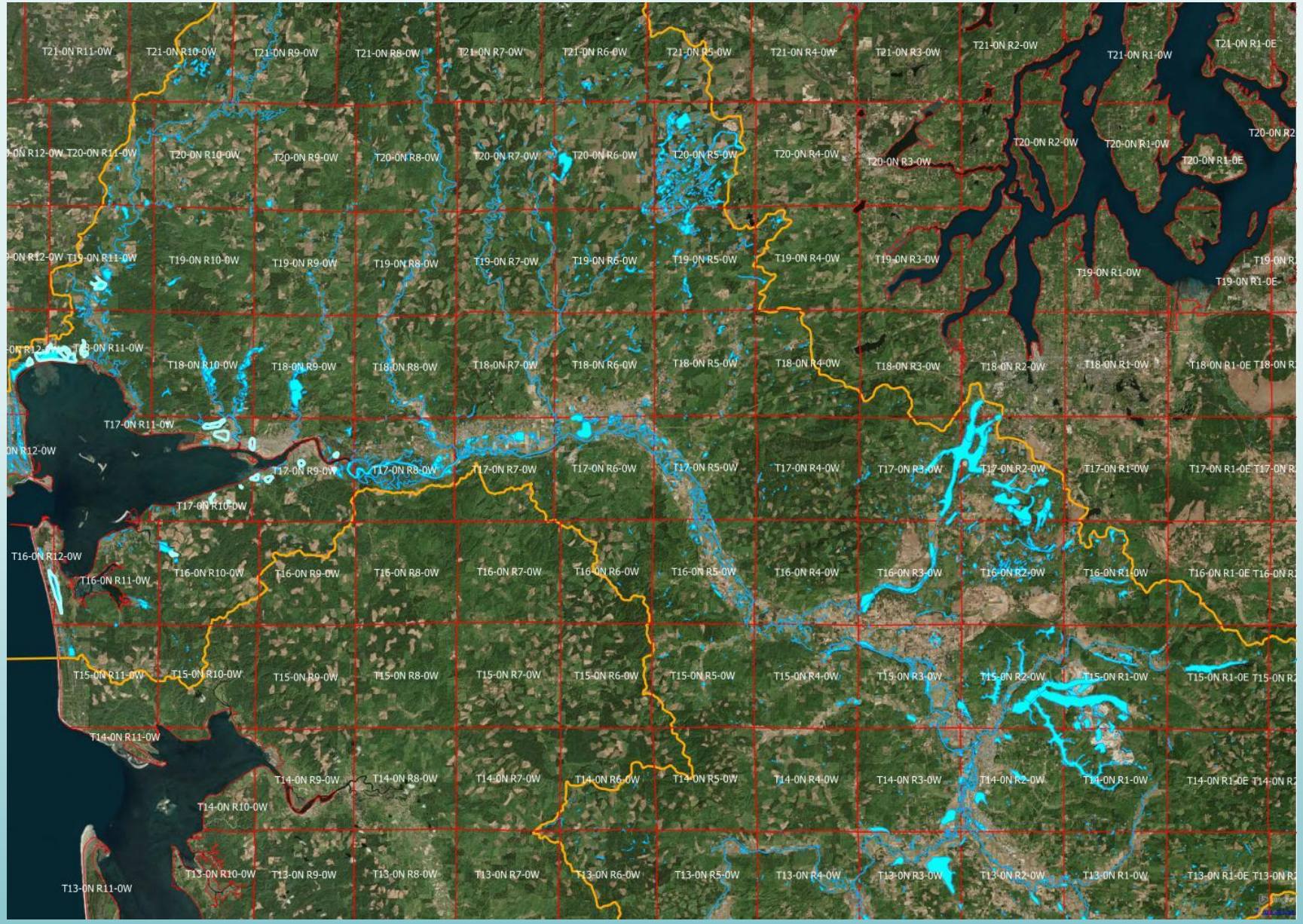
- Estimate habitat areas by reach
  - e.g., area of pools, riffles, beaver ponds, floodplain habitats, large river edge habitats
- Summarize current and historical habitat areas and attributes by sub-basin and EDR
- Create diagnostic and restoration scenarios
  - LCM input files of life stage capacities and productivities by sub-basin

Habitat Analysis Outputs

- Output files from the habitat analysis are input files for the life-cycle models
  - Include life stage capacities and productivities for each sub-basin
  - One file for each species and scenario (current, historical, 9 diagnostic, 4 ASRP)

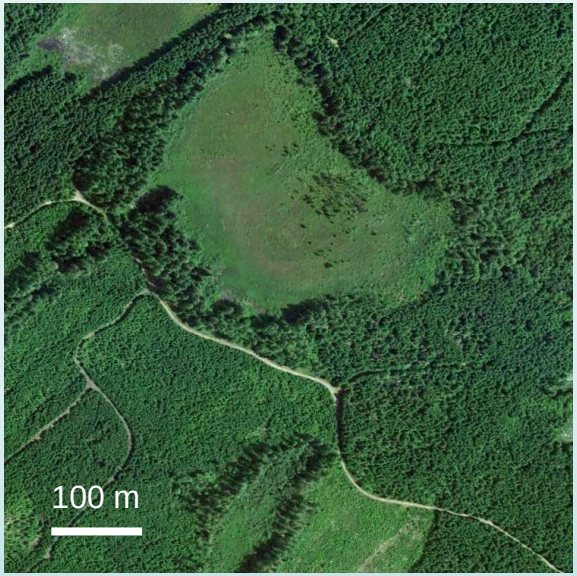
	Subbasin number (1-63)					
Stage	1	2	3	4	5	6
Egg to fry productivity	0.26	0.29	0.29	0.23	0.27	0.31
Adult capacity	24,421	8,892	14,765	2,303	51,286	3,350
Egg capacity	38,158,136	13,895,229	23,071,376	3,598,986	80,134,388	5,235,077
Summer capacity	257,093	189,151	650,014	33,555	607,397	106,249
Summer productivity	0.63	0.55	0.84	0.47	0.50	0.62
Winter capacity	34,324	44,973	101,733	36,827	487,904	26,138
Winter productivity	0.25	0.30	0.41	0.60	0.58	0.44
Prespawn productivity	0.84	0.80	0.87	0.89	0.80	0.64

Floodplain Habitat Change

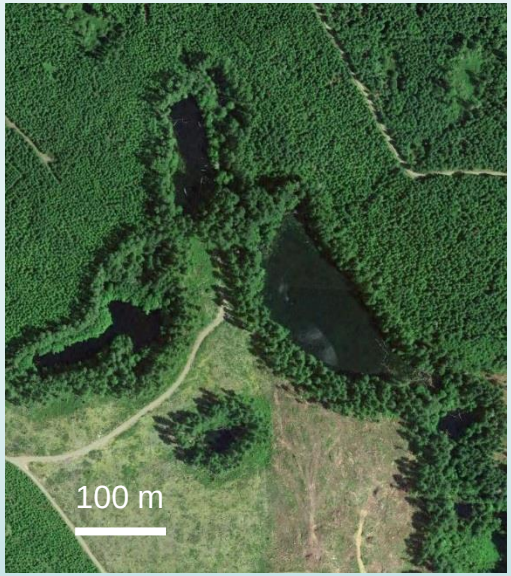


Floodplain Habitat Change

Marsh



Pond

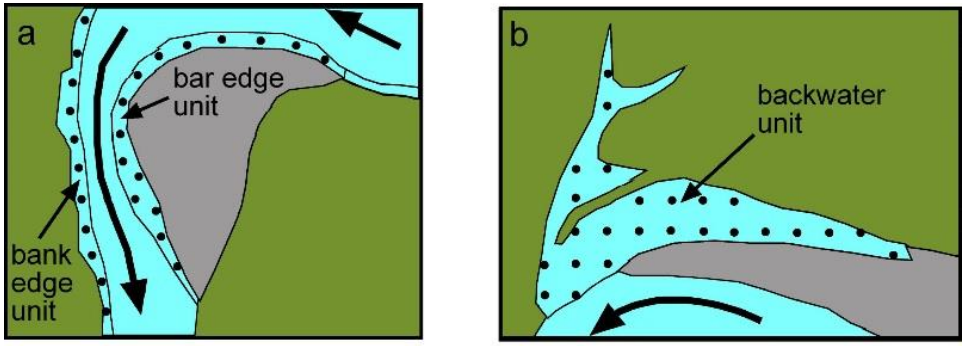


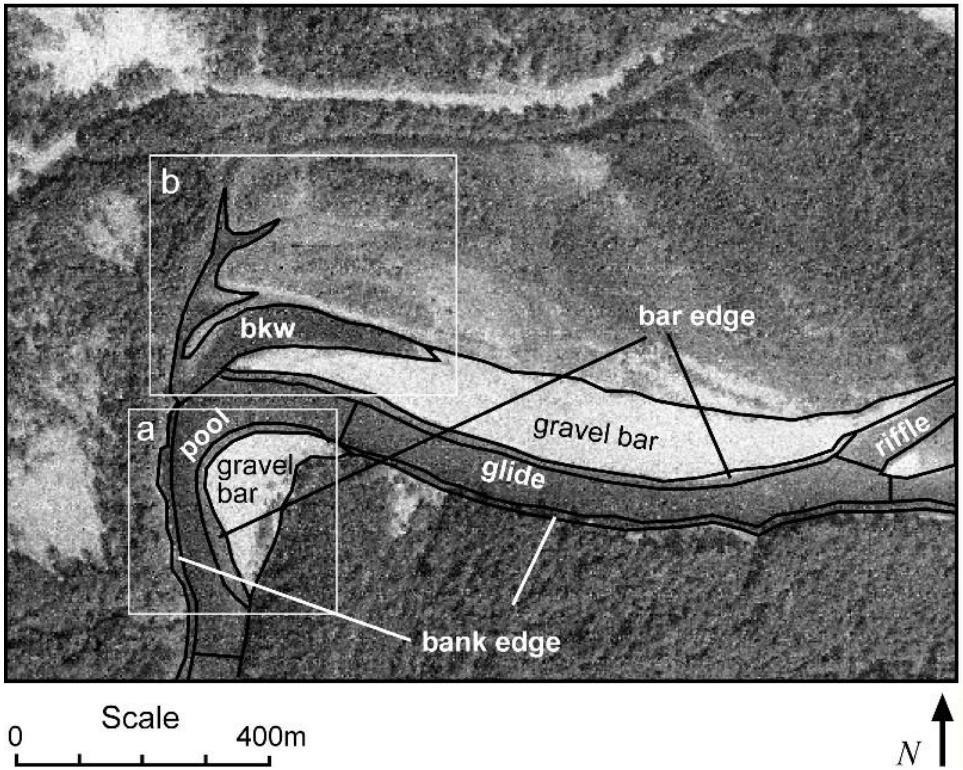
Side-channel

	Fish Density (fish/m^2)	
Habitat Type	Coho (summer)	Coho (winter)
Marsh	0	0.32
Pond	1.8	1.8
Side Channel	0.9	0.2
Slough	0.9	0.9

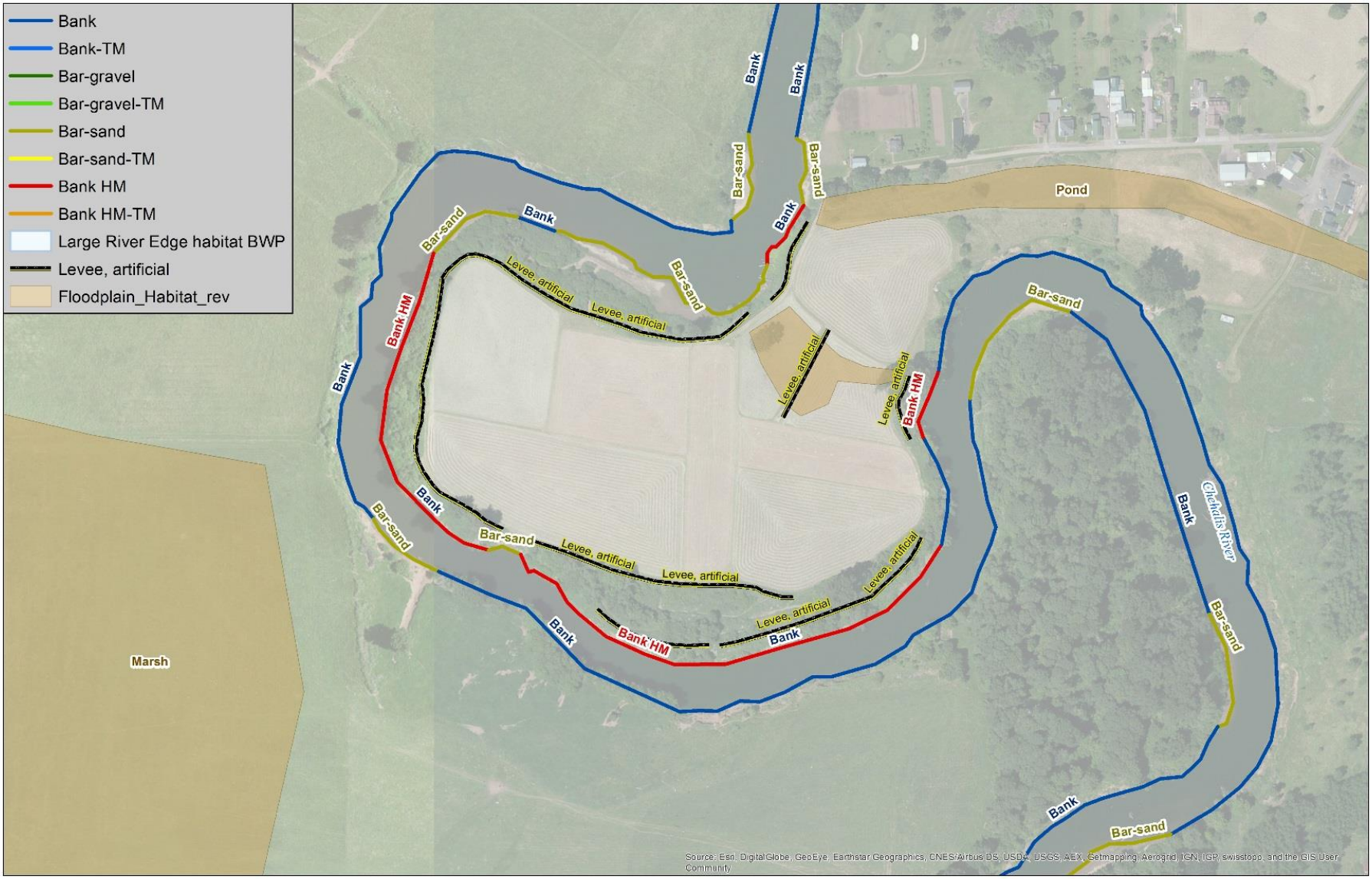
Large River Habitat Change

- Habitat types from Beechie et al. (2005) and Beamer and Henderson (1998)
- Fish densities from Beamer and Henderson (1998)





Large River Habitat Change



Small Stream Habitat Change

Slope class	Reference	Forest	Wetland	Agriculture	Developed	Bare
0-2%	81	75	89	92	74	83
2-4%	66	48	53	60	51	50
>4%	35	34	--	31	54	34

Based on 339 field survey sites from WDFW; reference site data from other studies

Small Stream Habitat Change

Current Condition

Slope class	Reference	Forest	Wetland	Agriculture	Developed	Bare
0-2%	81	75	89	92	74	83
2-4%	66	48	53	60	51	50
>4%	35	34	--	31	54	34

Based on 339 field survey sites from WDFW; reference site data from other studies

Small Stream Habitat Change

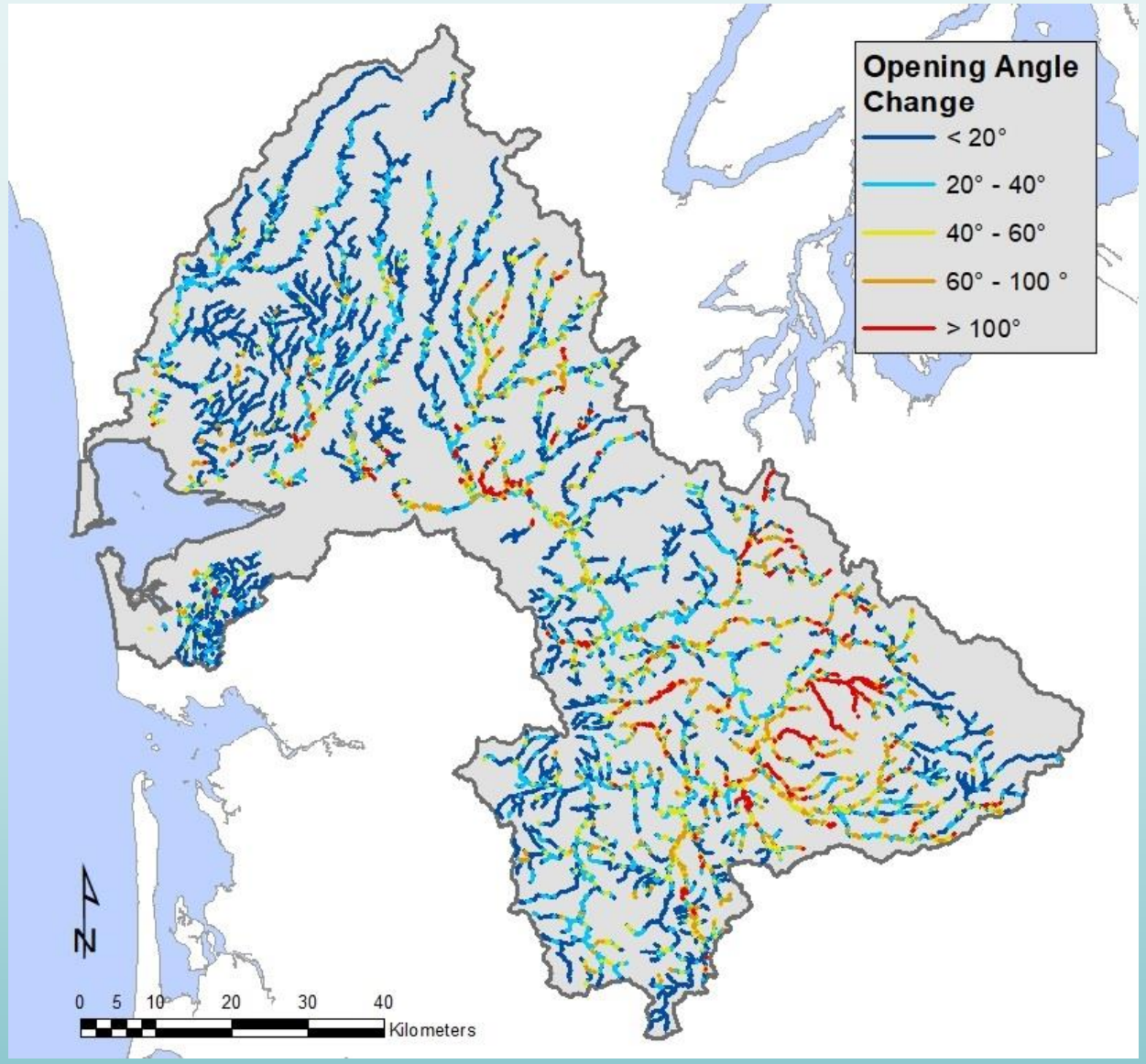
Historical Condition

Slope class	Reference	Forest	Wetland	Agriculture	Developed	Bare
0-2%	81	75	89	92	74	83
2-4%	66	48	53	60	51	50
>4%	35	34	--	31	54	34

Based on 339 field survey sites from WDFW; reference site data from other studies

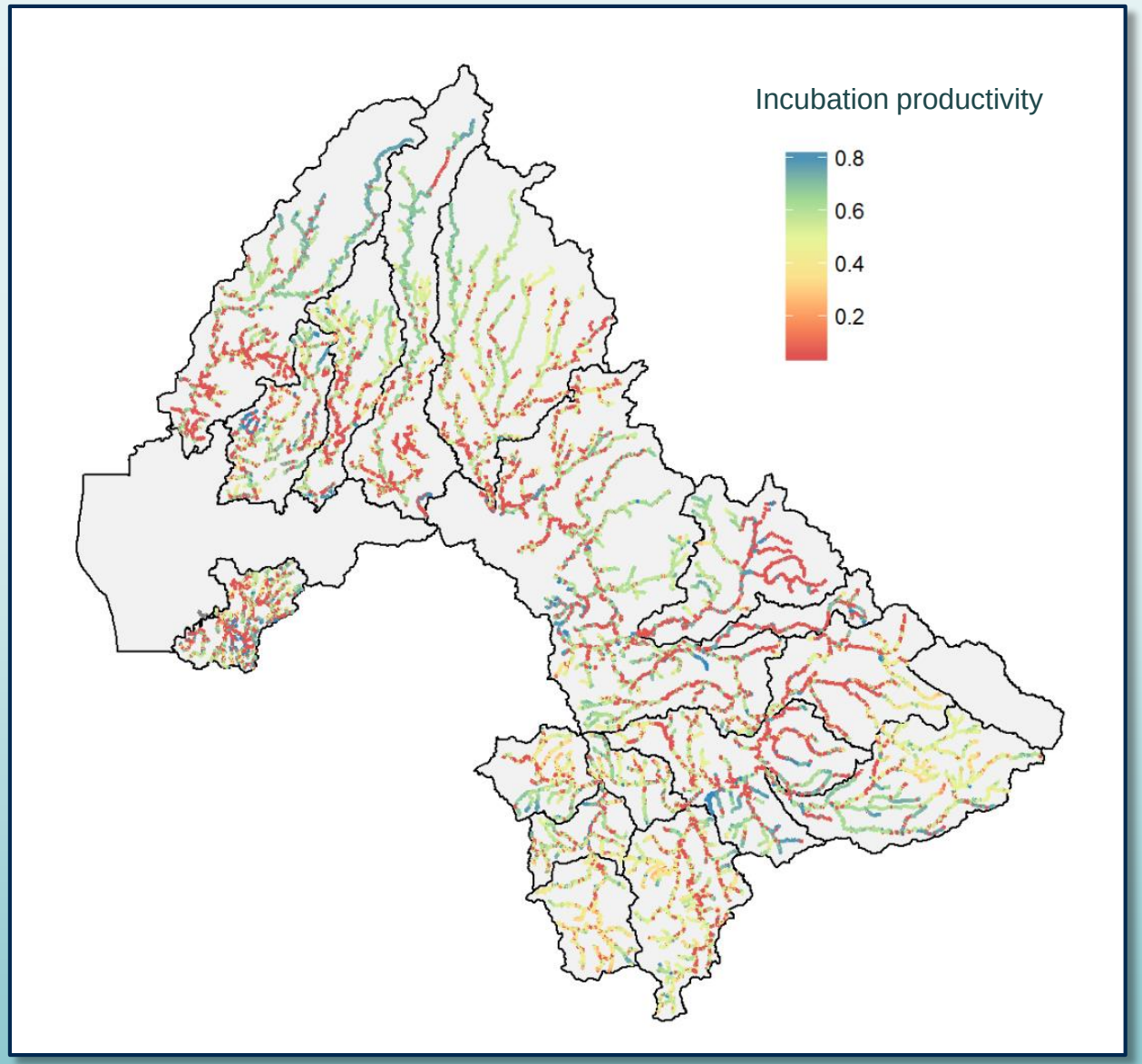
Riparian Condition

- Current shade inventory using lidar and aerial photos
- Reference tree heights for historical shade
- Change in shade and temperature model



Fine sediment

- Percent fine sediment based on forest road density
- Incubation productivity related to percent fine sediment (Jensen et al. 2009)



Habitat effects on LCM parameters

Coho and Steelhead

	Egg capacity	Egg-to-fry productivity	Summer rearing capacity	Summer rearing productivity	Winter rearing capacity	Winter rearing productivity
Barriers	X		X[1]	X	X[1]	X
Fine sediment		X				
Wood loading	X	X	X	X	X	X
Shade			X	X		
Channel length	X		X	X	X	X
Bank condition			X	X	X	X
Beaver pond area	X		X	X	X	X
Floodplain			X	X	X	X
Wood + floodplain	X		X	X	X	X

1. Effect expressed only when barrier is 100% blocking

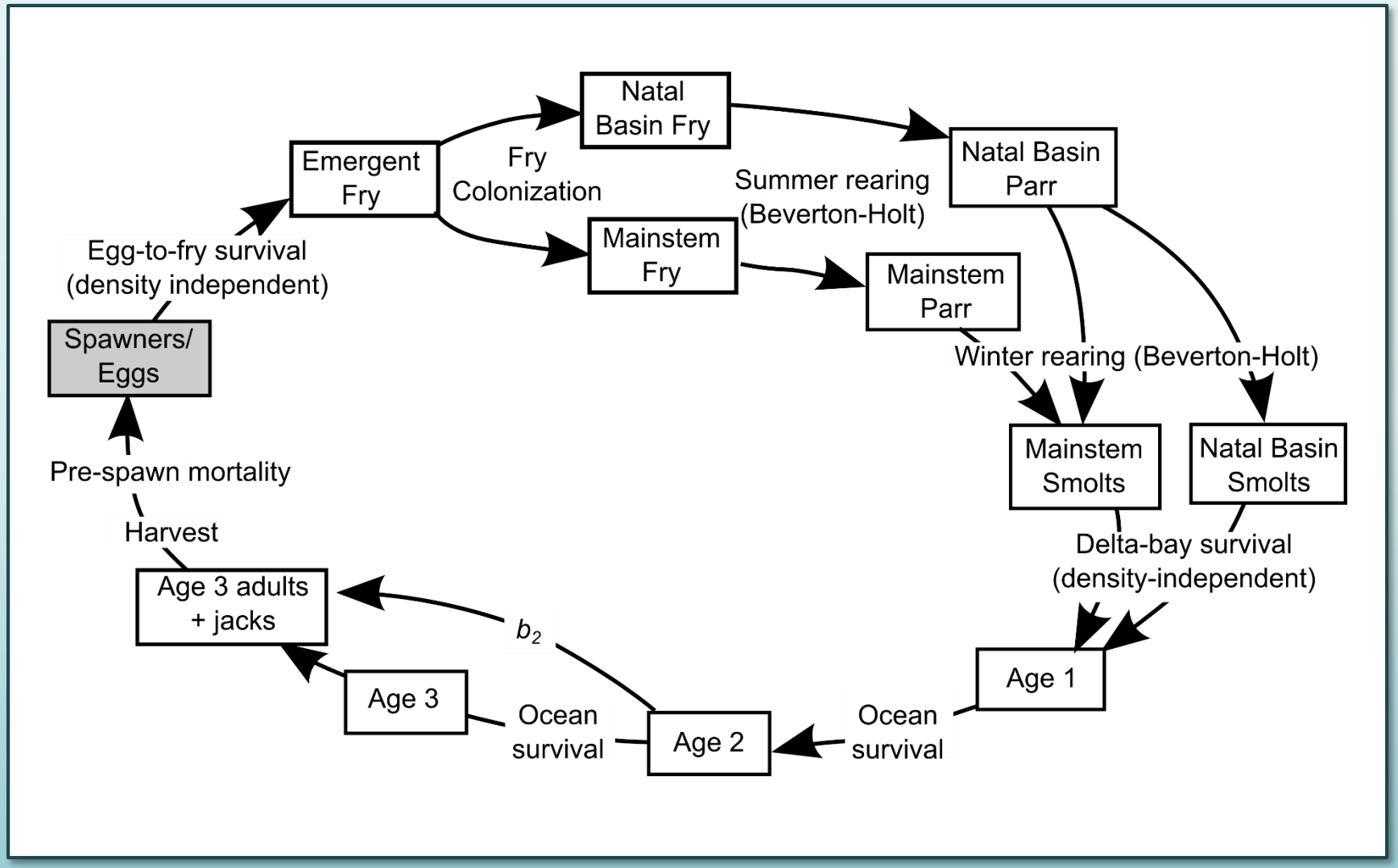
Habitat effects on LCM parameters

Spring and Fall Chinook

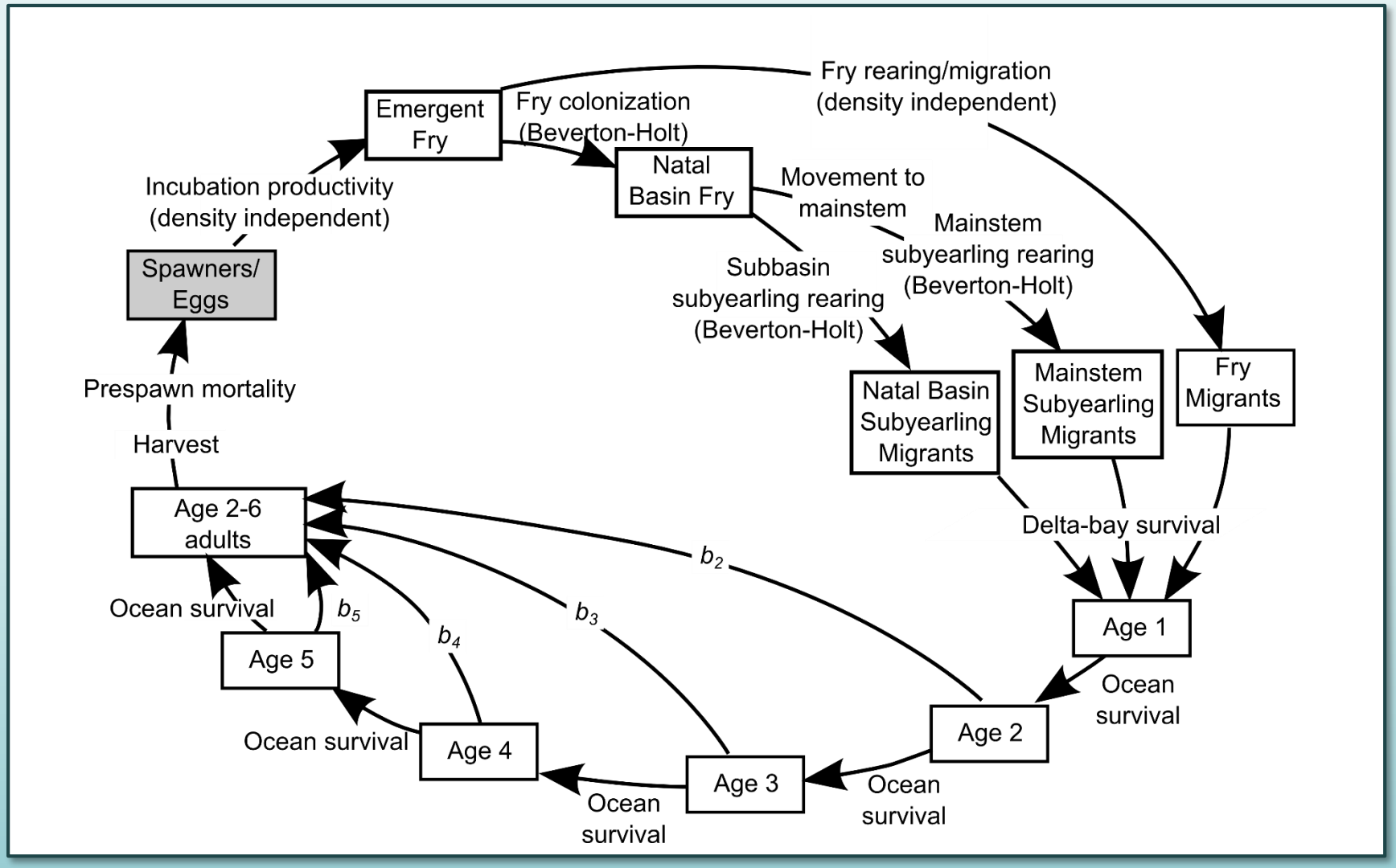
	Pre-spawn productivity	Egg capacity	Egg-to-fry productivity	Subyearling rearing capacity	Subyearling rearing productivity
Barriers		X		X[1]	X
Fine sediment			X		
Wood loading		X	X	X	X
Shade	X[2]			X	X
Channel length		X		X	X
Bank condition				X	X
Beaver pond area		X		X	X
Floodplain				X	X
Wood + floodplain		X		X	X

1. Effect expressed only when barrier is 100% blocking
2. Spring Chinook only

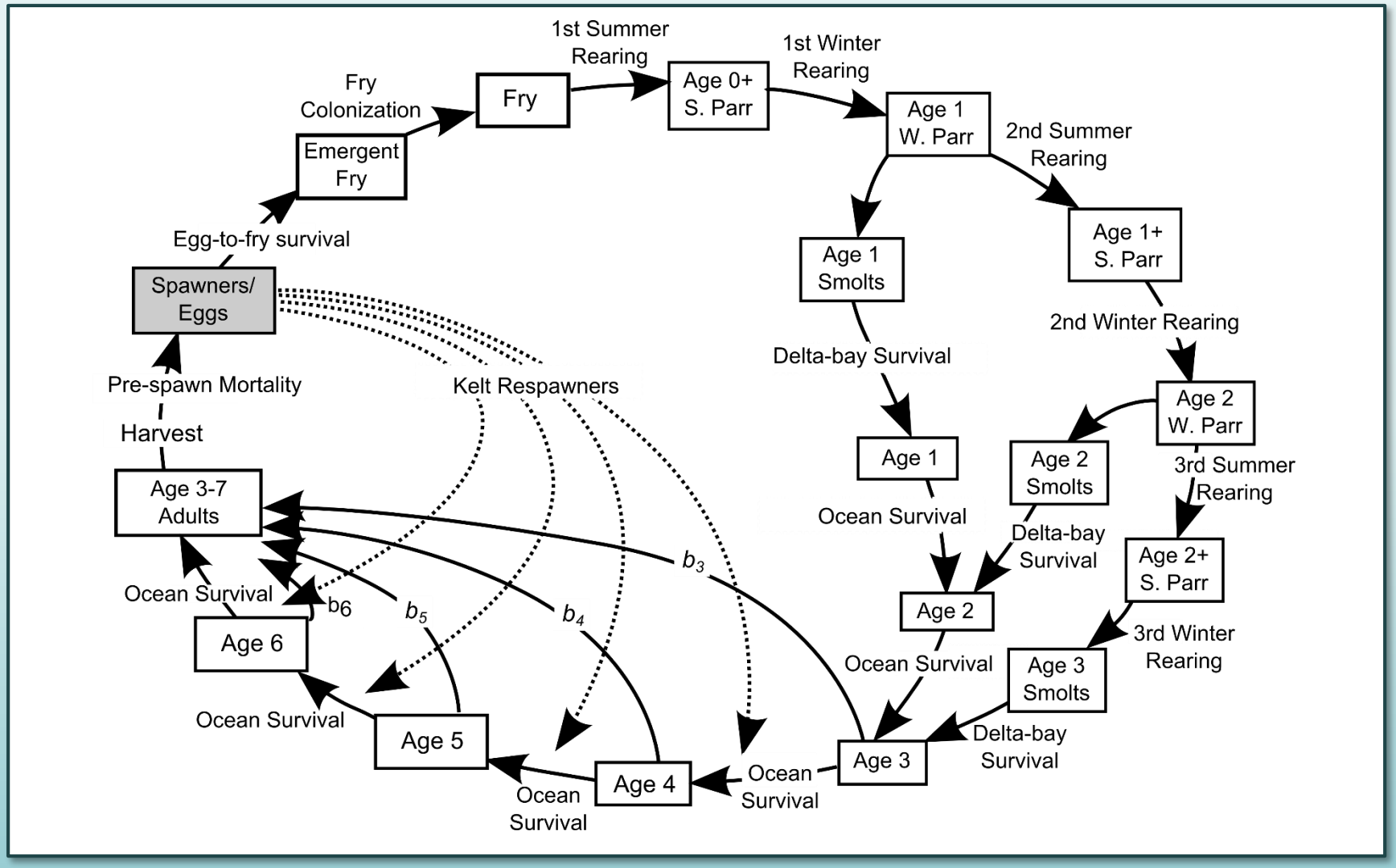
Coho Life Cycle Model



Chinook Life Cycle Model



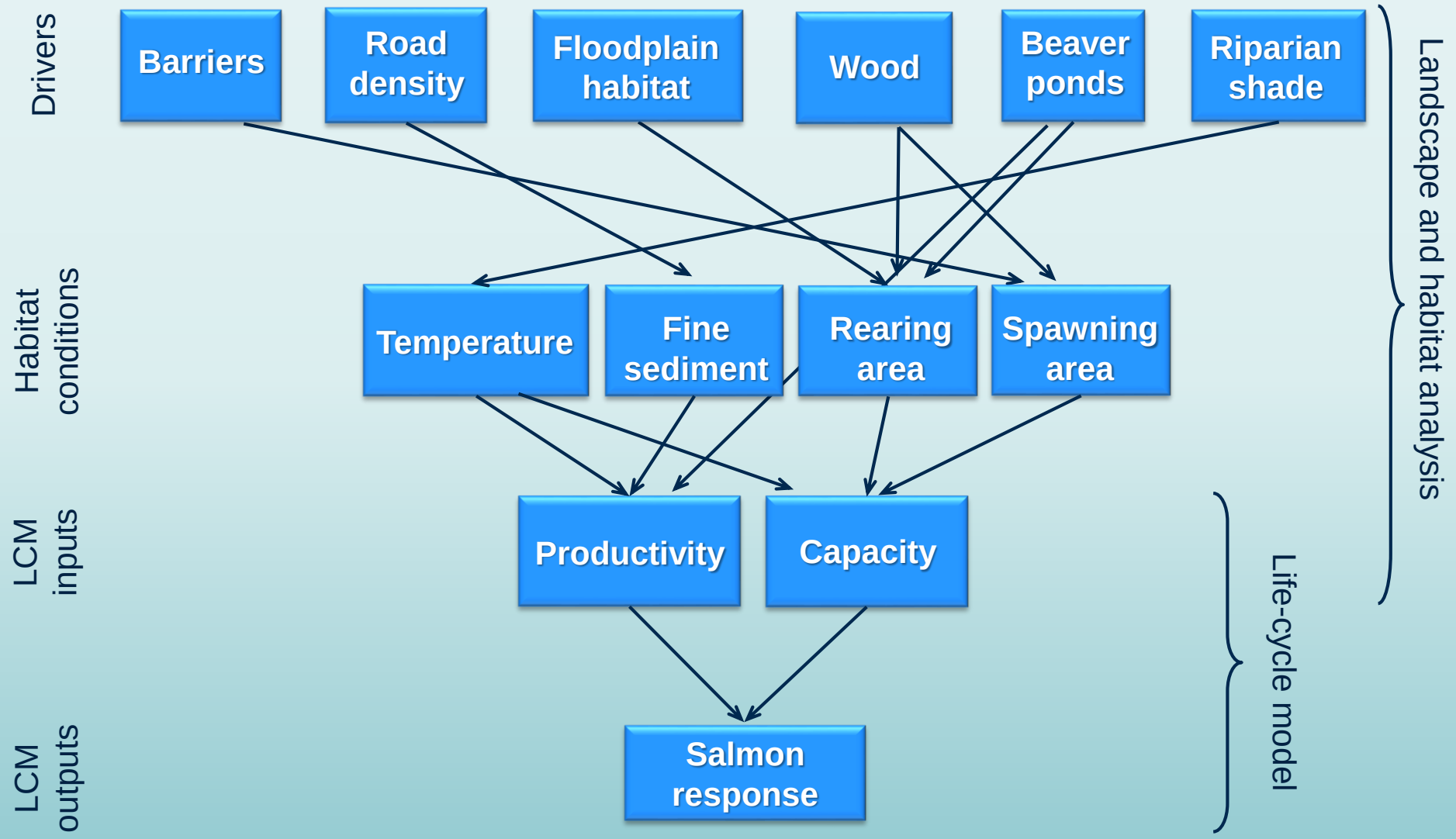
Steelhead Life Cycle Model



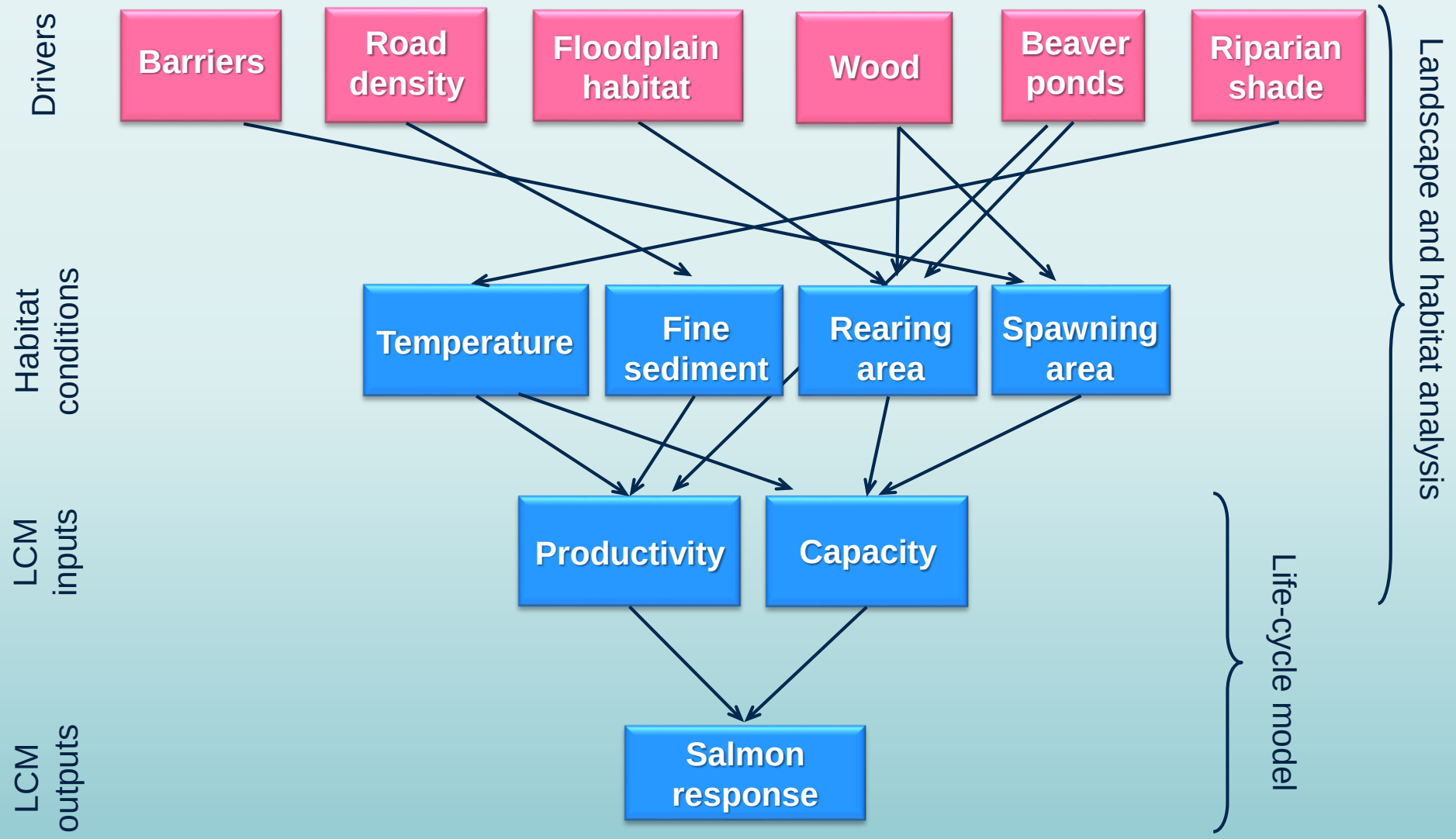
Life Cycle Model Outputs

- Spawner abundance (N_{eq} by subbasin, EDR, or basin)
- Intrinsic productivity (P_n, empirical fit of Beverton-Holt slope at origin)
- Cumulative capacity (C_n, calculated based on N_{eq} and P_n)

Diagnosis and Restoration



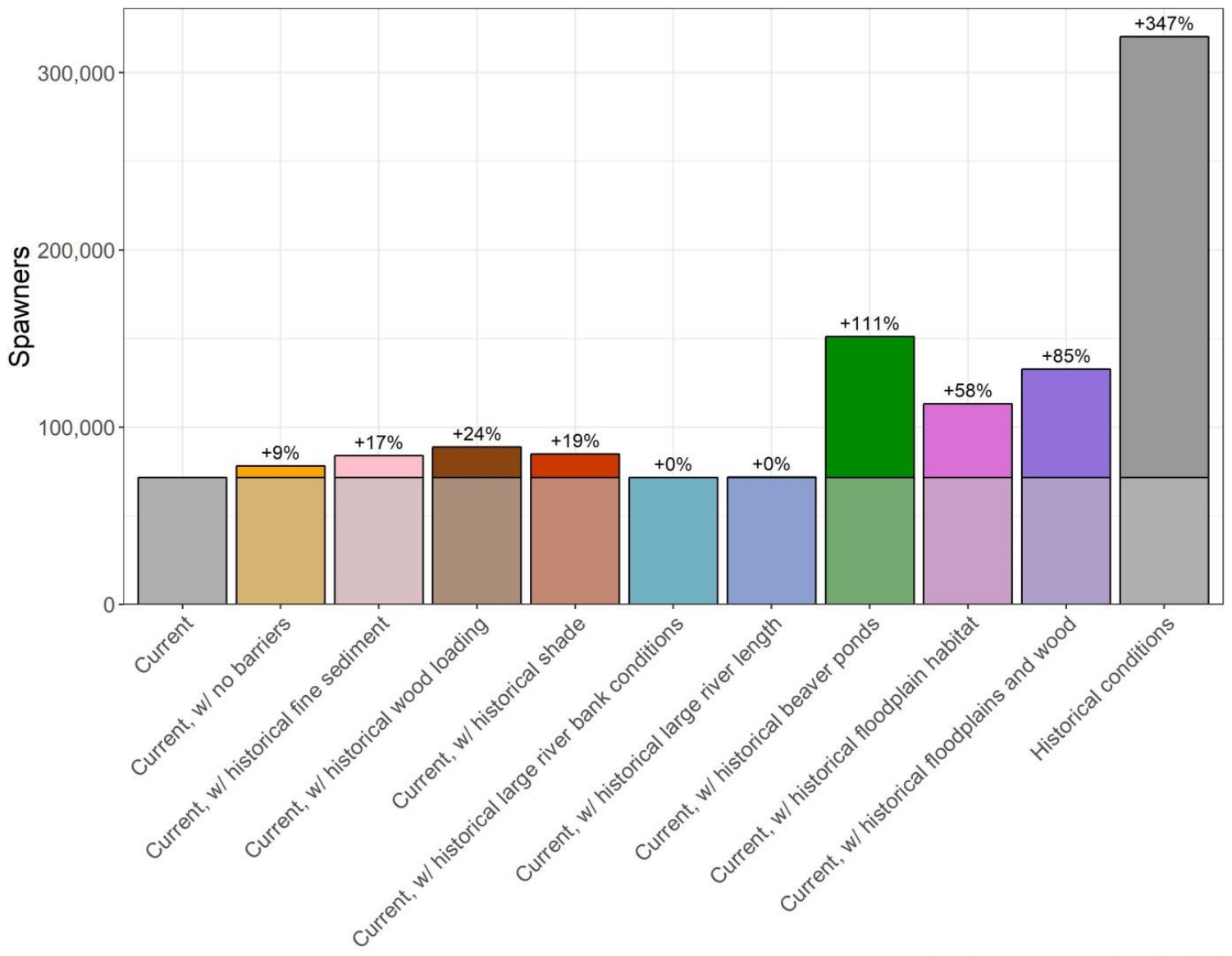
Diagnosis and Restoration



Diagnostic scenarios

Scenario	Description
Current	Current conditions for all habitat variables
No barriers	Current conditions for all habitats, no migration barriers
Historical fine sediment	Historical fine sediment levels
Historical wood	Historical wood loading
Historical shade	Historical shade and temperature
Historical large river length	Historical large river channel length multiplier
Historical bank condition	Historical bank condition (no rip-rap in large river)
Historical beaver	Historical beaver pond areas
Historical floodplain	Historical marsh, pond, and side-channels in floodplains
Historical wood + floodplain	Historical wood loading and historical marsh, pond, and side-channels in floodplains

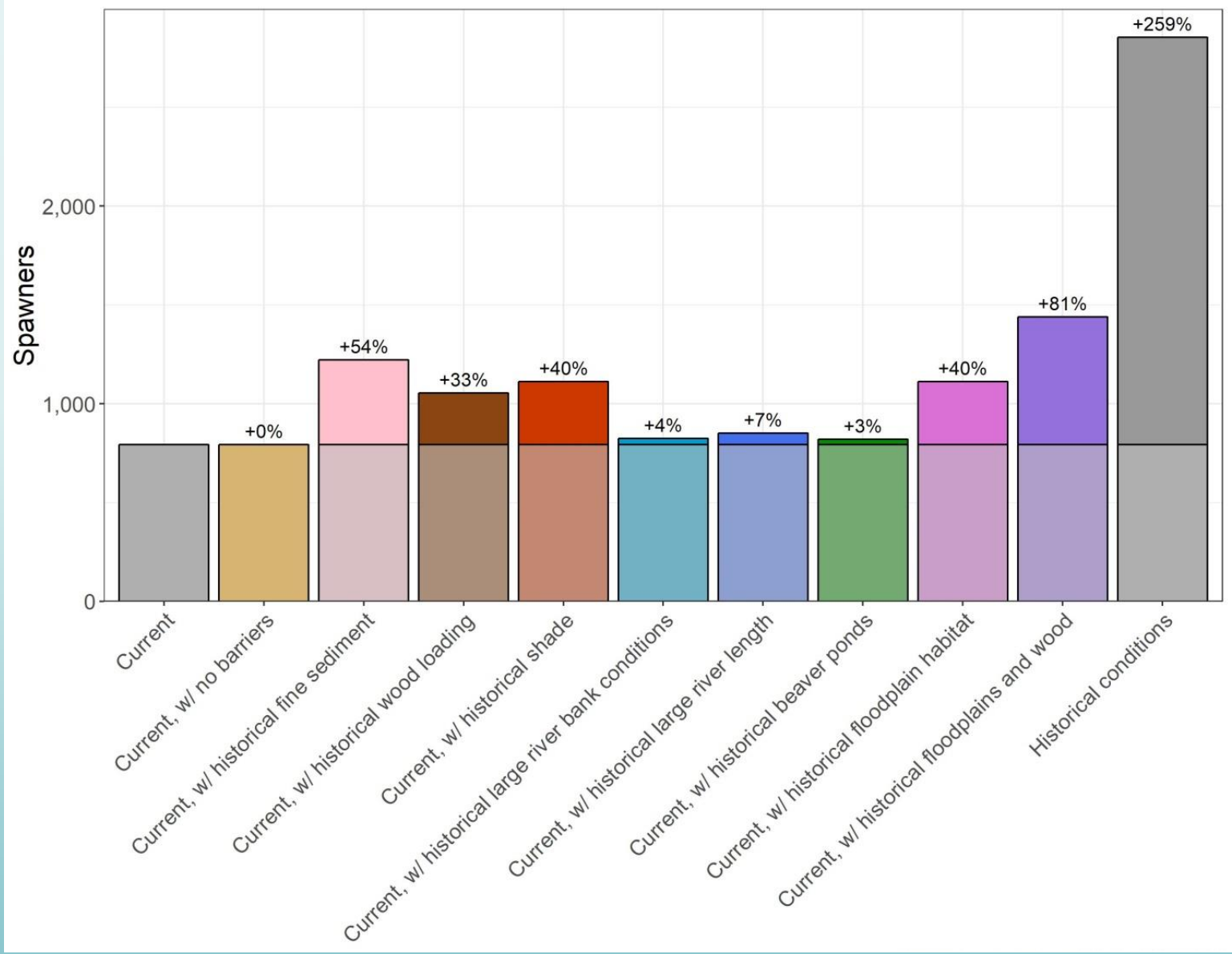
Coho Diagnostic Results



Summary: Coho

- Loss of overwinter habitat has likely had the largest effect on coho populations
  - Beaver ponds
  - Floodplain habitat
- Other effects are also important
  - Migration barriers
  - Loss of shade and increased temperature
  - Loss of wood
- Fine sediment may have a modest effect
  - High uncertainty

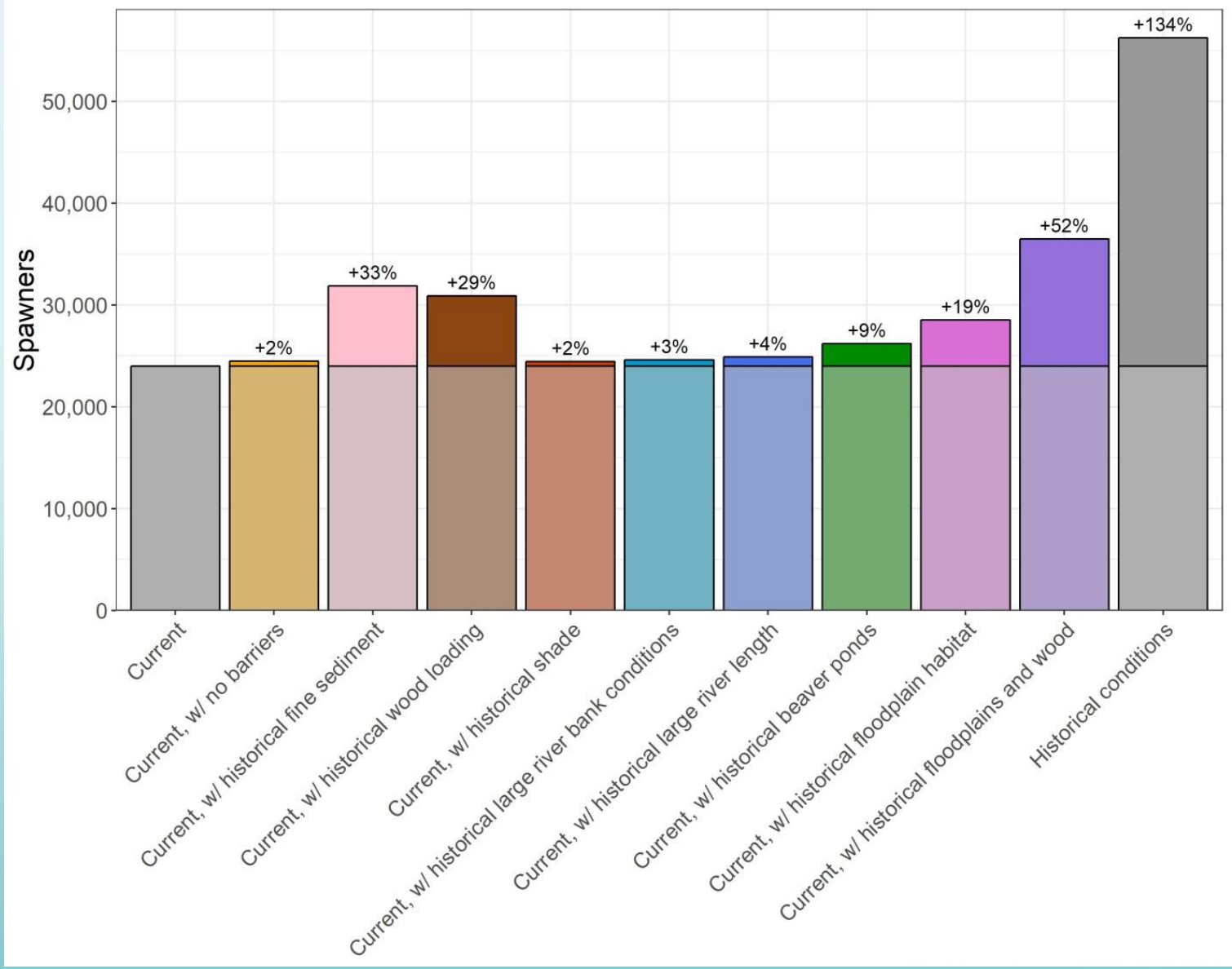
Spring Chinook Diagnostic Results



Summary: Spring Chinook

- Largest modeled effects from
  - Increased temperature
  - Increased fine sediment
- Wood loss has also had a significant effect
- Uncertainty:
  - Fine sediment model does not identify specific locations or actions for restoration

Fall Chinook Diagnostic Results



Summary: Fall Chinook

- Largest modeled effects from
  - Loss of wood
  - Increased fine sediment
- Smaller effects from:
  - Floodplain habitat loss
- Uncertainty:
  - Fine sediment model does not identify specific locations or actions for restoration

ASRP Restoration Scenarios

- No action baseline
  - Includes climate change (temperature increases 1°C by 2045 and 2°C by 2085, Isaak et al. 2017)
  - Includes future development (impervious area increase)

- Three ASRP restoration scenarios
  - Scenario 1: 200+ miles treated
  - Scenario 2: 300+ miles treated (adds to Scenario 1)
  - Scenario 3: 400+ miles treated (adds to Scenario 2)

ASRP Restoration Assumptions

Inside managed forest:

- Wood placement (scalar of 1.0, 75th percentile of natural loading)
- Barrier removal (includes all barriers in a selected GSU)
- Passive beaver recovery (scalar of 0.1)

Outside managed forest:

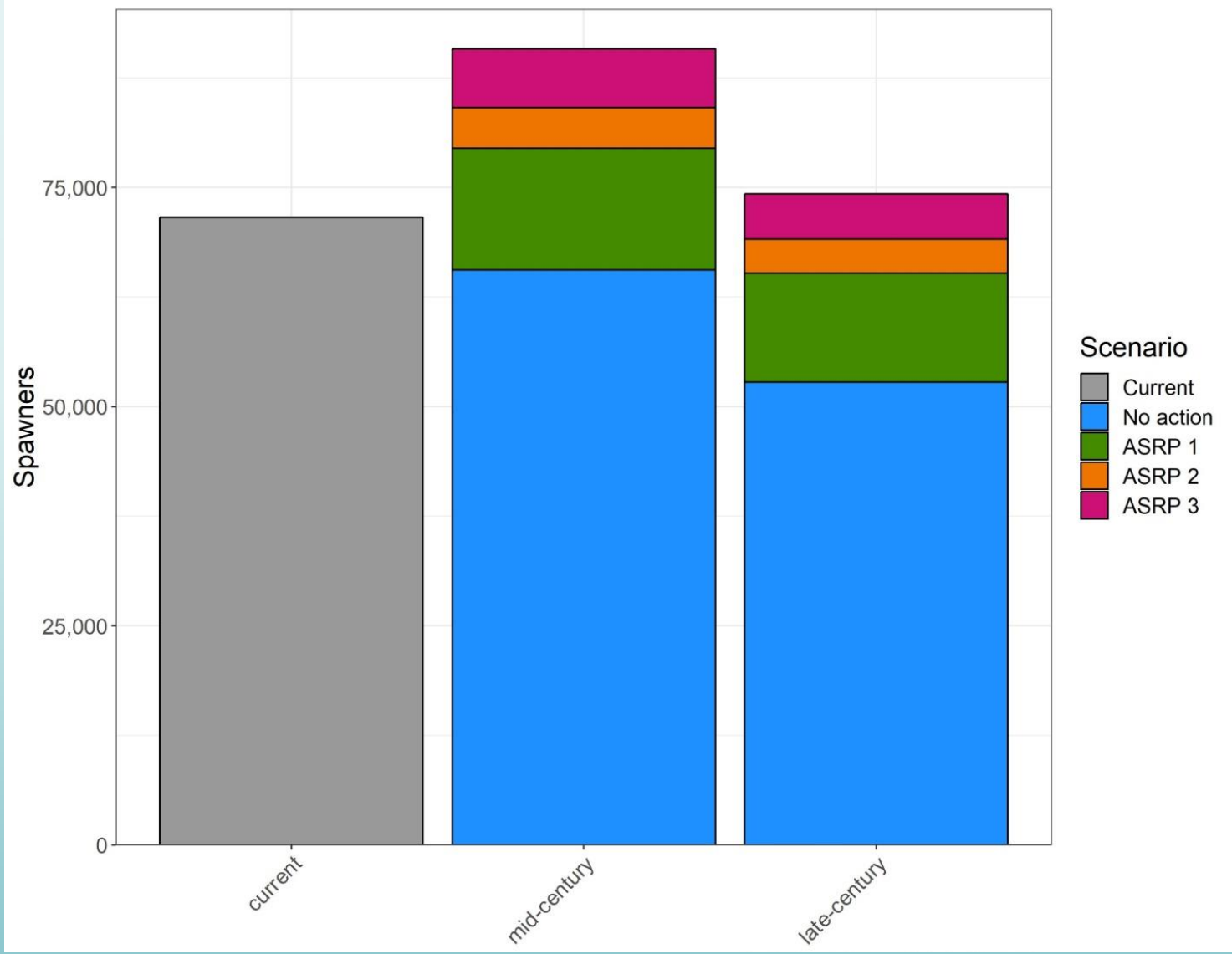
- Wood placement (scalar of 1.0)
  - Small streams: include beaver dam analogs (scalar of 1.0)
- Barrier removal (includes all barriers in a selected GSU)
- Riparian restoration: scalar of 0.75 (accounts for roads and structures)
- Within riparian corridor floodplain is also reconnected, which could include side channels, oxbows, floodplain wetlands (scalar of 1.0)

Coho Salmon

Scenario 1: 13% of coho stream length is treated

Scenario 2: 21% of coho stream length is treated

Scenario 3: 28% of coho stream length is treated

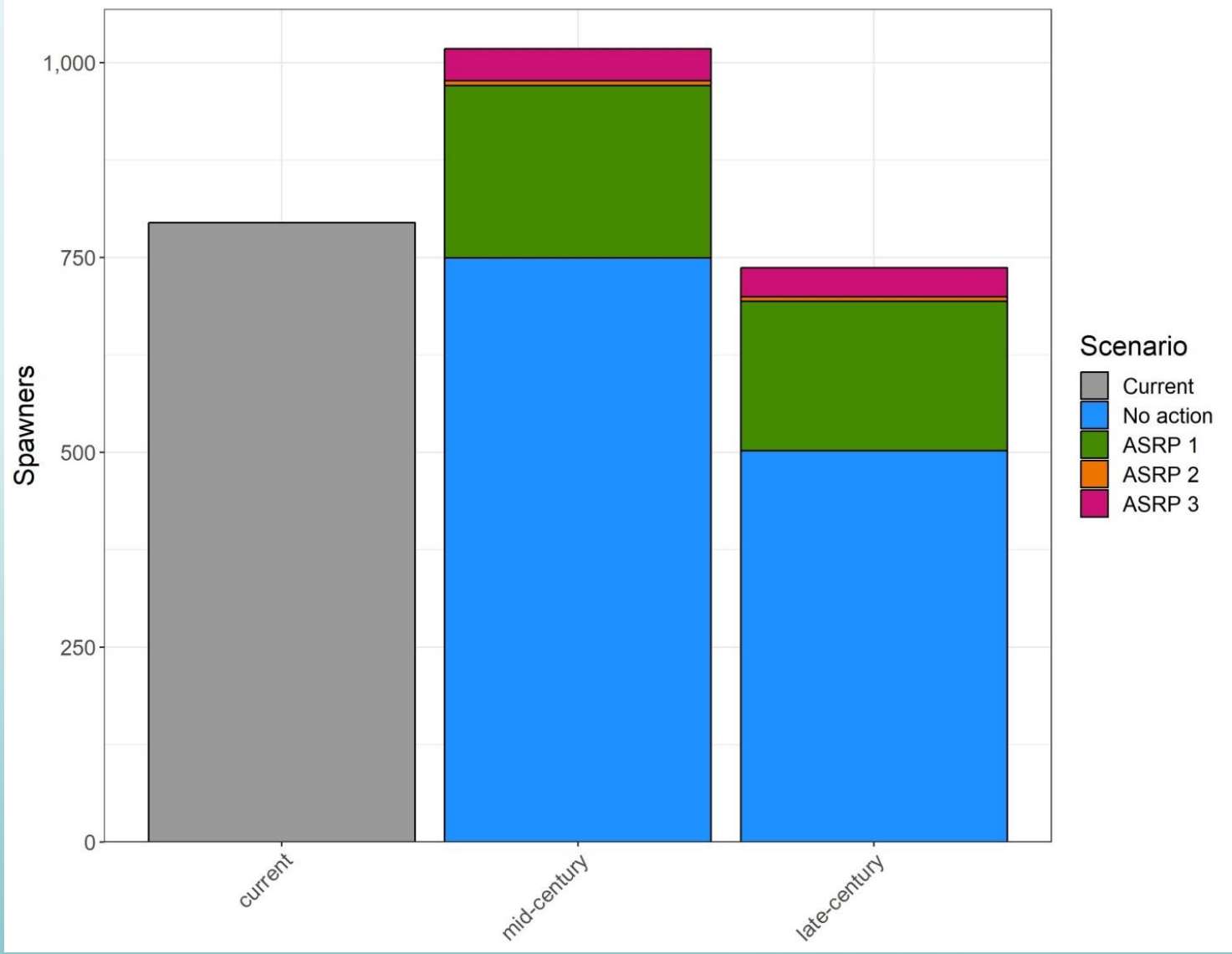


Spring Chinook

Scenario 1:
28% of Sp. Chin. stream length is treated

Scenario 2:
28% of Sp. Chin. stream length is treated

Scenario 3:
44% of Sp. Chin. stream length is treated

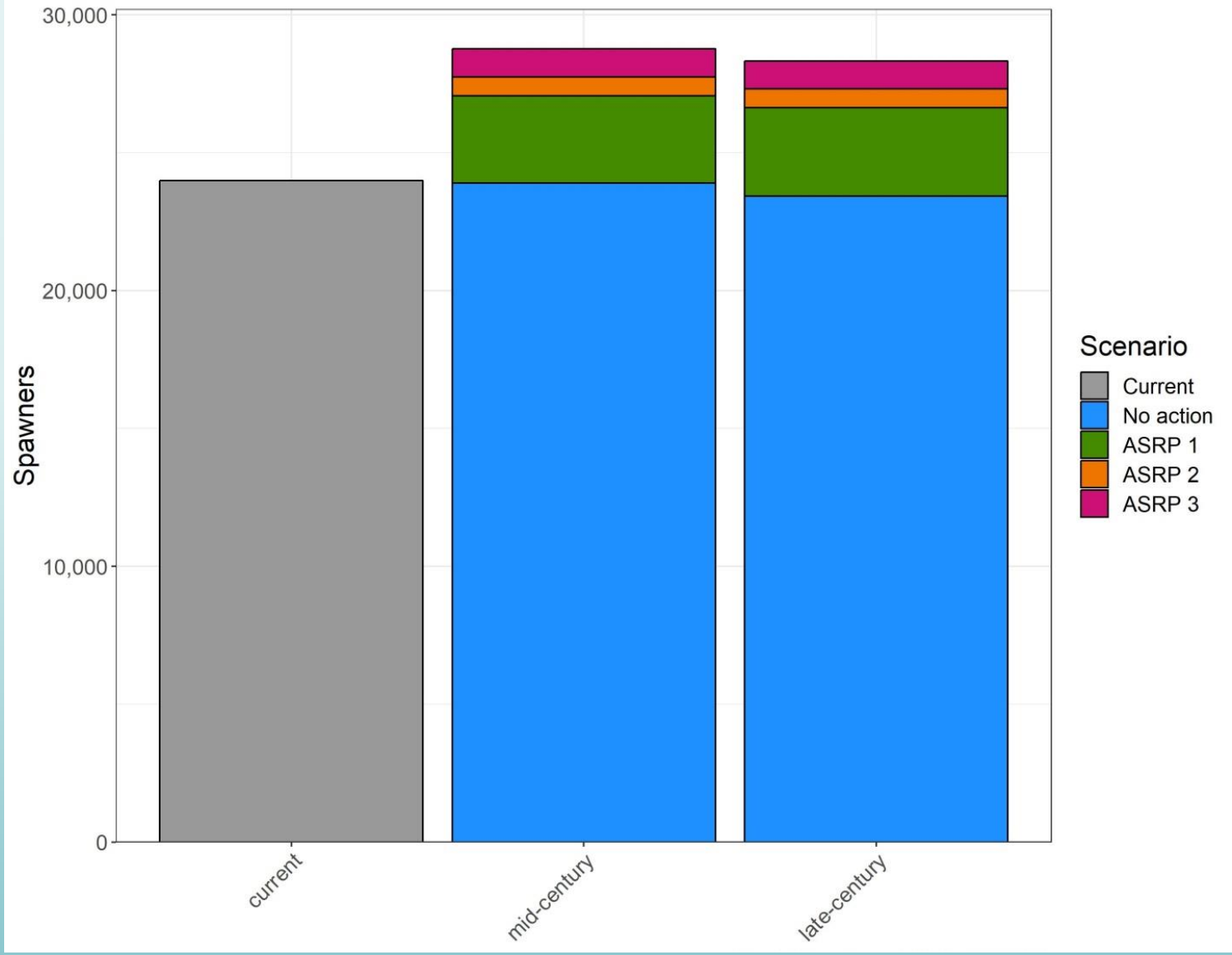


Fall Chinook

Scenario 1: 20% of F. Chin. stream length is treated

Scenario 2: 27% of F. Chin. stream length is treated

Scenario 3: 35% of F. Chin. stream length is treated



Restoration Scenario Summary

- Coho salmon
  - Sensitive to increasing temperature
  - Positive restoration effect by 2040s, near current levels by 2080s
- Spring Chinook
  - Very sensitive to increasing temperature
  - Positive restoration effect by 2040s, but population decline by 2080s
- Fall Chinook
  - Less sensitive to increasing temperature
  - Positive restoration effect by 2040s and 2080s

Next steps

- Complete 2019 report
  - Review comments received, editing now
  - Final report due December 30, 2019
- Complete steelhead model QA/QC
- 2020 updates
  - Updates to habitat data, restoration scenarios?
  - Add stochastic effects of peak flows
  - Complete chum salmon model