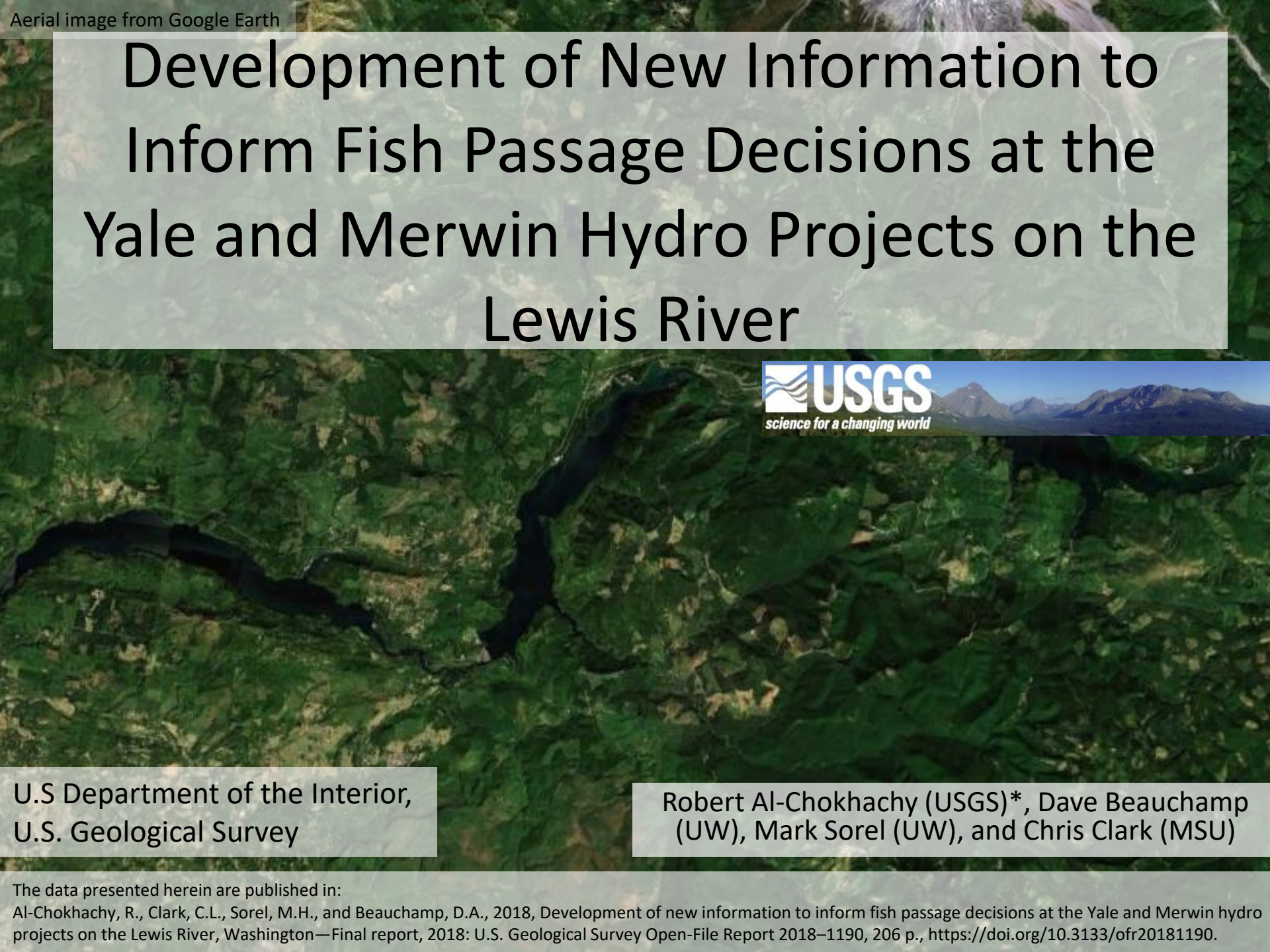

Development of New Information to Inform Fish Passage Decisions at the Yale and Merwin Hydro Projects on the Lewis River

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U.S Department of the Interior,
U.S. Geological Survey

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Outline

1. Project objectives

2. Task-by-task description of methods and results

3. Feasibility modeling

Scope of Work: project tasks

1. Review information regarding fish transport into Lake Merwin and Yale Lake
2. Habitat assessment of tributaries to Yale Lake and Lake Merwin
3. Assessment of adult potential for spawning success
4. Assess juvenile production potential and emigration success
5. Evaluation of Lake Merwin predator impacts
6. Assess anadromous/resident interactions

Scope of Work: project tasks

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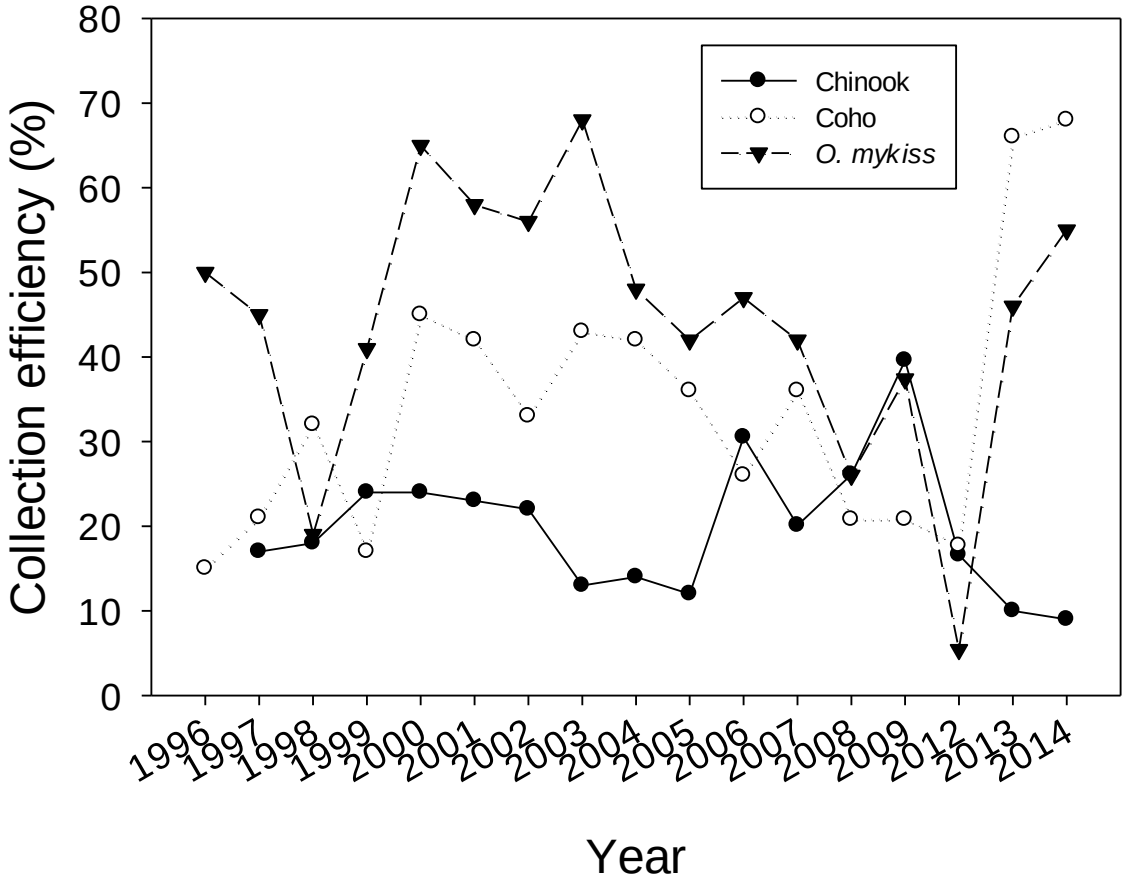
Scope of Work: project tasks

1. **Acclimation facilities**
2. **Downstream collection**
3. **Adult upstream collection**
4. **Community interactions during reintroductions**

Scope of Work: project tasks

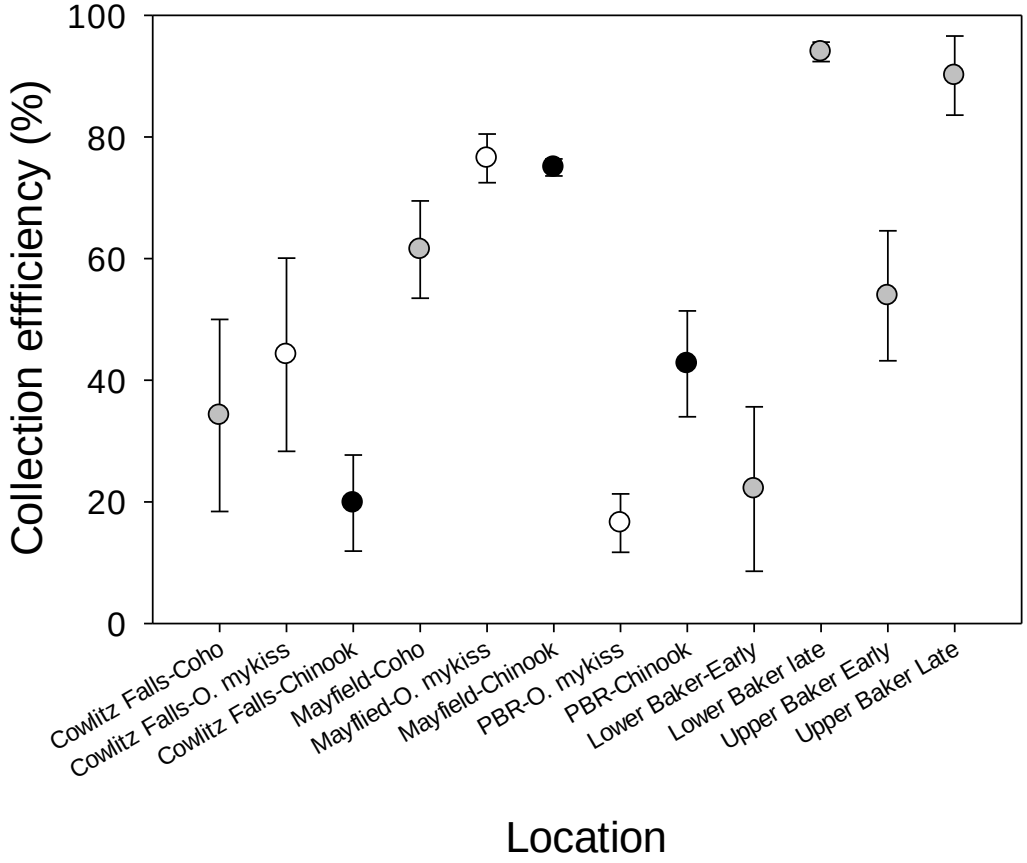
1. Acclimation facilities
2. **Downstream collection**
3. **Adult upstream collection**
4. Community interactions during reintroductions

Task 1-Downstream Collection, *Efficiency*



- Cowlitz Falls
- Variability
  - Annually
  - Between species

Task 1-Downstream Collection, *Efficiency/proportion of collected*



- Differences across locations and species
- Swift Reservoir
  - Coho = 15.2%
  - Chinook ~ 3%
  - Steelhead = 19%

Task 1-Downstream Collection, *Efficiency*

Study Year - 2015

– Results

Metric	Coho Salmon	Spring Chinook	Steelhead	Total
Total tagged (n)	149	14	47	200
Detected at ZOI	100	6	43	159
P_{RES}	67.1%	42.9%	91.5%	79.5%
Captured at FSC	12	0	7	19
Collection Efficacy (P_{CE})	12.0%	0.0%	16.3%	11.9%

– Results: 2014

Metric	Coho Salmon	Spring Chinook	Steelhead	Total
Total tagged (n)	157	20	16	193
Detected at ZOI	31	3	4	38
P_{RES}	19.7%	15.0%	25.0%	19.7%
Captured at FSC	9	0	1	10
Collection Efficacy (P_{CE})	29.0%	0.0%	25.0%	26.3%

- Swift Reservoir
  - Coho = 15.2%
  - Chinook ~ 3%
  - Steelhead = 19%

PacifiCorp and Cowlitz Public Utility District [PUD], 2017, Lewis River fish passage program 2016 annual report: Portland, Oreg., PacifiCorp and Cowlitz Public Utility District, 176 p.

Task 1-Downstream Collection, *Survival and Injury*

River	Facility	Collector type	Survival	SD	n
Baker	Upper Baker	Forebay collector - Surface collector	1	0	4
Clackamas	North Fork	Forebay collector	0.92	0.07	8
		Forebay collector - V-Screen Collector	0.99	0.01	3
	River Mill	Surface spill - Spillway weir	0.99	0.01	3
Columbia	Bonneville	Bonneville floating surface collector	0.86	0.15	21
		Sampled from barge	0.89	0.12	33
Cowlitz	Cowlitz Falls	Forebay collector - retrofit baffle	0.99	0.02	45
	Mayfield	Louver system	0.96	0.02	32
Deschutes	Pelton Round Butte	Guidance net/skimmer	0.98	0.01	14
Willamette	Willamette Falls	Mixed	0.99	0.01	5

Swift FSC

- Average injury = 1.1% (range = 0 – 2.2%)
  - Predominantly descaling (>70%)
- Average survival = 99.3% (range = 92 – 100%)
  - Parr and smolts

Task 1-Downstream Collection, *Survival and Injury*

River	Facility	Species	Survival (%)	SD	n
Cowlitz	Cowlitz Falls	Coastal cutthroat	99.6	0.3	13
	Mayfield	Coastal cutthroat	99.9	-	1
Deschutes	Round Butte	Bull Trout	98.8	0.3	5
		Kokanee	93.5	1.5	5
		Mt. Whitefish	99.9	0.02	5
		Rainbow trout	99.2	1.2	5

Swift	Survival (%)	
Species	2014	2015
Rainbow trout	100	100
Bull Trout	100	90.0
Goldendale	99.7	-
Coastal cutthroat (smolt)	100	99.2
Coastal cutthroat (fry)	99.3	52.9

Task 1-Upstream Collection, *Trap Efficiency*

- Little reported information on upstream trap collection efficiency
- Lewis
  - Recent study at Merwin trap (Caldwell et al. 2017)
    - Trap efficiencies
      - Steelhead = 61%
      - Chinook = 38%
      - Coho = 9%
    - Mortality rates low

Caldwell, L., D. Stroud, F. Carpenter, L. Belcher, M. Morasch, K. Denton, and K. Ross. 2017. Merwin Upstream Passage Adult Trap Efficiency: 2016 Final Report. Prepared by: Cramer Fish Sciences and K. Denton & Associates. Prepared for: Pacific Power (A Division of PacifiCorp).

Task 1: Summary

- Injury rates (upstream and downstream) appear to be relatively low for most years/species

- Proportion of emigrants collected at sites is highly variable-years, sites, species

- Efforts to improve collection are underway-pattern that has continued at other facilities (e.g., Cowlitz Falls)

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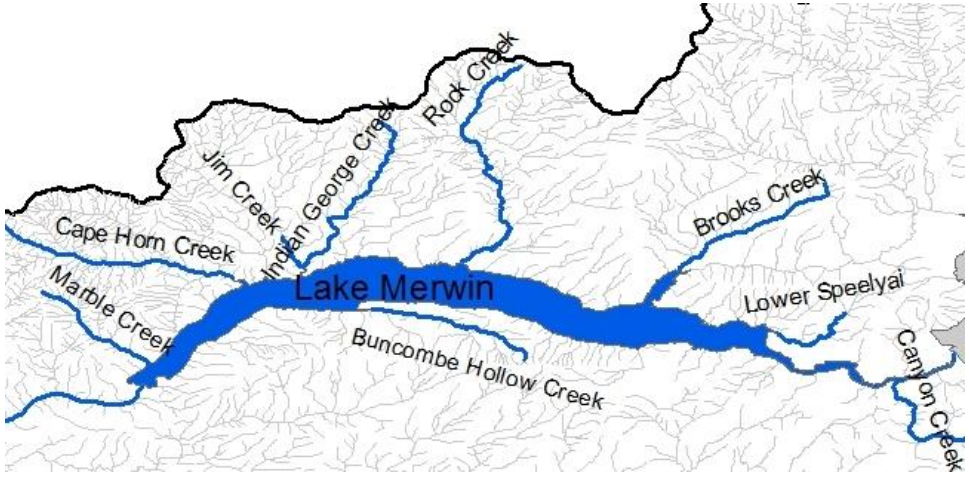
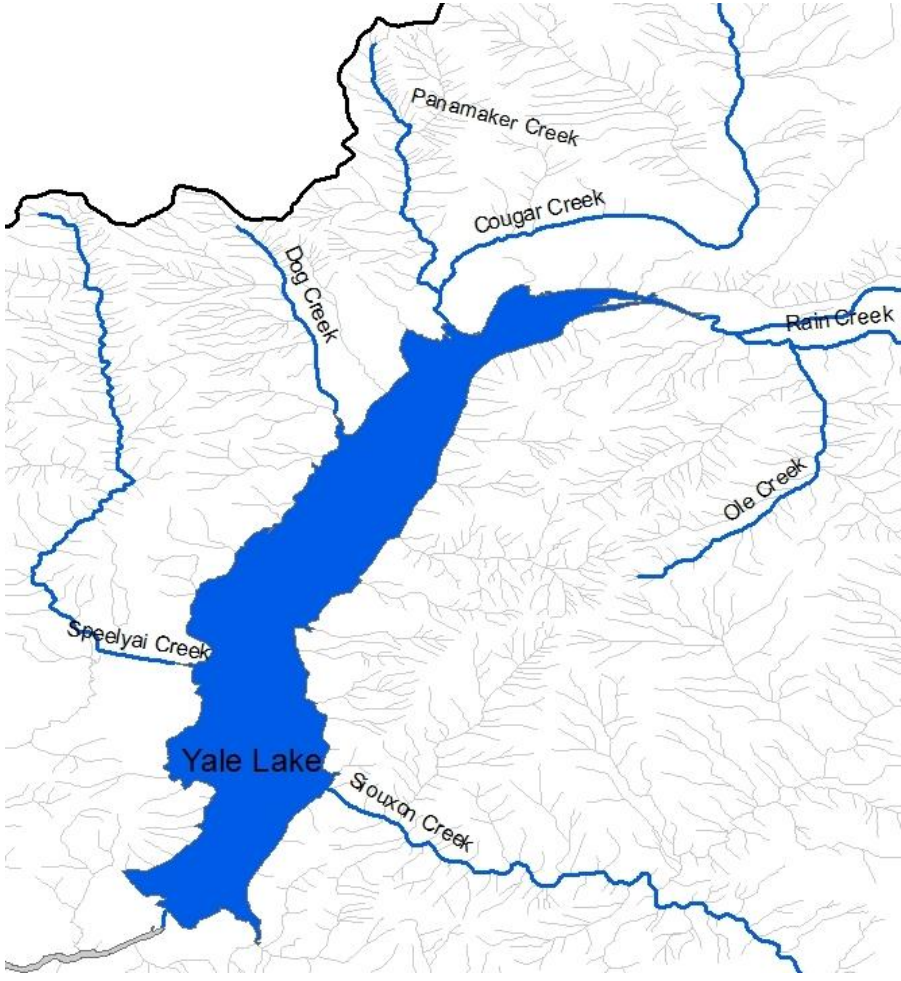
Task 2: Habitat assessment of tributaries to Yale Lake, Lake Merwin, Swift Reservoir





- Study tributaries

Task 2: Habitat assessment of tributaries to Yale Lake, Lake Merwin, Swift Reservoir

- **Objectives and methods**
  - Quantify the extent of habitat within the tributaries-Yale and Merwin
  - Quantify flow and thermal regimes in tributaries
  - Assess tributary habitat and riparian conditions
  - Rerun EDT model with quantitative field-bases measures of habitat

Task 2: Habitat assessment of tributaries to Yale Lake and Lake Merwin

Quantify flow and thermal regimes in tributaries

- Methods:
  - Install pressure transducers at top and bottom of tributaries
  - Quantify stage-discharge relationships

Photo: R. Al-Chokhachy, USGS

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Task 2: Habitat assessment of tributaries to Yale Lake, Lake Merwin, Swift Reservoir

Assess tributary habitat and riparian conditions

- Methods:
  - Utilize existing habitat protocols within the PNW (CHaMP)
  - Continuous habitat surveys
    - Given site-site variability in reach-based assessments

Channel unit attributes

- Habitat attributes
  - Bankfull width, wetted width, depth
  - Substrate
  - Channel units
  - Large woody debris
  - Gradient
  - Riparian condition
- All georeferenced

- Collected specifically for parameterizing EDT model

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Photo: R. Al-Chokhachy, USGS

Task 2: Habitat assessment-Extent of habitat in Merwin and Yale

	Stream	Length (km)	Gradient (%)
Lake Merwin	Brooks Creek/B1	4.1	4.4 (2.4)
	Buncombe Hollow Creek	1.1	3.2 (1.8)
	Cape Horn Creek	0.5	5.2 (0.9)
	Indian George Creek	1.5	5.7 (1.8)
	Jim Creek	0.5	4.7 (1.1)
	Lower Speelyai	0.3	2.8 (0)
	Rock Creek	0.2	na
Total		**8.2**	
Yale Lake	Cougar Creek	3.9	1.6 (0.9)
	Dog Creek	0.3	4.9 (0)
	North Siouxon Creek	0.7	7.0 (2.7)
	Ole Creek	1.7	2.0 (1.7)
	Panamaker Creek	0.4	-
	Siouxon Creek	6.1	2.1 (2.3)
	Speelyai Creek	6	6.2 (4.4)
	Swift Bypass Channel	6.5	0.7 (0.5)
	W. Fork Speelyai Creek	1.3	10.7 (2.5)
	W. Tributary Speelyai CK	1.1	9.0 (5.6)
Total		**28**	

Photo: R. Al-Chokhachy, USGS

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Task 2: Habitat assessment

Swift

Stream	Bedrock	Boulder	Cobble	Gravel	Fines
Chickoon Creek	31.4	11.8	48.3	8	0.5
Clear Creek	0	4	60.4	28.1	5.7
Cussed Hollow Ck	24.9	12.7	45.2	10.4	2.1
Diamond Creek	0	36.4	46.3	17.2	0
Little Creek	0	0	24.5	21.7	53.7
P3 creek	0	50	22	16	12
P7 creek	0	18.4	53.5	24.2	2
Pepper Creek	6	9.2	52	28.3	3.2
Range Creek	2.5	49.3	28.9	14.5	0
S15 creek	7.8	60.9	28.6	2.7	0
S20 creek	0	23.7	73.8	1.8	0.7
Spencer Creek	5.9	30.6	56.5	7	0
Upper Lewis Creek	6.2	17.8	60.7	14.5	0.6

Lake Merwin

Stream	Bedrock	Boulder	Cobble	Gravel	Fines
Brooks Ck	0.5	7.4	25.9	57.7	7.4
Buncombe Hollow Ck	38.2	0	22	33.1	6.6
Cape Horn Creek	27.4	15.4	31.1	19.8	6.4
Indian George Creek	5.1	5.9	43.7	42.4	1.8
Jim Creek	20.4	13.5	22.1	37.7	5.9
Lower Speelyai	0	6.4	15.5	53.6	15.5

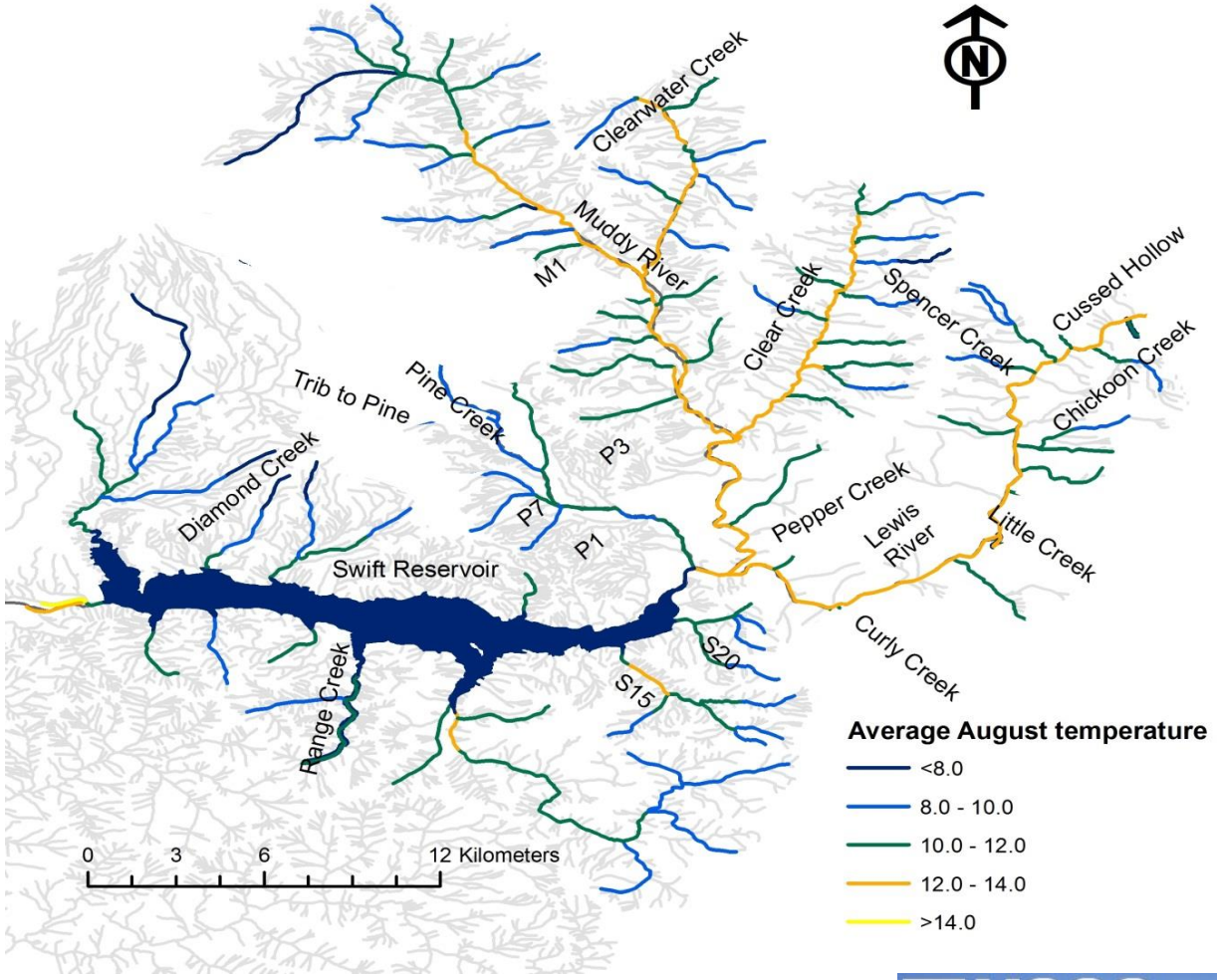
Yale Lake

Cougar Creek	0	0.9	34.4	52.7	3.5
Dog Creek	0	23.6	31.8	35.5	9.1
North Siouxon Creek	16.7	58.3	13.3	11.7	0
Ole Creek	0	14	52.7	32.3	1
Panamaker Creek	10	12.4	57.1	20	0
Siouxon Creek	13.3	46.1	33.3	7.2	0
Speelyai Creek	4.7	38	40.8	11.3	0.6
Bypass Channel	0.4	26.7	57	10.8	4.2
W. Fork Speelyai Ck	2	59.5	30.6	7.9	0
W. Tributary Speelyai	0.5	34.7	48.1	15.4	0.1

Task 2: Temperature in Merwin and Yale

		July		August	
Reservoir	Stream	Avg.	Range	Avg.	Range
Lake Merwin	Brooks Creek	13.8	12.4 - 19.4	13.8	12.8 - 14.8
	Buncombe Hollow Creek	**17.0**	**14.9 - 19.1**	**17.5**	**15.6 - 19.0**
	Cape Horn Creek	14.2	12.4 - 15.8	14.9	13.5 - 16.2
	Indian George Creek	15.1	13.1 - 16.7	16.0	14.7 - 17.1
	Jim Creek	14.9	13.1 - 16.4	15.6	14.3 - 16.6
	Lower Speelyai	-	-	-	-
Yale Lake	Cougar Creek	7.3	7.1 - 7.7	7.4	7.1 - 7.6
	Dog Creek	12.7	11.2 - 14.1	-	-
	North Siouxon Creek	13.8	11.4 - 15.6	15.3	14.1 - 16.3
	Ole Creek	13.4	11.5 - 14.7	14.7	13.6 - 15.4
	Panamaker Creek	12.7	11.1 - 13.9	14.4	13.7 - 14.9
	Siouxon Creek	**15.4**	**12.4 - 17.7**	**16.9**	**14.9 - 18.6**
	Speelyai Creek	**15.0**	**12.8 - 17.0**	**16.8**	**15.0 - 17.8**
	Swift Bypass Channel	12.3	11.0 - 13.1	13.4	12.4 - 14.3
	W. Fork Speelyai Creek	13.6	11.6 - 15.3	15.0	13.4 - 15.9
	W. Tributary Speelyai Ck	14.4	12.3 - 16.4	15.5	13.9 - 16.9

Task 2: Swift temperature



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Task 2: Habitat Assessment Summary

- Empirical data used to parameterize EDT model including new data (USGS), USFS, and Meridian

- High quality habitat in tributaries

- The extent of habitat in Lake Merwin (8.2 km) is low suggesting limited capacity for reintroductions

Scope of Work: project tasks

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3. **Assessment of adult potential for spawning success in Yale and Merwin**
4. Assess juvenile production potential and emigration success
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Task 3: Merwin adult potential for spawning success-Methods

- Capacity for adults to access and successfully reproduce

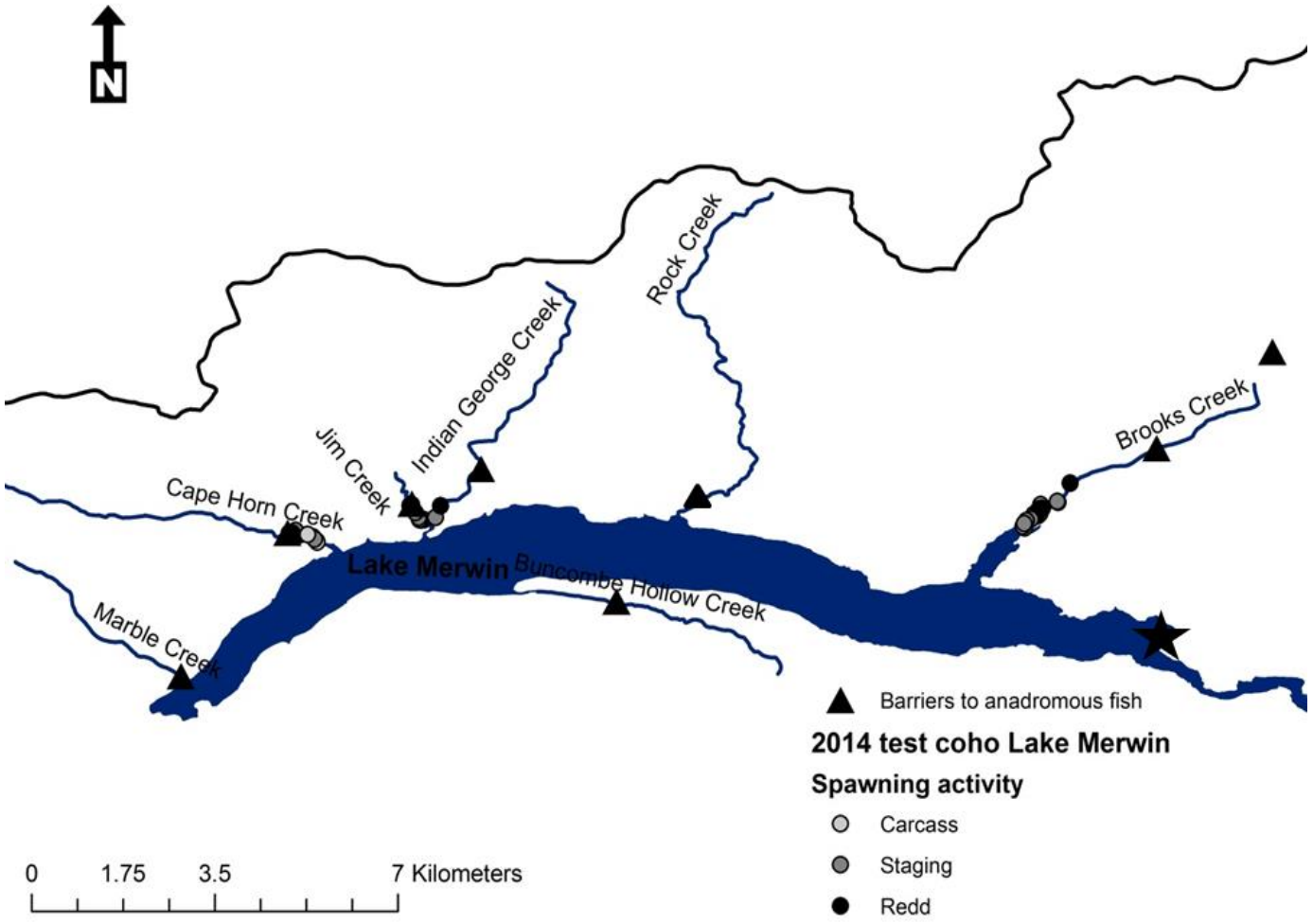
Task 3: Merwin adult potential for spawning success-Methods

- Capacity for adults to access and successfully reproduce
  - 2014 only
  - ~300 test adult Coho
- Identify locations of spawning
  - Weekly redd surveys of all available habitat
- Juvenile surveys in tributaries with spawning activity in 2015

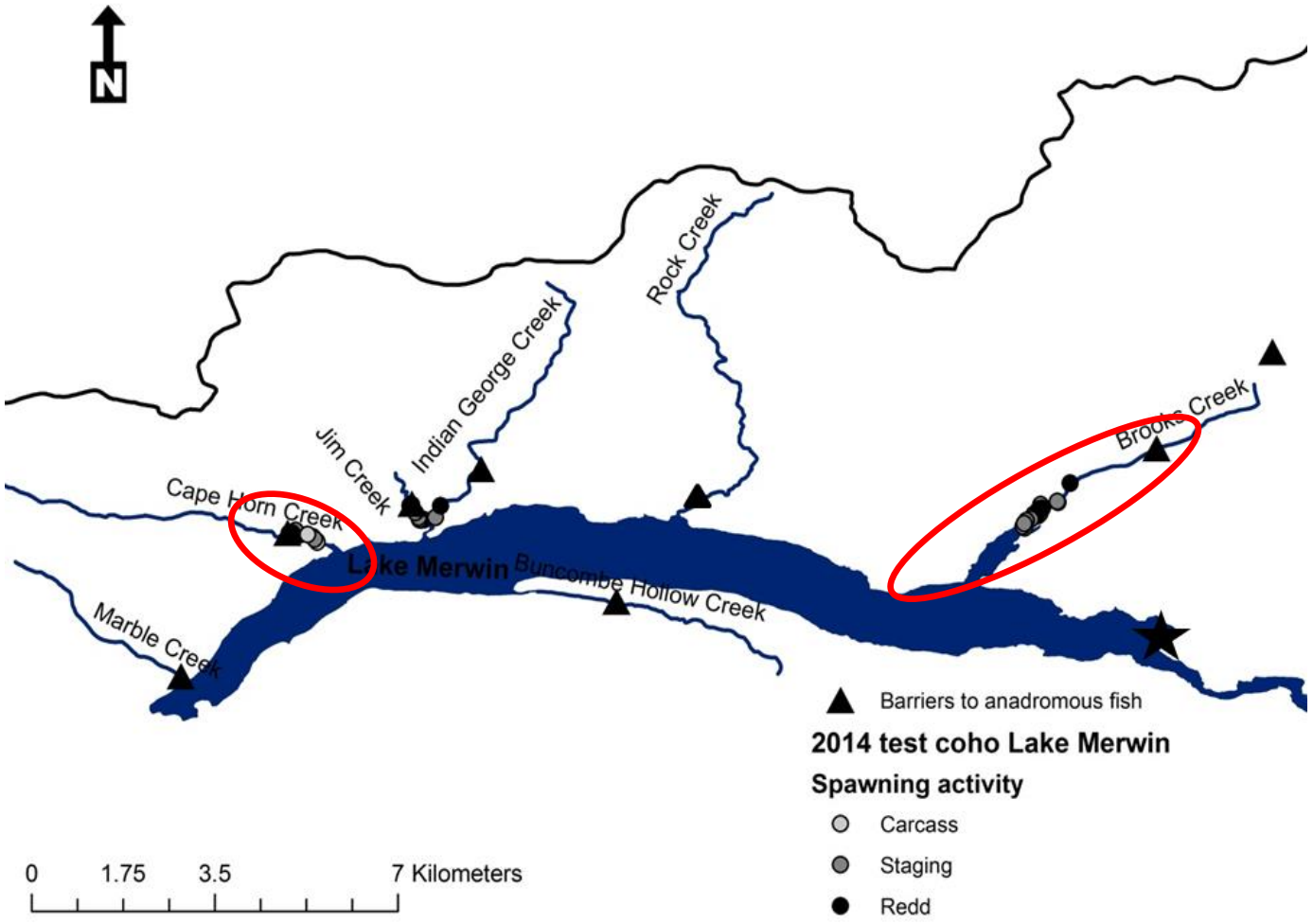
Task 3: Merwin adult potential for spawning success-Methods

- Capacity for adults to access and successfully reproduce
- Identify locations of spawning
- Juvenile surveys in tributaries with spawning activity in 2015
  - Snorkel surveys and electrofishing surveys

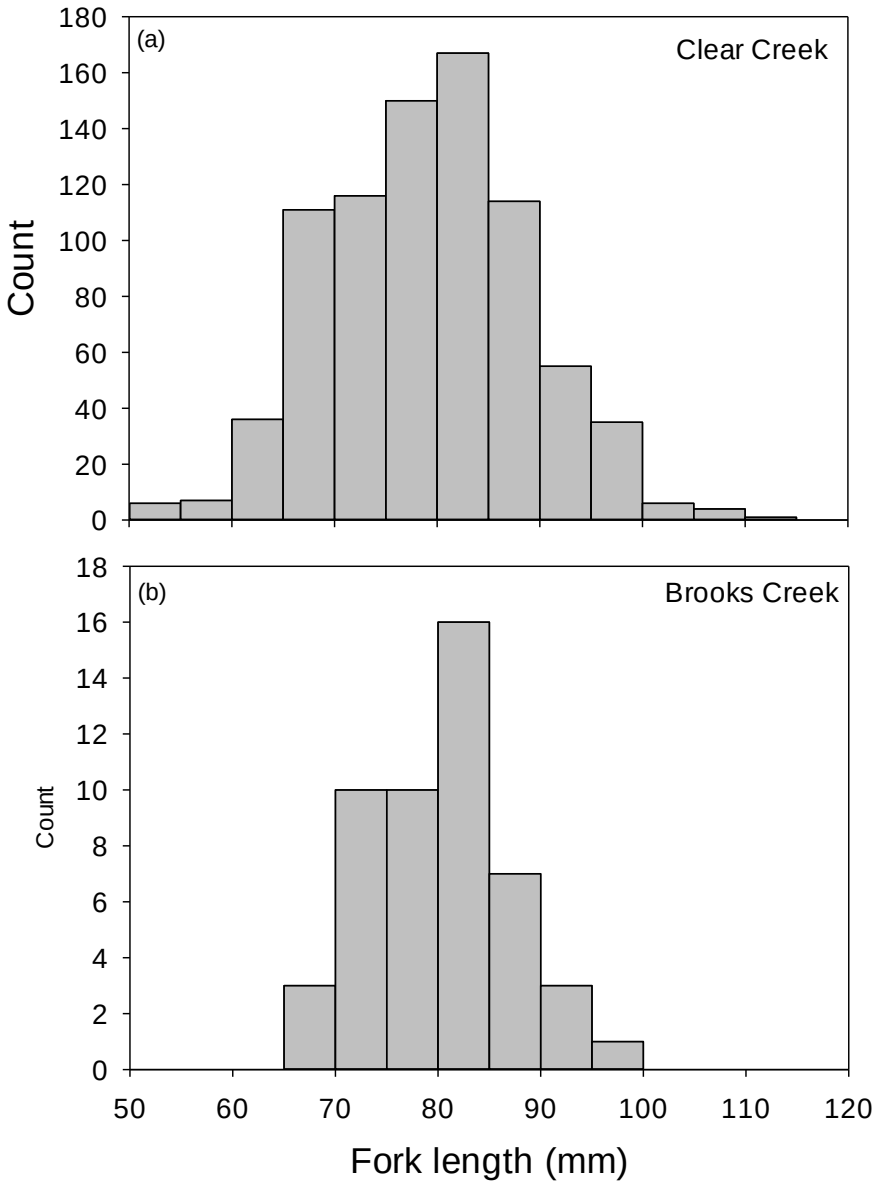
Task 3: Merwin adult spawning (2014)

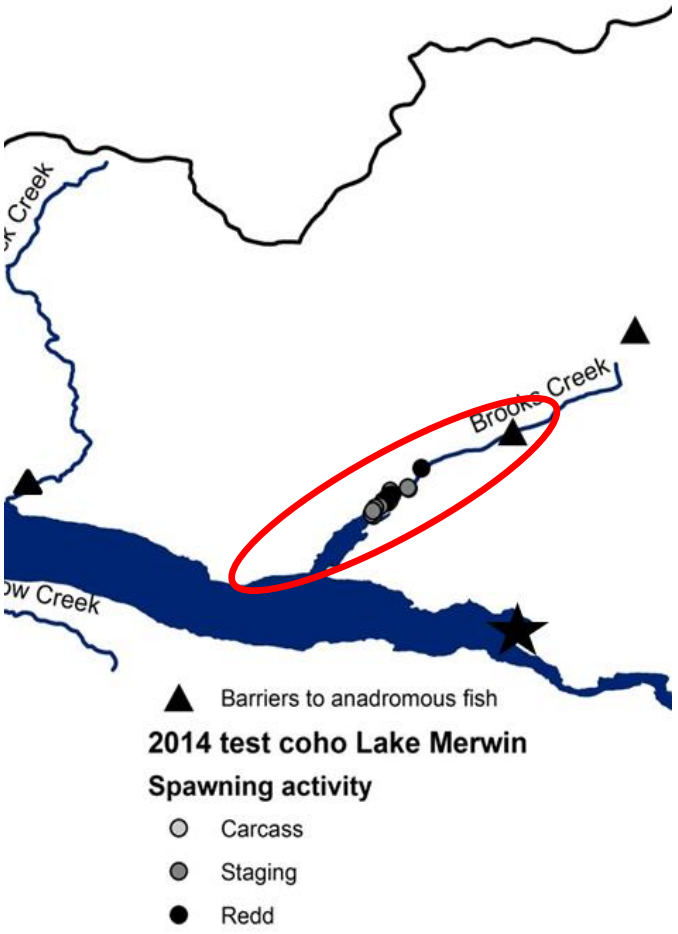


Task 3: Merwin-2015 juvenile surveys

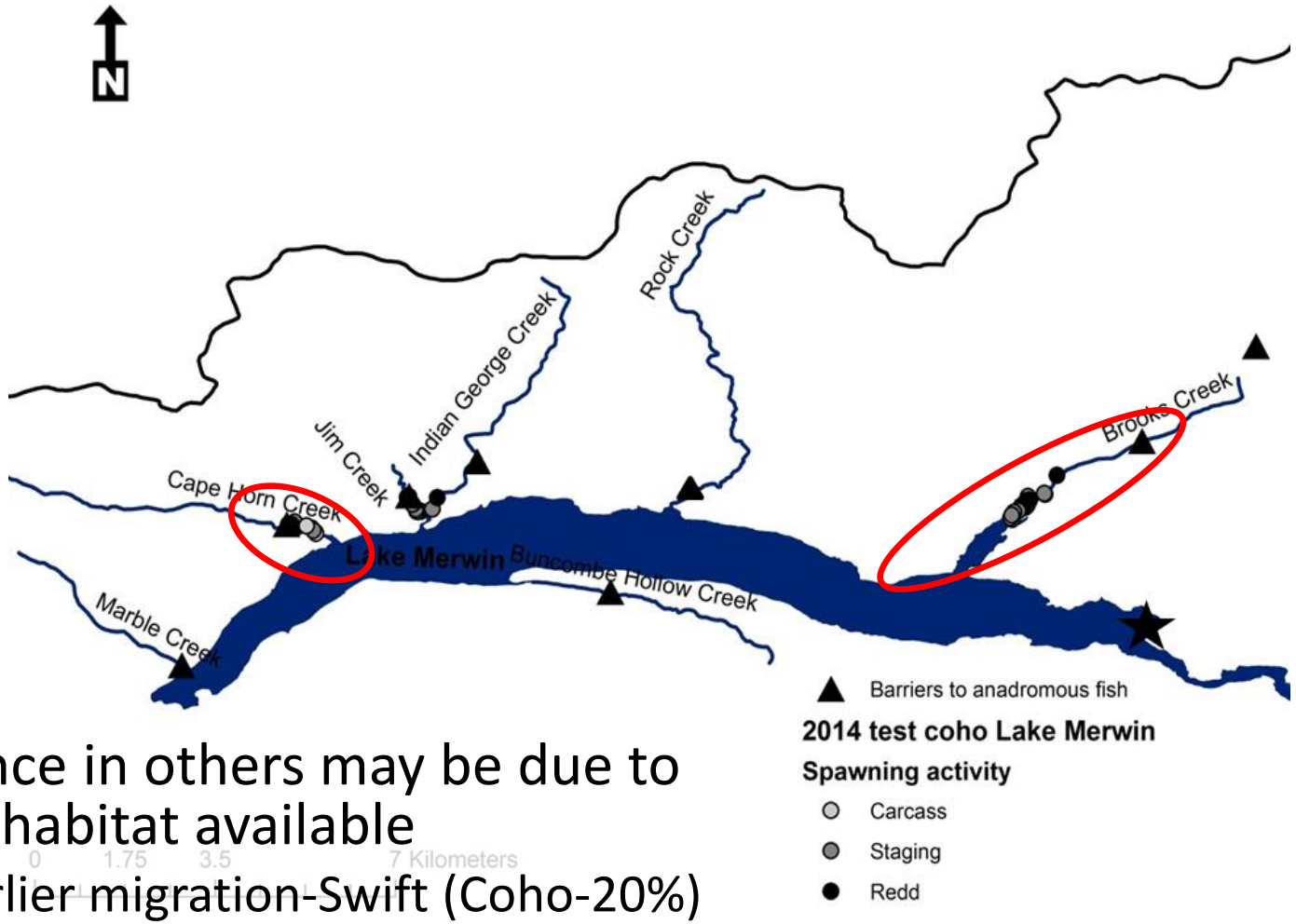


15 juvenile surveys



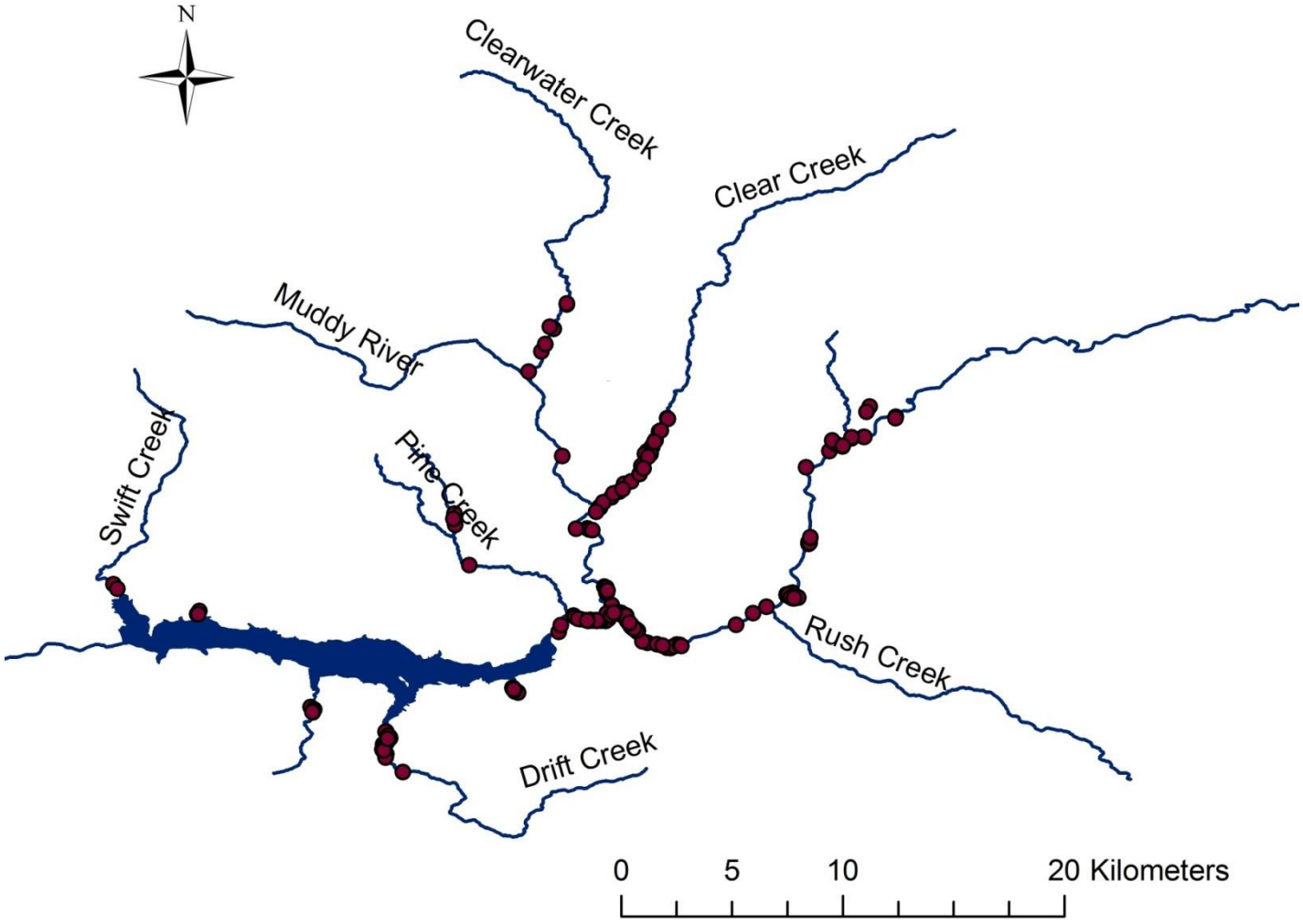


Task 3: Merwin-2015 juvenile surveys



- Absence in others may be due to short habitat available
  - Earlier migration-Swift (Coho-20%)
  - Longer reservoir residence

Task 3: Spawning patterns Swift



Task 3: Spawning habitat

Lake Merwin					
Stream	Bedrock	Boulder	Cobble	Gravel	Fines
Brooks Ck	0.5	7.4	25.9	57.7	7.4
Buncombe Hollow Ck	38.2	0	22	33.1	6.6
Cape Horn Creek	**27.4**	**15.4**	**31.1**	**19.8**	**6.4**
Indian George Creek	5.1	5.9	43.7	42.4	1.8
Jim Creek	20.4	13.5	22.1	37.7	5.9
Lower Speelyai	0	6.4	15.5	53.6	15.5
Yale Lake					
Cougar Creek	0	0.9	34.4	52.7	3.5
Dog Creek	0	23.6	31.8	35.5	9.1
North Siouxon Creek	16.7	58.3	13.3	11.7	0
Ole Creek	0	14	52.7	32.3	1
Panamaker Creek	10	12.4	57.1	20	0
Siouxon Creek	**13.3**	**46.1**	**33.3**	**7.2**	**0**
Speelyai Creek	4.7	38	40.8	11.3	0.6
Bypass Channel	0.4	26.7	57	10.8	4.2
W. Fork Speelyai Ck	2	59.5	30.6	7.9	0
W. Tributary Speelyai	0.5	34.7	48.1	15.4	0.1

Photo: R. Al-Chokhachy, USGS

Task 3: Summary

- Test fish and empirical data from Swift suggest variety of habitats (spatially) will be utilized by reintroduced anadromous Salmon

- Habitat is generally in good condition-spawning gravel in some locations may be too large, but fines are not limiting

- Lack of YOY in tributaries with spawning may be due to early life-stage emigration, leading to increased reservoir rearing (capacity, Task 6)and potential predation effects (Task 5)

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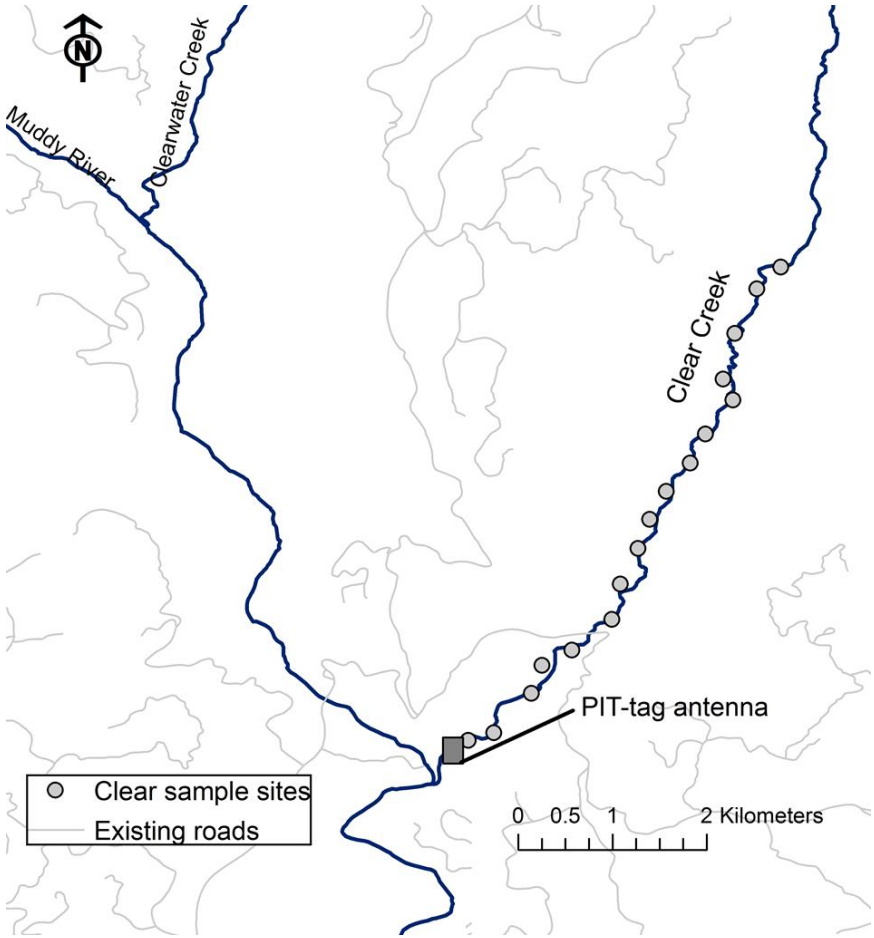
Task 4: Assess juvenile production potential and emigration success

- **Objectives and methods**
  1. Determine emigration timing into Swift Reservoir
  2. Quantify behavioral relationships with streamflow, temperature, and interannual differences
  3. Quantify travel times and survival to collection facility
  4. Evaluate reservoir behavior

Task 4: Methods-stream habitat



- Determine emigration timing into Swift Reservoir
  - **Wild Coho**
  - 20 reaches per year-5 km of habitat
    - Marking fish with 12 mm PIT-tag
      - 2013 = 357 fish
      - 2014 = 883 fish
      - 2015 = 800 fish

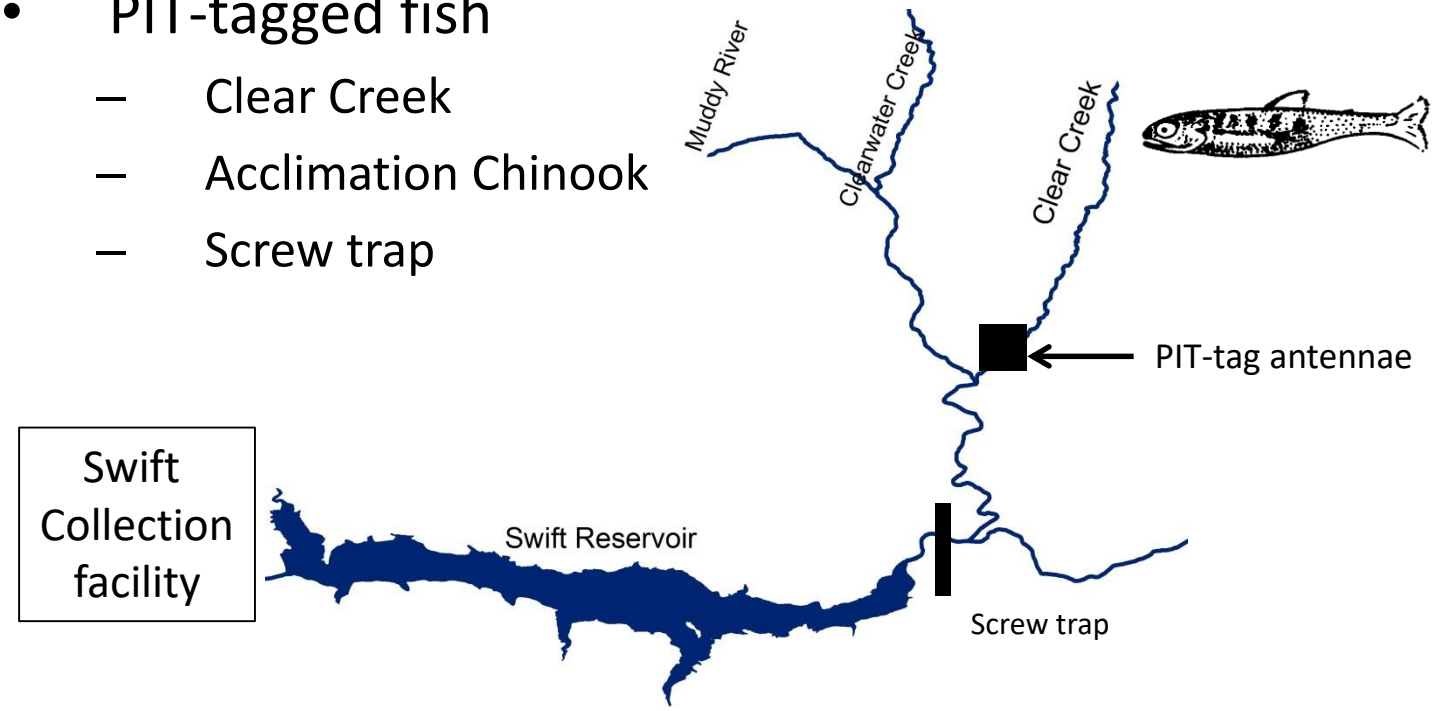
Task 4: Methods-stream habitat

- Determine emigration timing into Swift Reservoir
  - Wild Coho
  - **Releases PIT-tagged acclimation Chinook**
    - Acclimation ponds
  - Migration timing

Year	Species	Clear Creek	Crab Creek	Muddy River
2013	Chinook	1,750	750	1,750
	Coho			2,000
2014	Chinook	7,576[1]		
2015	Chinook	3,400	3,300	3,300

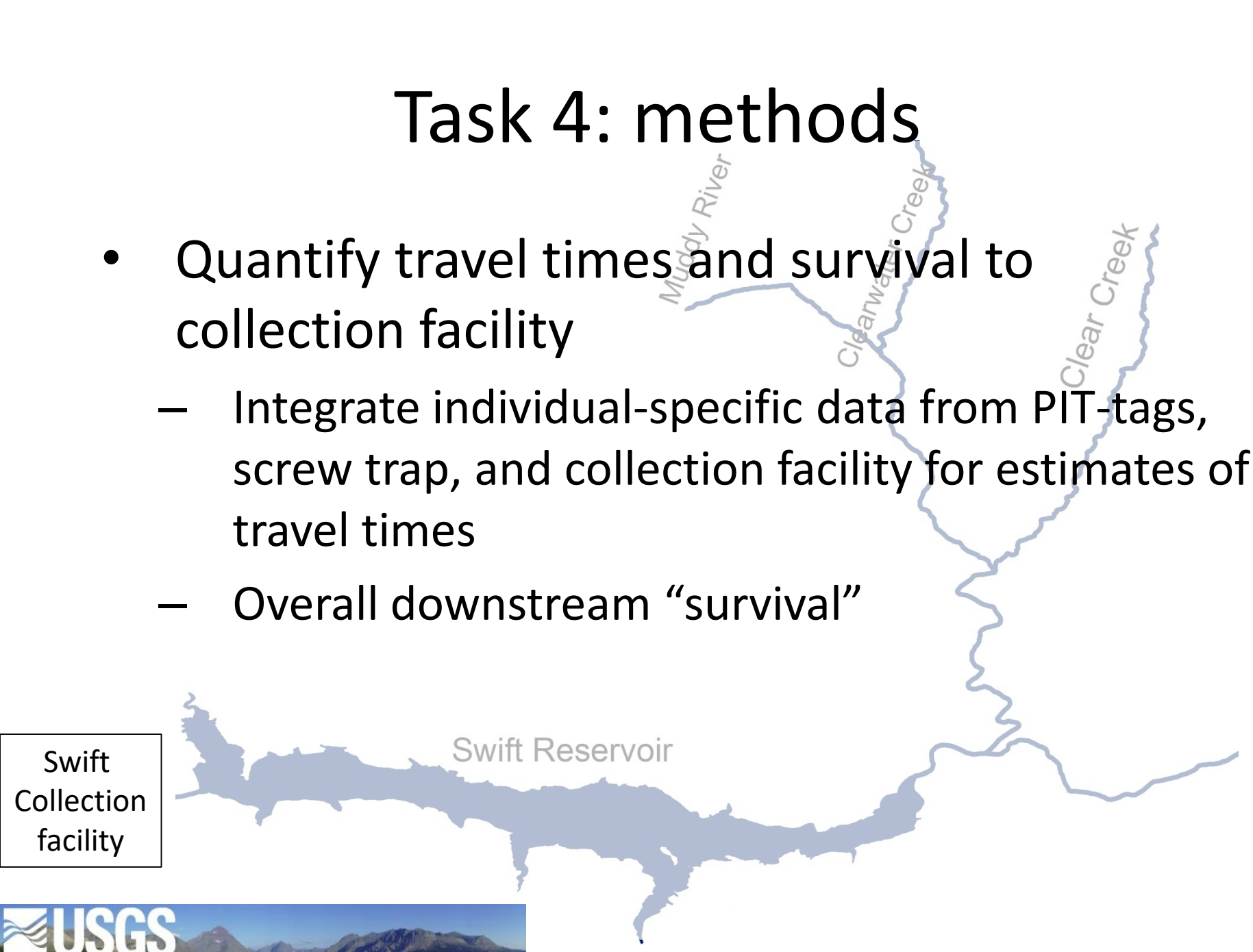
Task 4: methods

- Quantify travel times and survival to collection facility
  - PIT-tagged fish
    - Clear Creek
    - Acclimation Chinook
    - Screw trap



Task 4: methods

- Quantify travel times and survival to collection facility
  - Integrate individual-specific data from PIT-tags, screw trap, and collection facility for estimates of travel times
  - Overall downstream “survival”

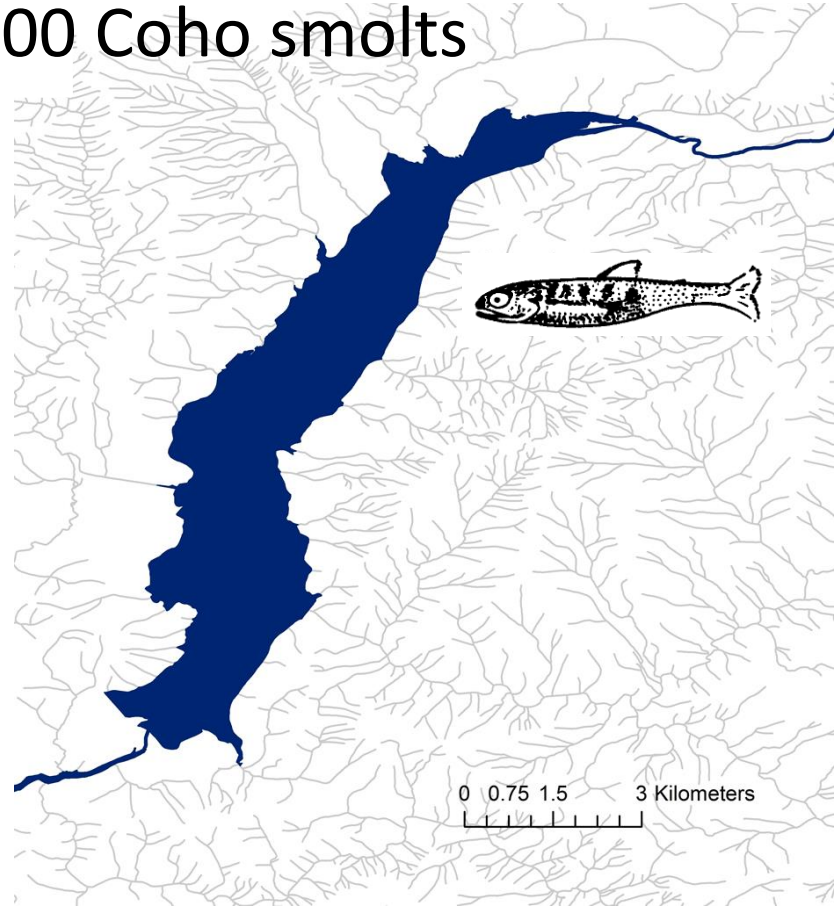


Task 4: methods **reservoir**

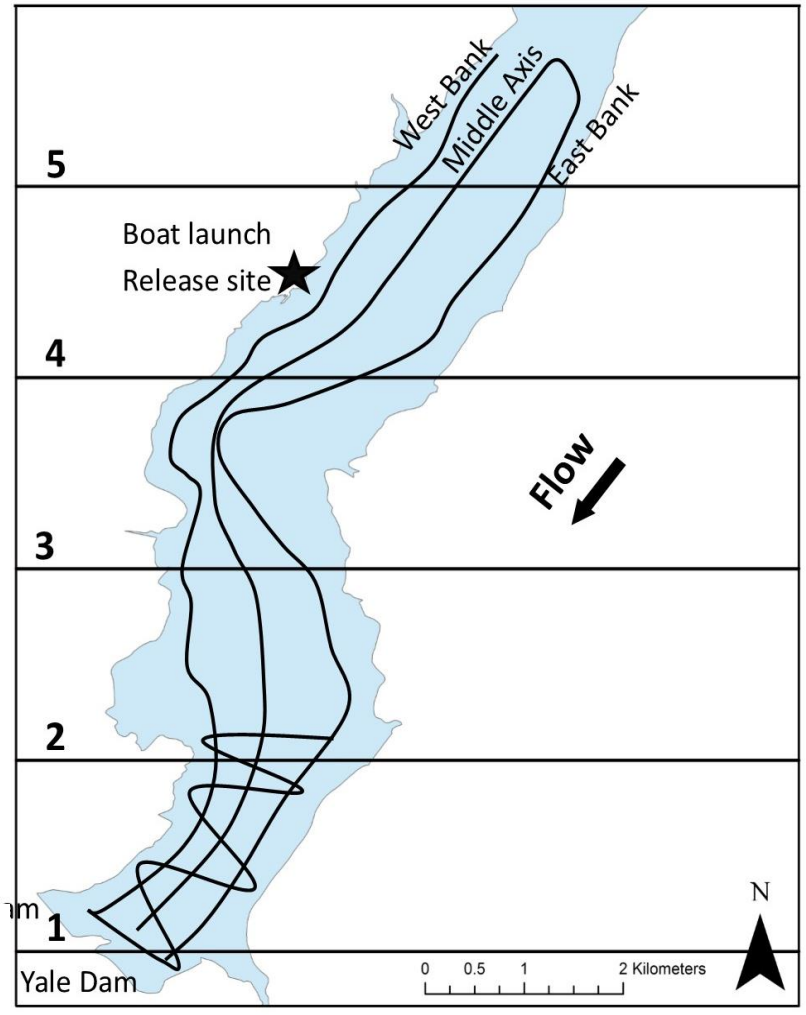
- Evaluate travel behavior and near potential collection facilities
  - Yale Lake
  - Compliment PIT-tag data and previous radiotelemetry data for assessments of variability of travel times
  - Depth use near dam~potential collection facility

Task 4: methods **reservoir**

- Evaluate travel behavior and near potential collection facilities
  - 2014 test release of 5,000 Coho smolts
    - Release at Yale Park



Task 4: methods **reservoir**



- Evaluate travel behavior and near potential collection facilities
  - 2014 (5,000 Coho smolts)
  - Hydroacoustic surveys (UW)
    - Pre-release
    - Day of release
      - Near Yale Park to identify targets
    - Post-release

Task 4: Results

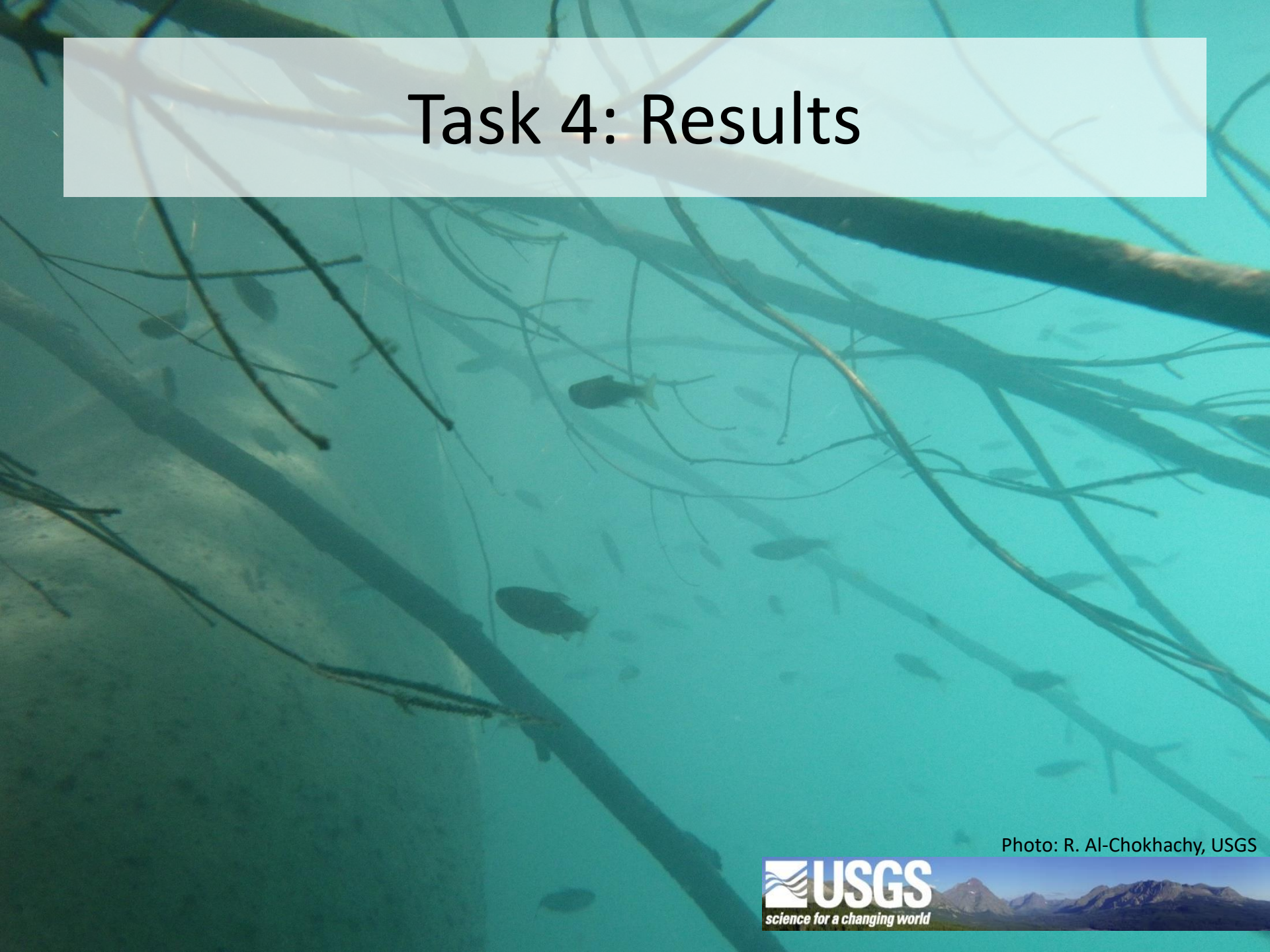


Photo: R. Al-Chokhachy, USGS

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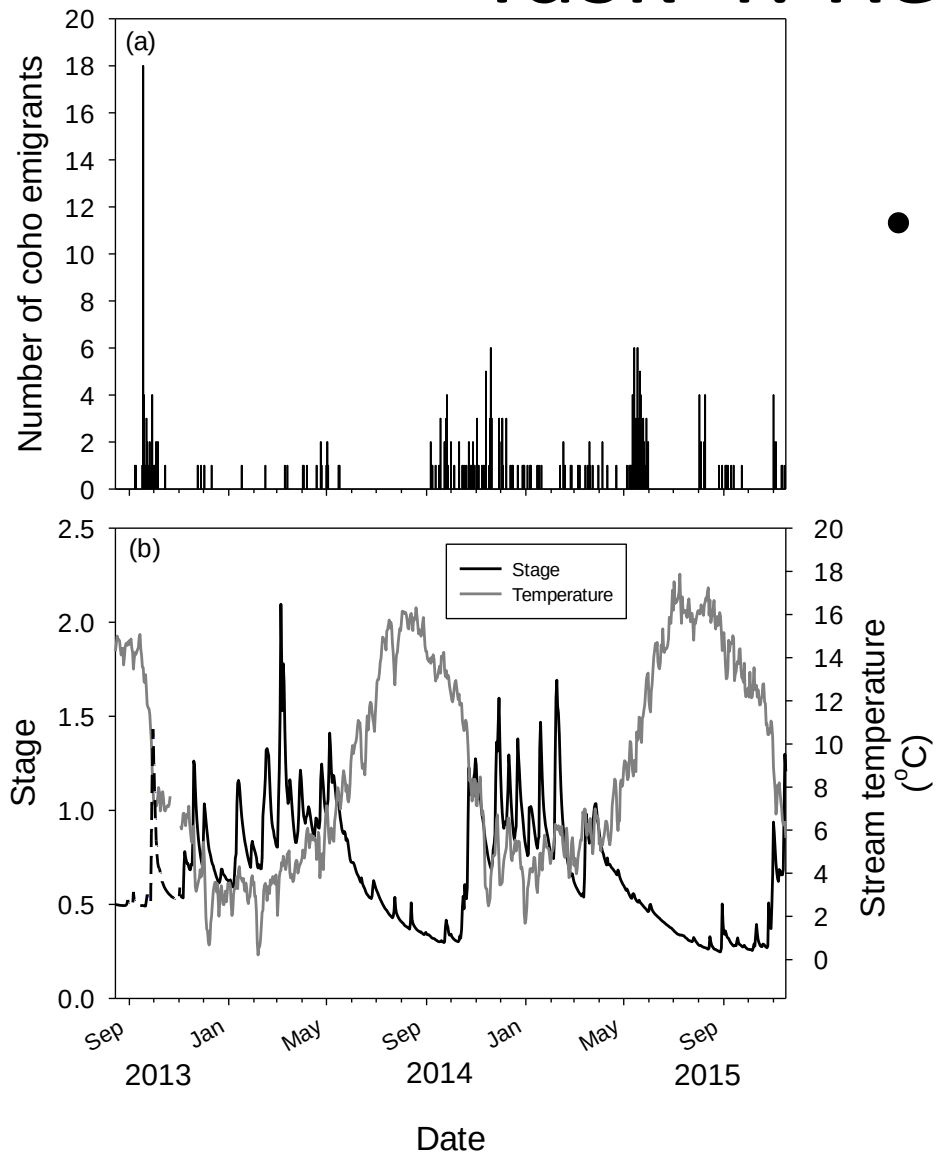
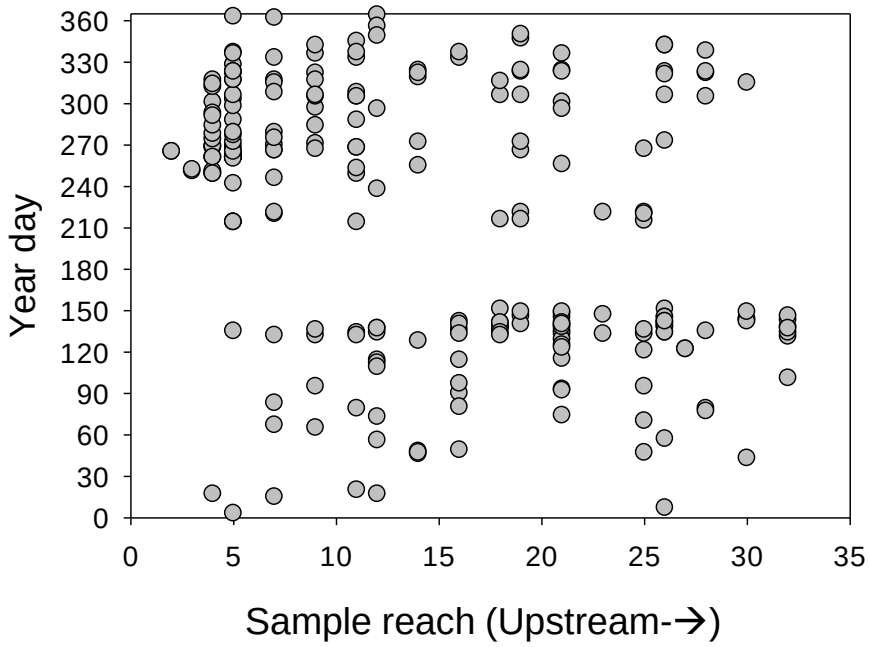
Task 4: Results-Coho



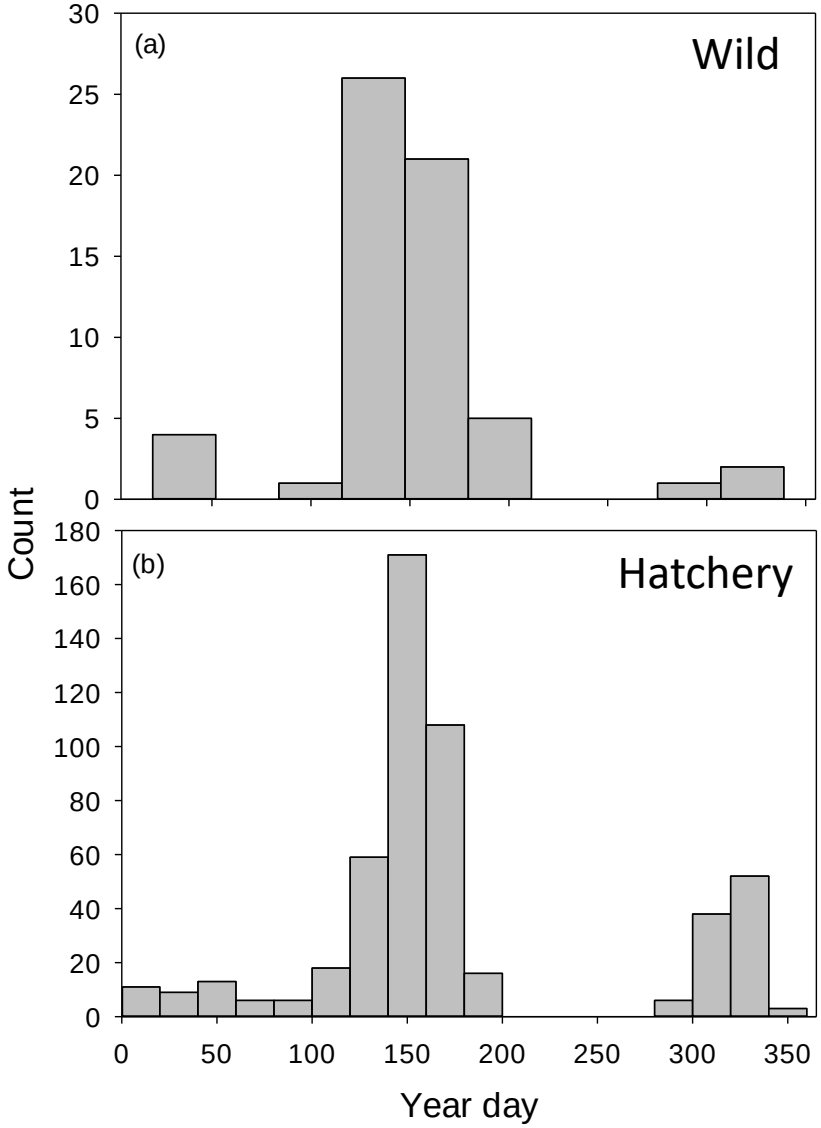
- Emigration timing varied considerably across years
  - 2013-high flow event
  - 2014-mixed results
    - Association with high flow events similar to Pess et al. (2011)
      - No summer emigration-Mid-May-early August

Task 4: Results-Coho



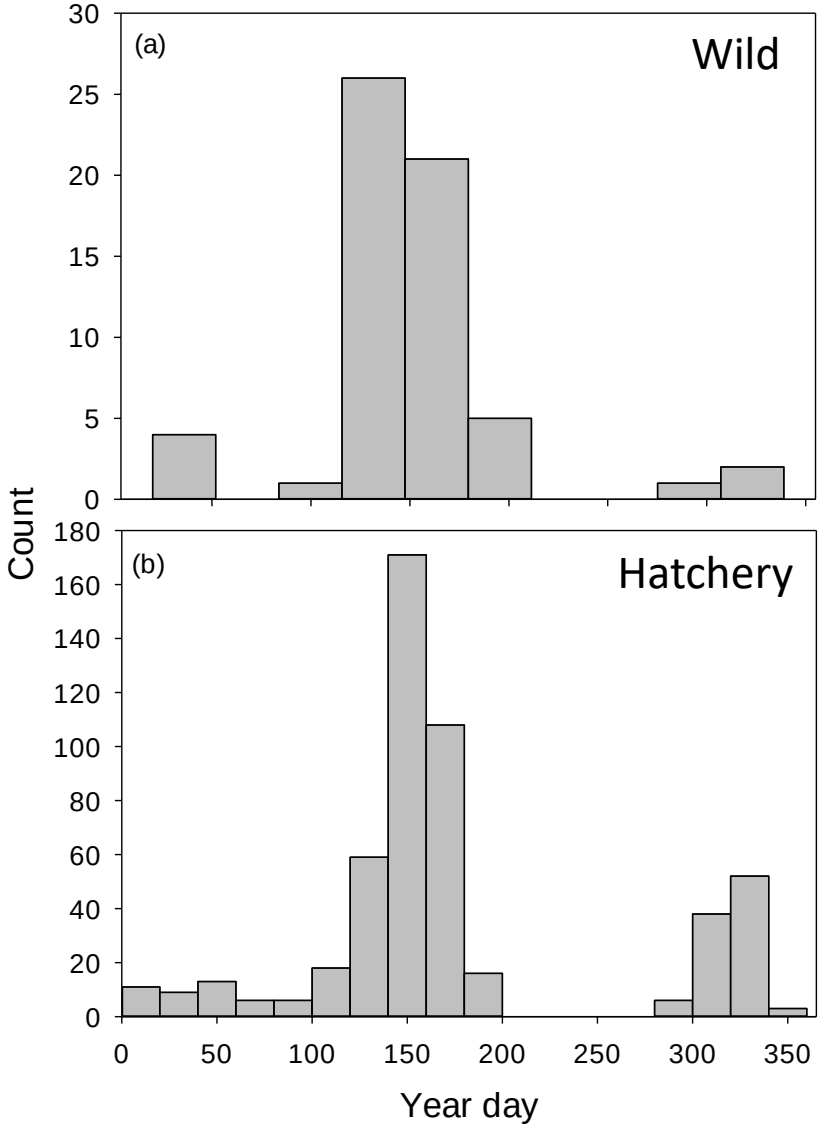
- No summer emigration
  - Mid-May-early August
- No clear patterns of outmigration timing and tagging location

Task 4: Results-Coho

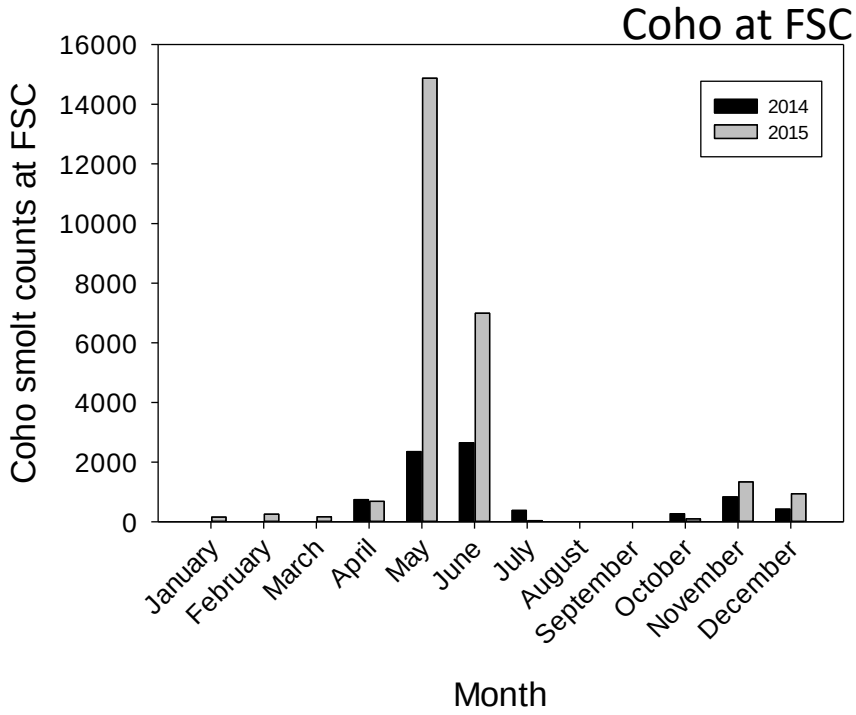


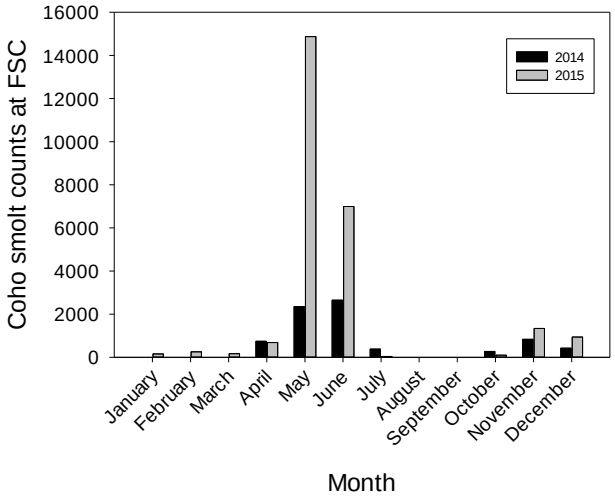
- Timing to collector
  - Similar for wild and hatchery Coho
  - May

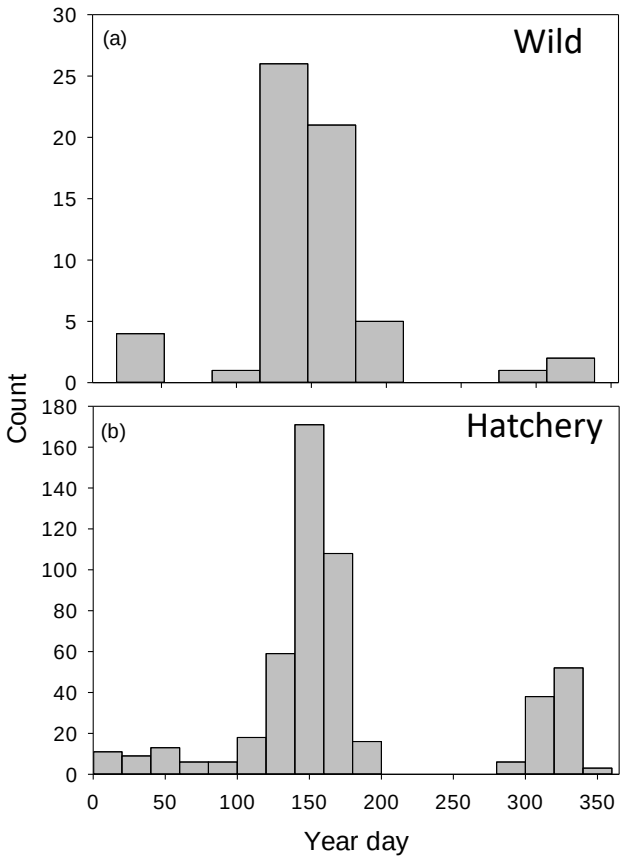
Task 4: Results-Coho



- Timing to collector





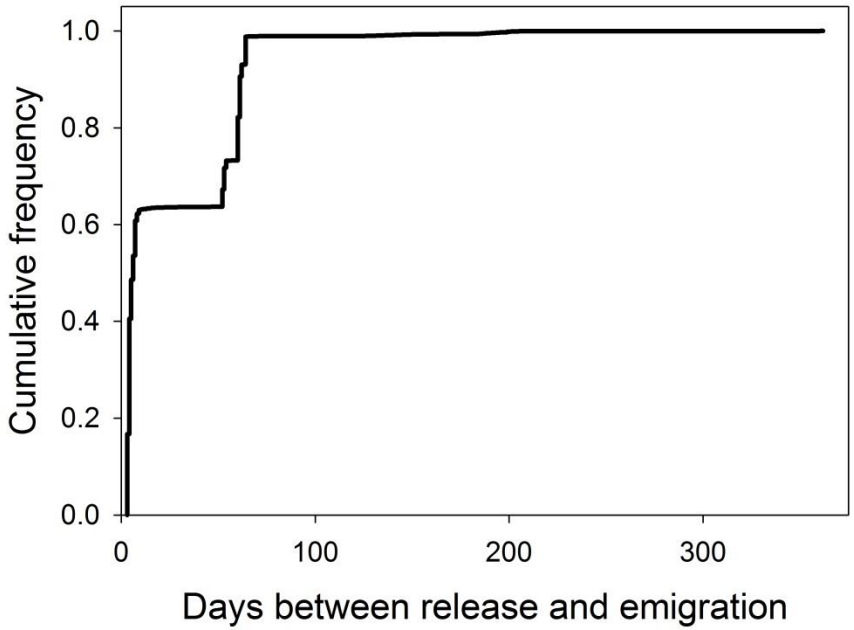


Task 4: Results-Coho

- Travel time to FSC
  - Leaving Clear Creek
    - Median = 121 days
    - Range = 21-347
  - Screw trap
    - Median = 37
    - Range = 8 – 391 days

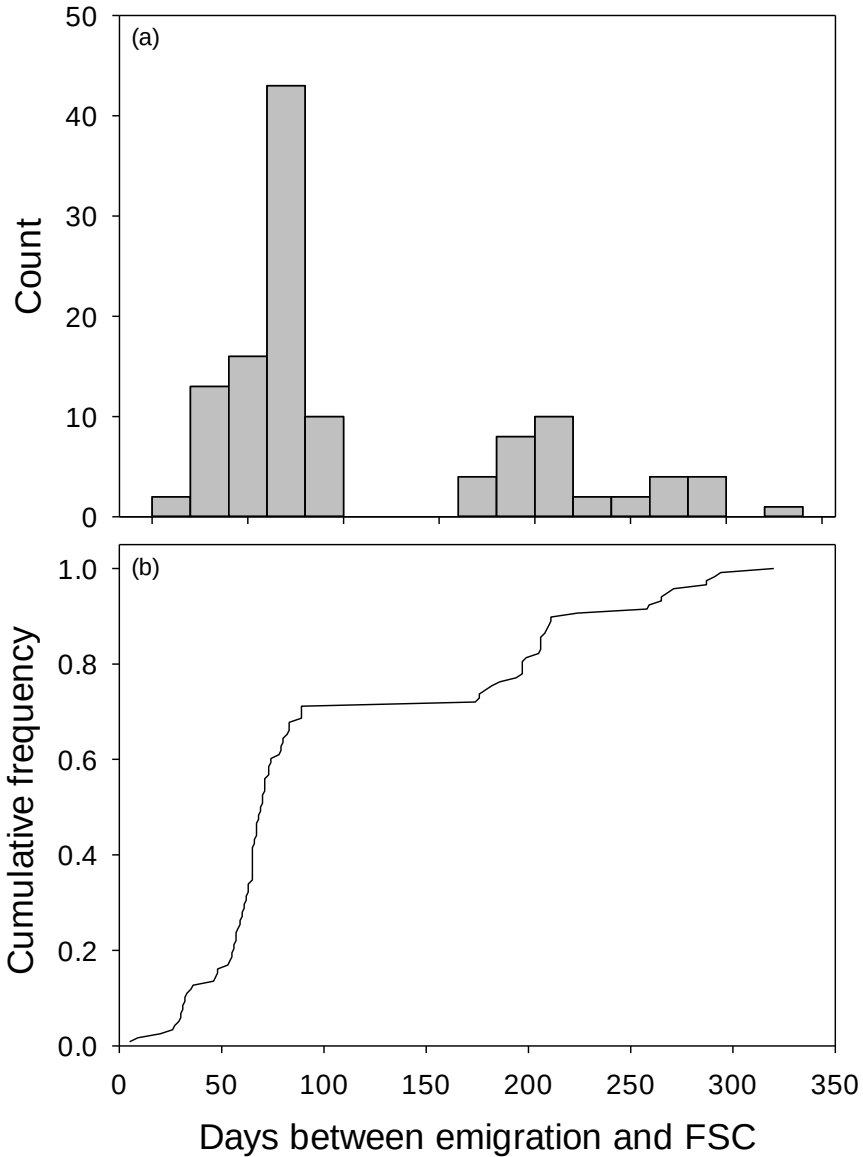
- Difference a result of when emigrating from tributaries
  - Also variability in reservoir rearing

Task 4: Results-Chinook



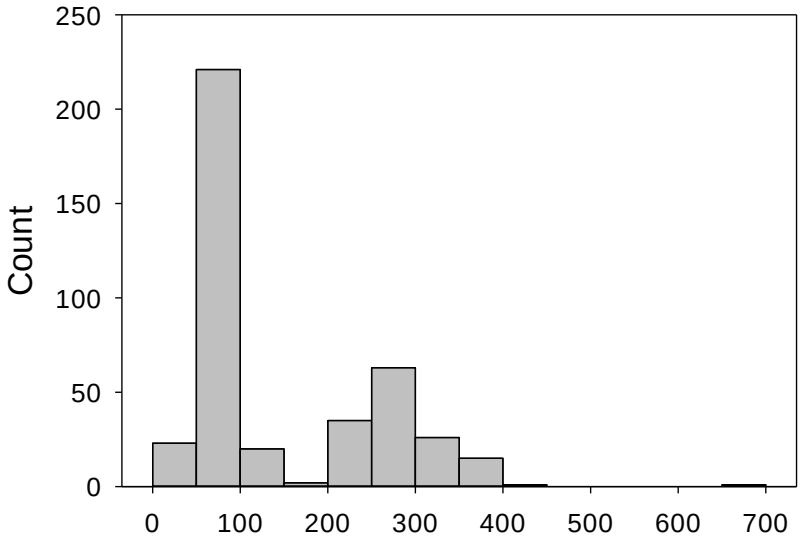
- Acclimation Chinook in Clear Creek
  - Direct and acclimation pond releases (2014 – 2015)
  - ~60% emigrate within a week
  - 98% within 60 days

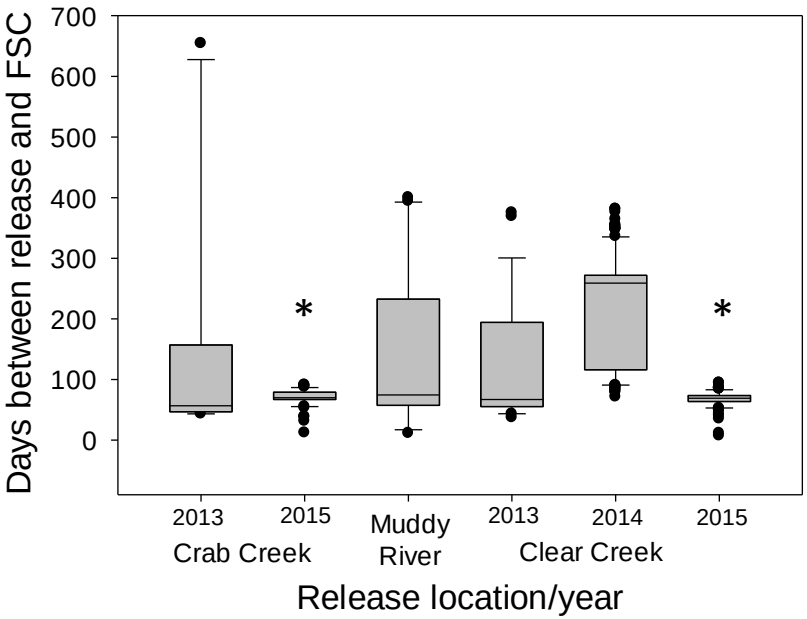
Task 4: Results



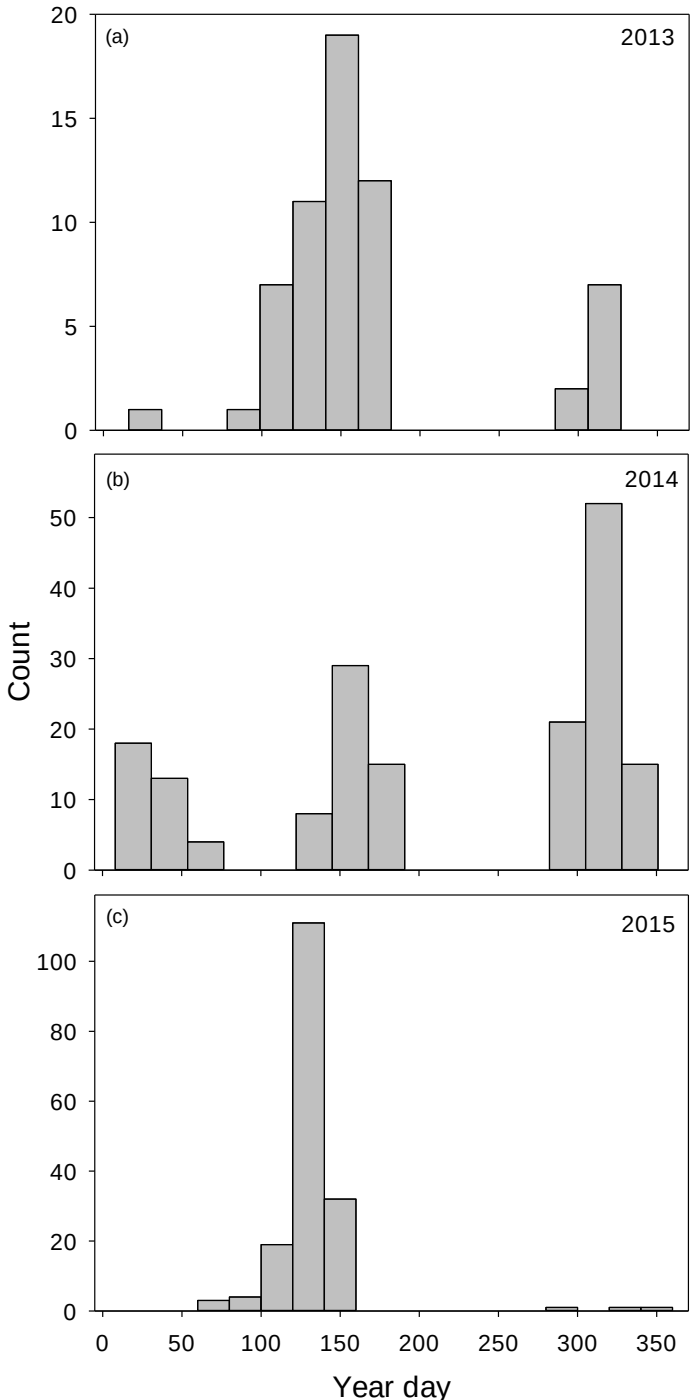
- Acclimation Chinook (Clear Creek) time in Swift after passing antenna
  - Median days = 69
  - Range = 5 – 320 days

Task 4: Results





- All acclimation Chinook
  - From release
    - Crab Creek, Muddy River, Clear Creek
    - Bimodal
  - Apparent differences across sites and years



Task 4: Results

- All acclimation Chinook
  - Considerable differences across years
    - 2013 and 2015 vs. 2014

Task 4: Results

- **Fish reaching the FSC in Swift Reservoir**
- As December 31, 2015 focusing specifically on PIT-tagged fish reaching the FSC:
  - Coho
    - 14% of hatchery Coho (2013)
    - 3.4% of wild Coho PIT-tagged 2013-2015
    - 15.2 % from screw trap (2013, 2014)
      - Difference from Clear Creek data due to overwinter and migration mortality
  - Steelhead
    - 18.7% of fish marked at screw trap (2013-2014)

Photo: R. Al-Chokhachy, USGS

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Task 4: Results

- **Fish reaching the FSC in Swift Reservoir**
  - Coho
    - 14% of hatchery Coho (2013-spring release)
    - 3.4% of wild Coho PIT-tagged 2013-2015
    - 15.2 % from screw trap (2013, 2014)
  - Steelhead
    - 18.7% of fish marked at screw trap (2013-2014)
  - Acclimation Chinook
    - 1.4-2.0% of PIT-tagged fish (2013-2015)
    - 3.7% of the 202,666 released fish

Photo: R. Al-Chokhachy, USGS

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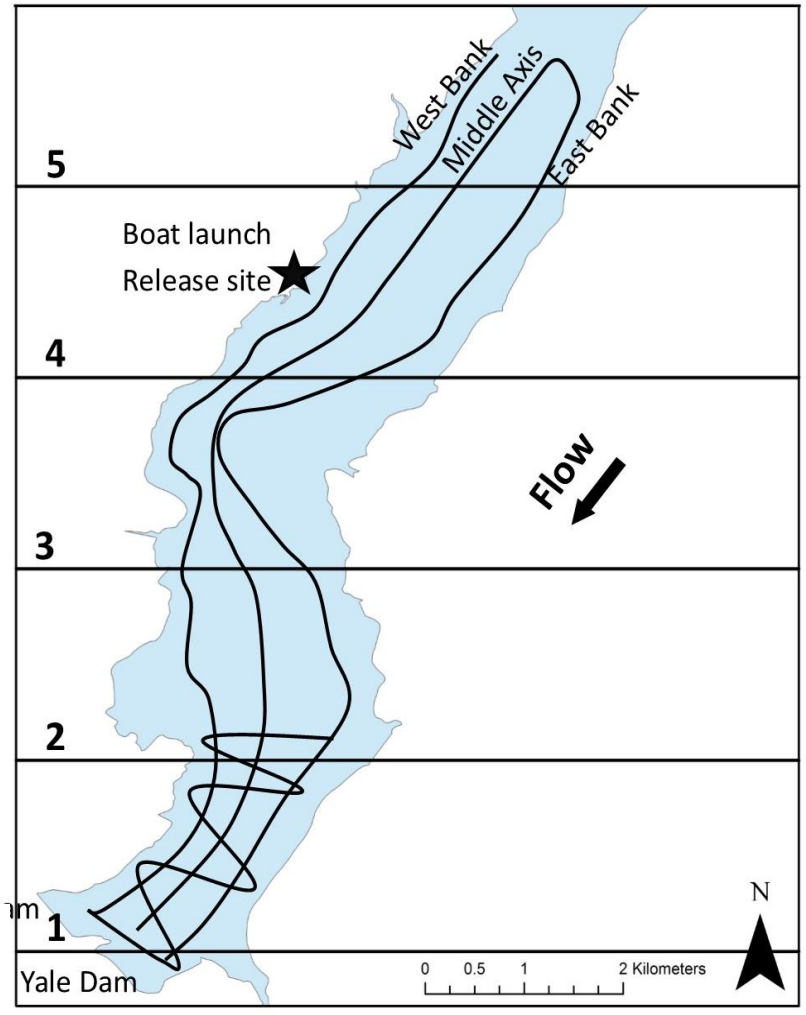
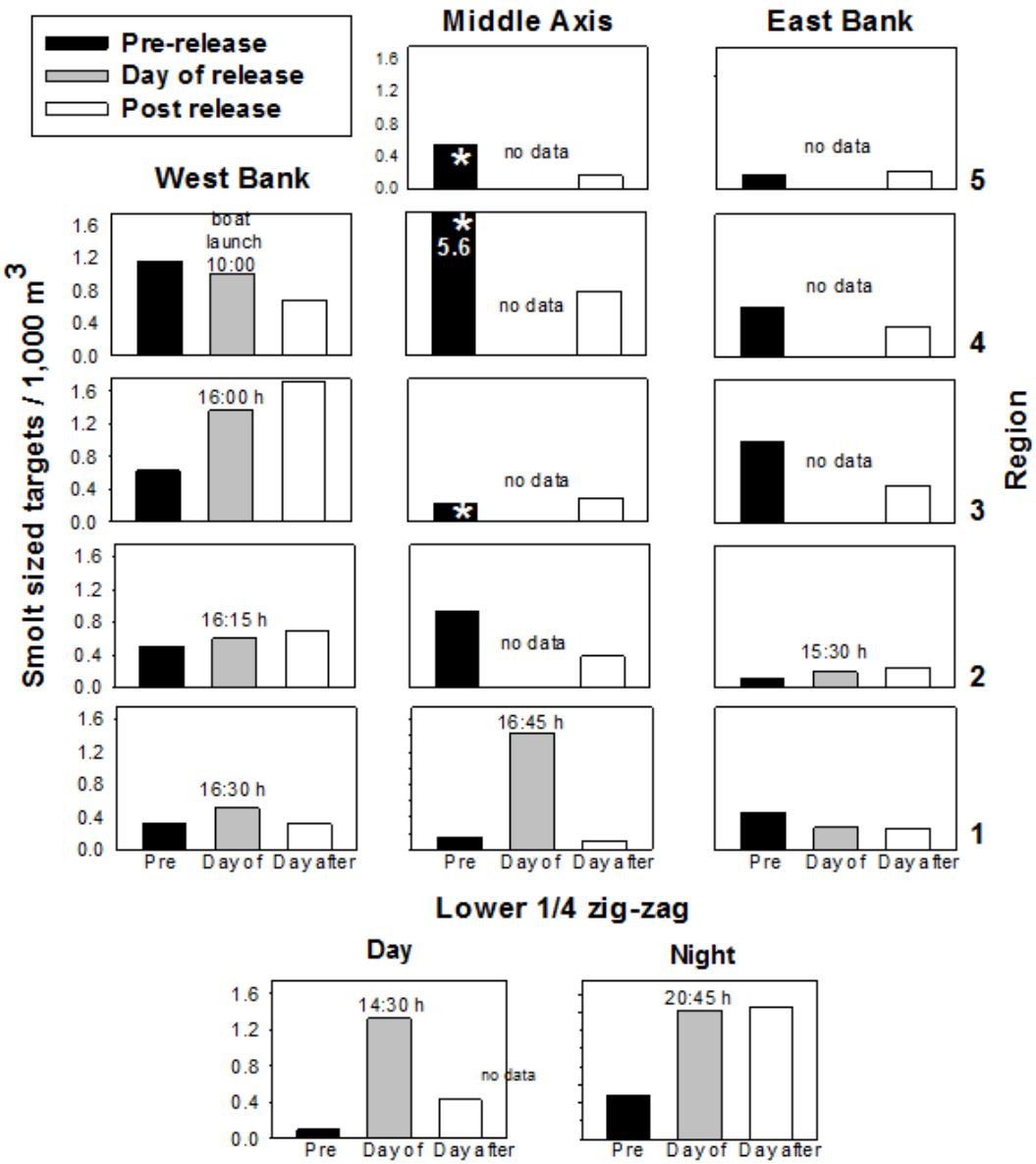
Task 4: methods **reservoir**



- Hydroacoustic survey
  - Pre-release
  - Day of release
  - Post-release
- Zones
- Paths

Task 4: Reservoir Results



- Hydroacoustic results
  - Smolts relatively rapidly movements to collector
  - Use of upper water column (<20 m)
    - Side-looker data

Task 4: Summary

- Proportion of fish collected (remains low)

Collection

Study Year - 2015

– Results

8% 0% 15%

Metric	Coho Salmon	Spring Chinook	Steelhead	Total
Total tagged (n)	149	14	47	200
Detected at ZOI	100	6	43	159
P_{RES}	67.1%	42.9%	91.5%	79.5%
Captured at FSC	12	0	7	19
Collection Efficacy (P_{CE})	12.0%	0.0%	16.3%	11.9%

– Results: 2014

Metric	Coho Salmon	Spring Chinook	Steelhead	Total
Total tagged (n)	157	20	16	193
Detected at ZOI	31	3	4	38
P_{RES}	19.7%	15.0%	25.0%	19.7%
Captured at FSC	9	0	1	10
Collection Efficacy (P_{CE})	29.0%	0.0%	25.0%	26.3%

6% 0% 6%

Fish reaching the FSC in Swift Res

- Coho
  - 14% of hatchery Coho (2013-spring release)
  - 3.4% of Coho PIT-tagged 2013-2015
  - 15.2 % from screw trap (2013, 2014)
- Steelhead
  - 18.7% of fish marked at screw trap (2013-2014)
- Acclimation Chinook
  - 1.4-2.0% of PIT-tagged fish (2013-2015)
  - 3.7% of the 202,666 released fish

PacifiCorp and Cowlitz Public Utility District [PUD], 2017, Lewis River fish passage program 2016 annual report: Portland, Oreg., PacifiCorp and Cowlitz Public Utility District, 176 p.

Photo: R. Al-Chokhachy, USGS

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Task 4: Summary

- Proportion of fish collected (remains low)

- Emigration time
  - Juvenile Coho is ~ 5 weeks (highly variable)
  - Spring Chinook = > 2 months

- Test release data suggest relatively rapid migrations
  - Radiotelemetry data = 5.2 km/day travel rate
  - Hydroacoustics, Yale Yale Park – Dam (2014) = ~7 km

- Together results suggest difficulties of fish “finding” collector
  - Consistent with results from Cramer Fish Sciences (90%) within 140 m of collector

Scope of Work: project tasks

1. Review information regarding fish transport into Lake Merwin and Yale Lake
2. Habitat assessment of tributaries to Yale Lake and Lake Merwin
3. Assessment of adult potential for spawning success
4. Assess juvenile production potential and emigration success
5. **Evaluation of Lake Merwin predator impacts**
6. Assess anadromous/resident interactions

Task 5: Evaluation of Lake Merwin predator impacts

Objectives and methods

1. Estimate abundance and size structure of predators
2. Quantify predator-prey interactions and evaluate if predation will be a limiting factor for anadromous populations
3. Quantify spatial and temporal distributions of predators, which may provide information for potential control efforts, if needed

Task 5: Evaluation of Lake Merwin predator impacts: methods

- Estimate abundance and size structure of predators
  - Gill netting
    - Mark-recapture study to estimate abundance (2013 – 2014)
      - External floy tags
      - Chapman estimator

Photo: R. Al-Chokhachy, USGS

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Task 5: Evaluation of Lake Merwin predator impacts: methods

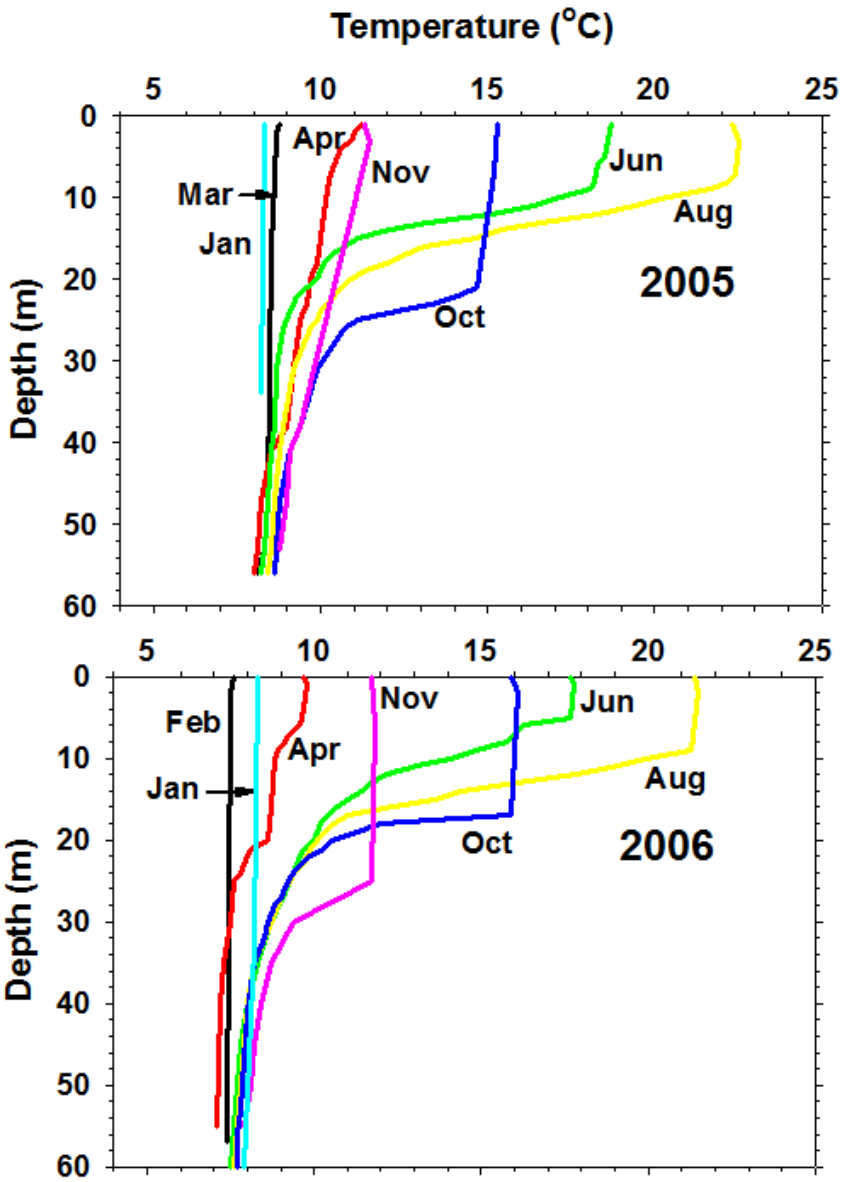
- Estimate abundance and size structure of predators
  - Tiger Muskie
    - Predation on Northern Pikeminnow

Photo: M. Sorel, U. Washington

- Stocking records
  - Average 1,340/year
  - Survival estimated via catch curves

Task 5: Thermal experiences

- Catch information by depth and season
- Limnological and thermal data collected



Task 5: Biological and diet data

- Biological data
  - Size, age, growth, diet, energetic, trophic & reproductive status

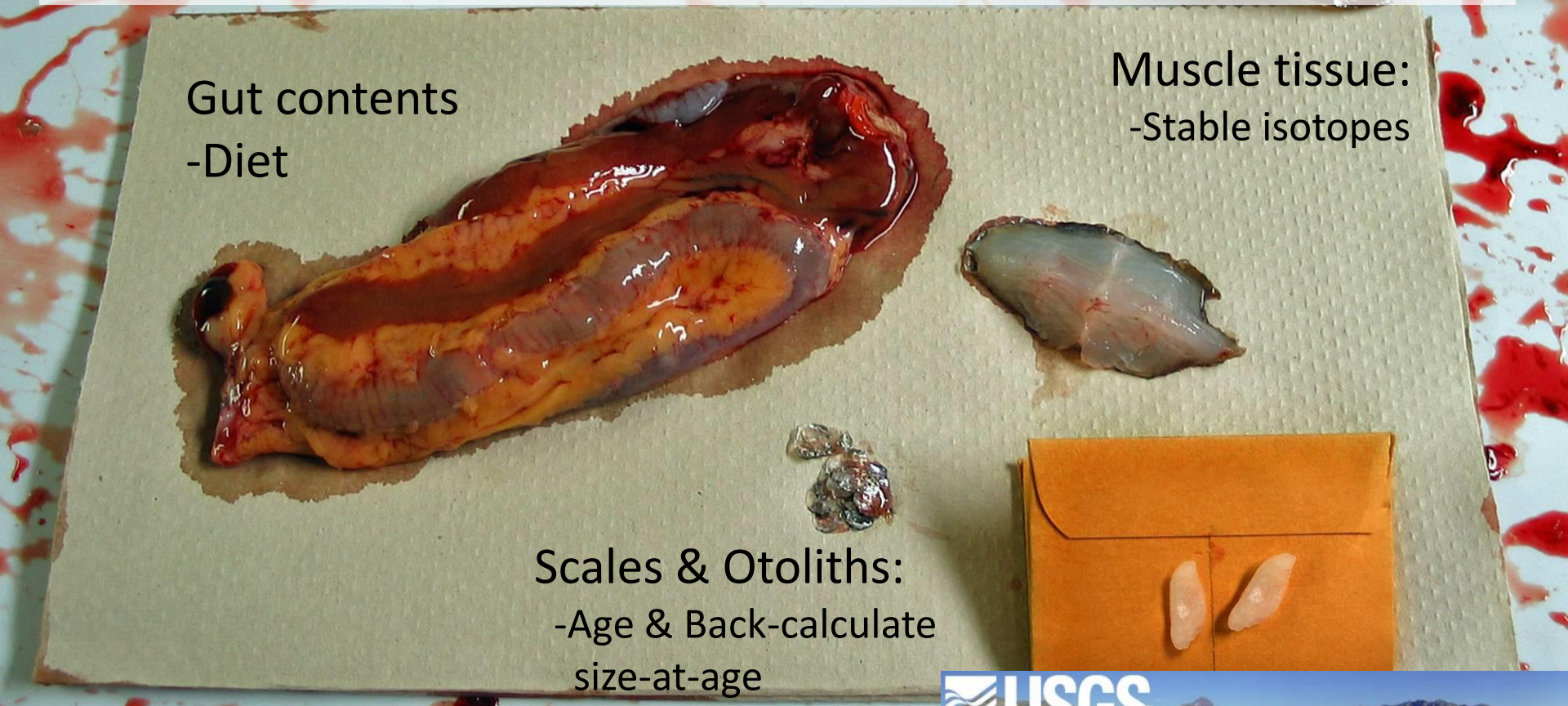


Photo: D. Beauchamp, USGS

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Task 5: Lake Merwin predation potential

Temporal Diet Composition

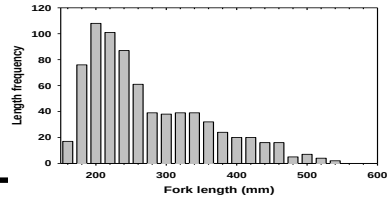
Consumer Growth

Predator Energy Density

Thermal Experience

Prey Energy Density

Bioenergetics Model



Consumer Size Structure & Abundance

Consumption Estimate

Population Consumption

Biomass of Exploitable prey

Consumption as % of Prey Biomass or Production

Task 5: Results

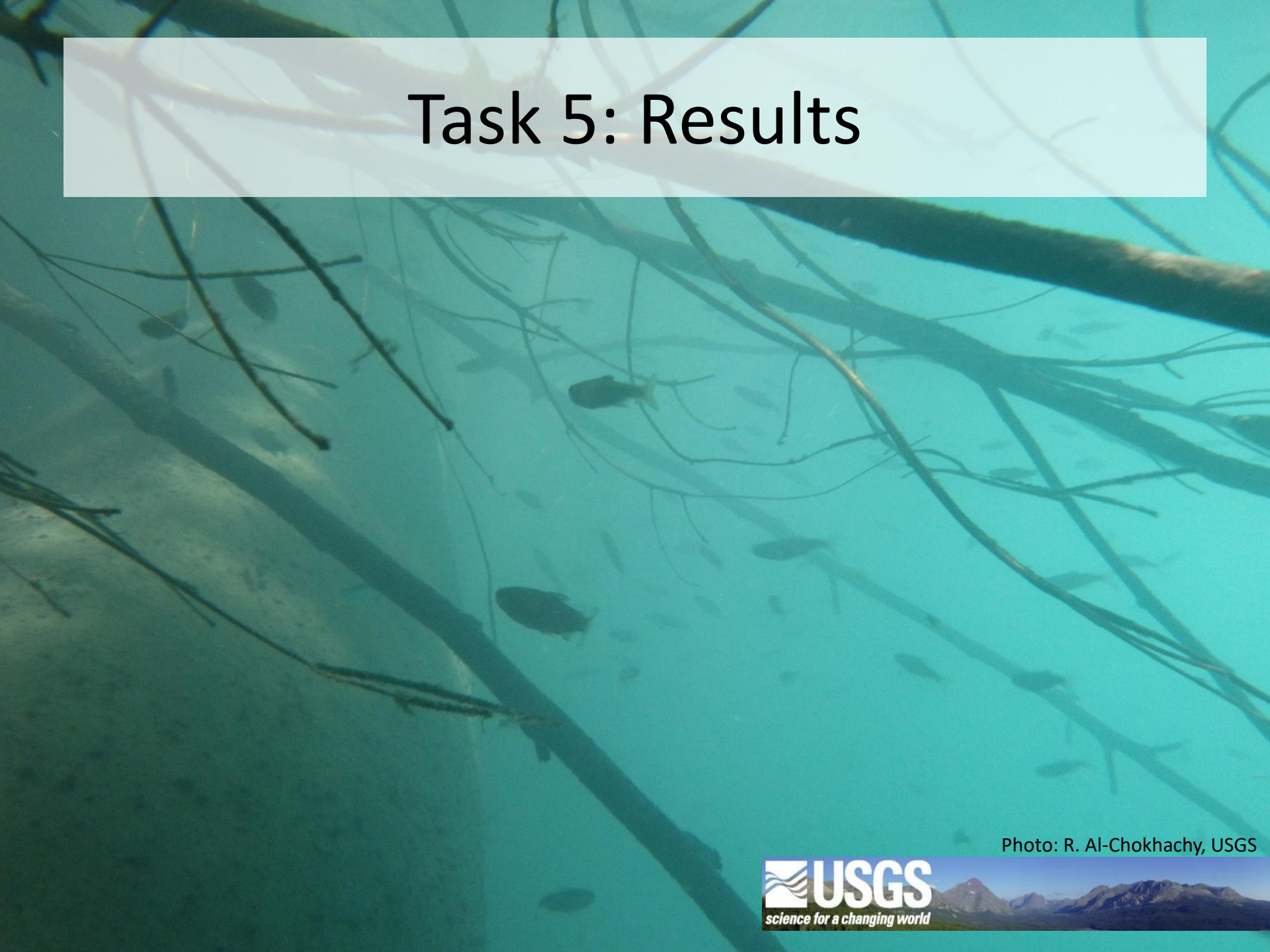


Photo: R. Al-Chokhachy, USGS

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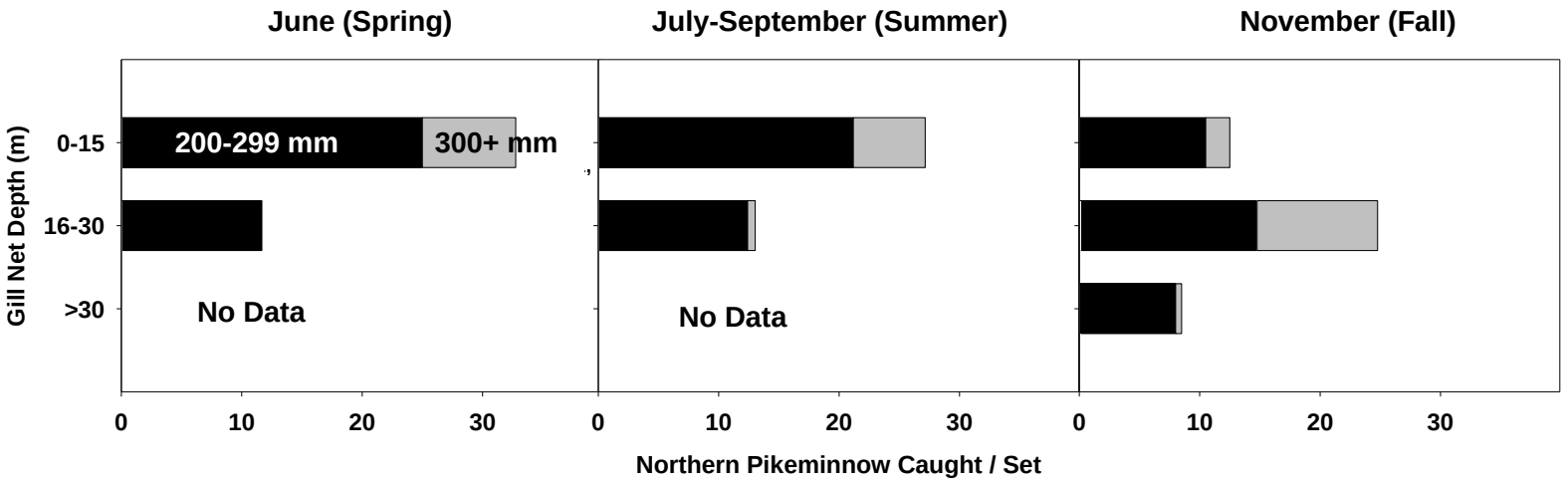
Task 5: Results

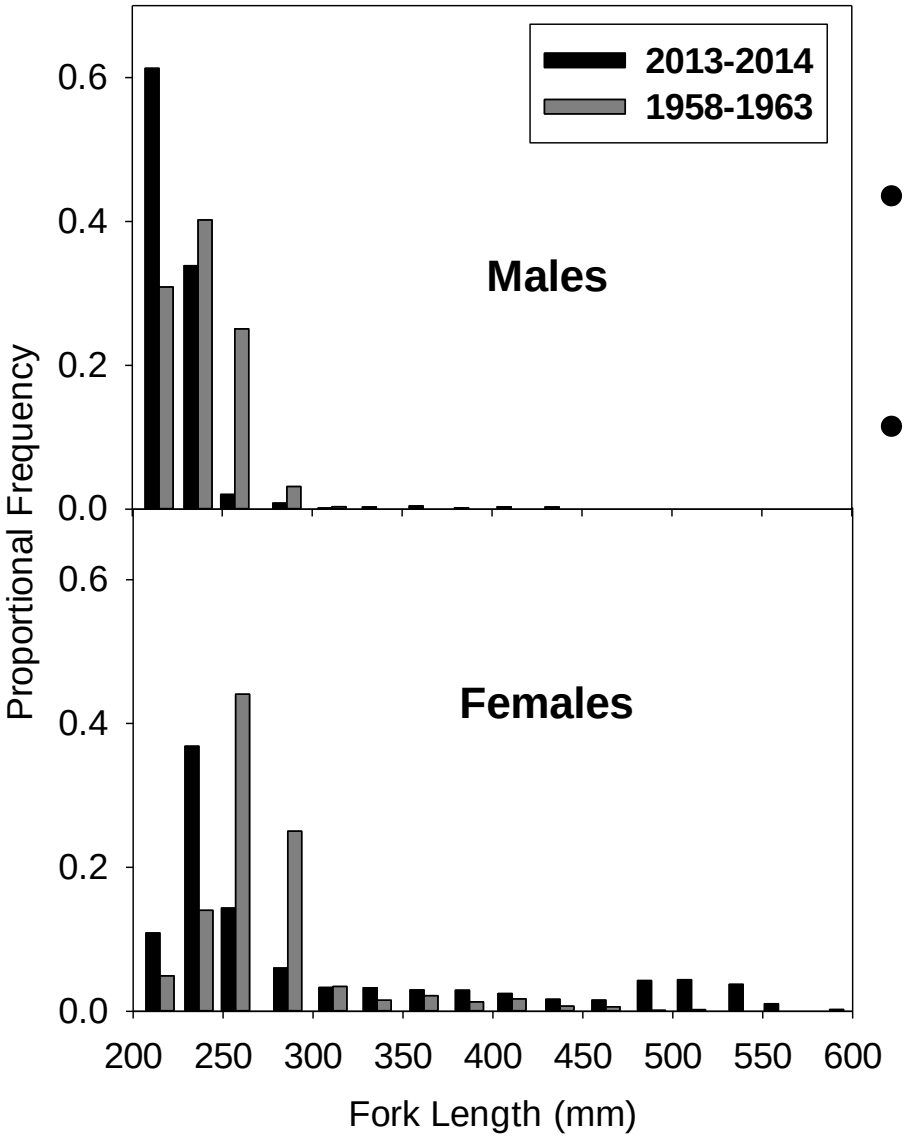
- Abundance
  - Northern Pikeminnow
    - Tagged > 2,000 fish
    - Abundance 200-300 mm = 544,259, (95% CI 190,609-1,554,062)
    - Abundance >300 mm = 11,240 (95% CI = 3,370 – 39,880)
  - Tiger Muskellunge
    - 5,488 (based on survival analysis and stocking)

Task 5: Results



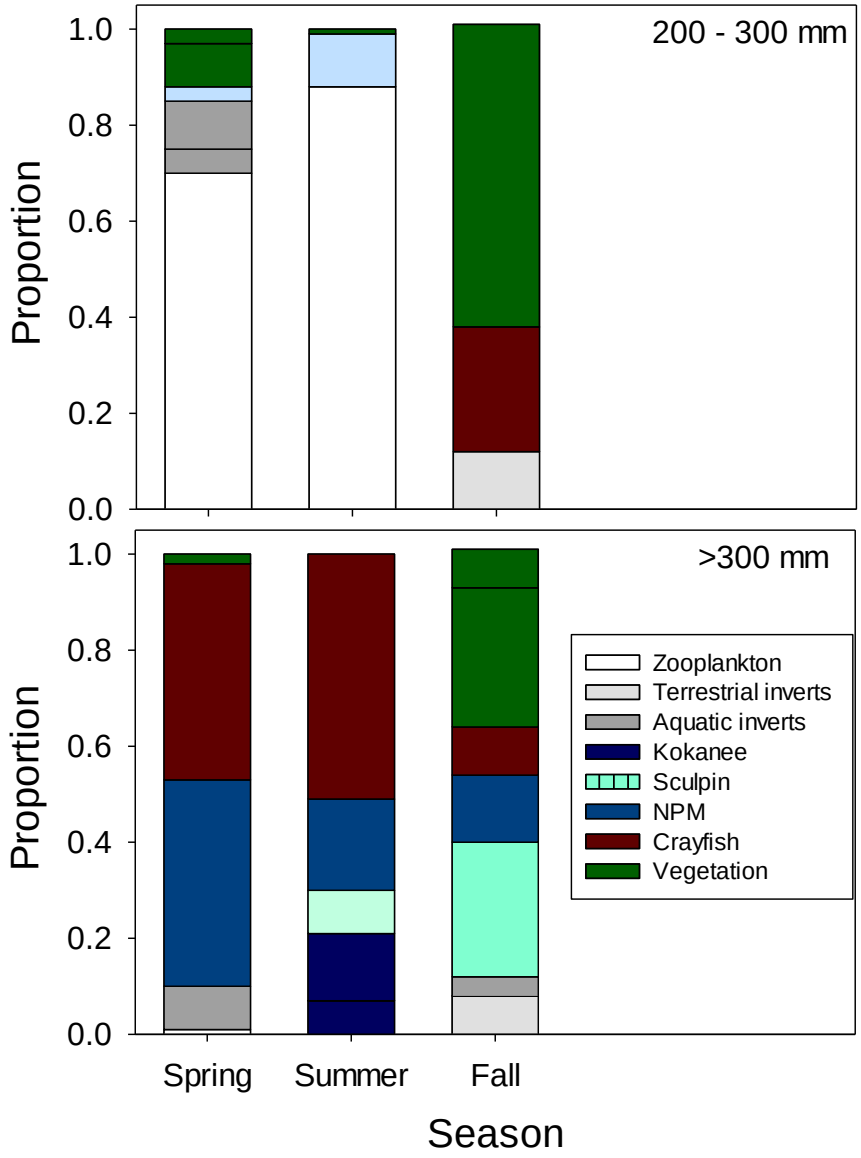
- Distribution
  - Majority of NPM in upper 15 m during stratification
  - High predation potential during all seasons, but particularly during spring/summer

Task 5: Results



- Size distribution
  - Northern Pikeminnow
- Tiger Muskie controls
  - Fewer >250mm fish (P<0.10)

Task 5: Results-NPM diets



- 200 – 300 mm
  - Zooplankton, inverts, vegetation
- >300 mm
  - Crayfish, NPM, Kokanee
- Shift with increasing abundance of salmon?

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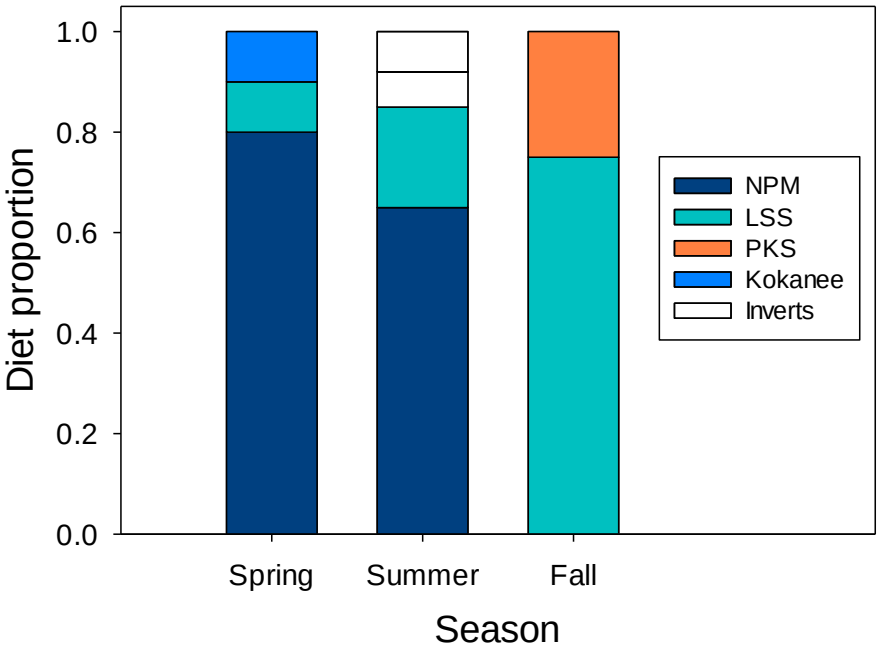
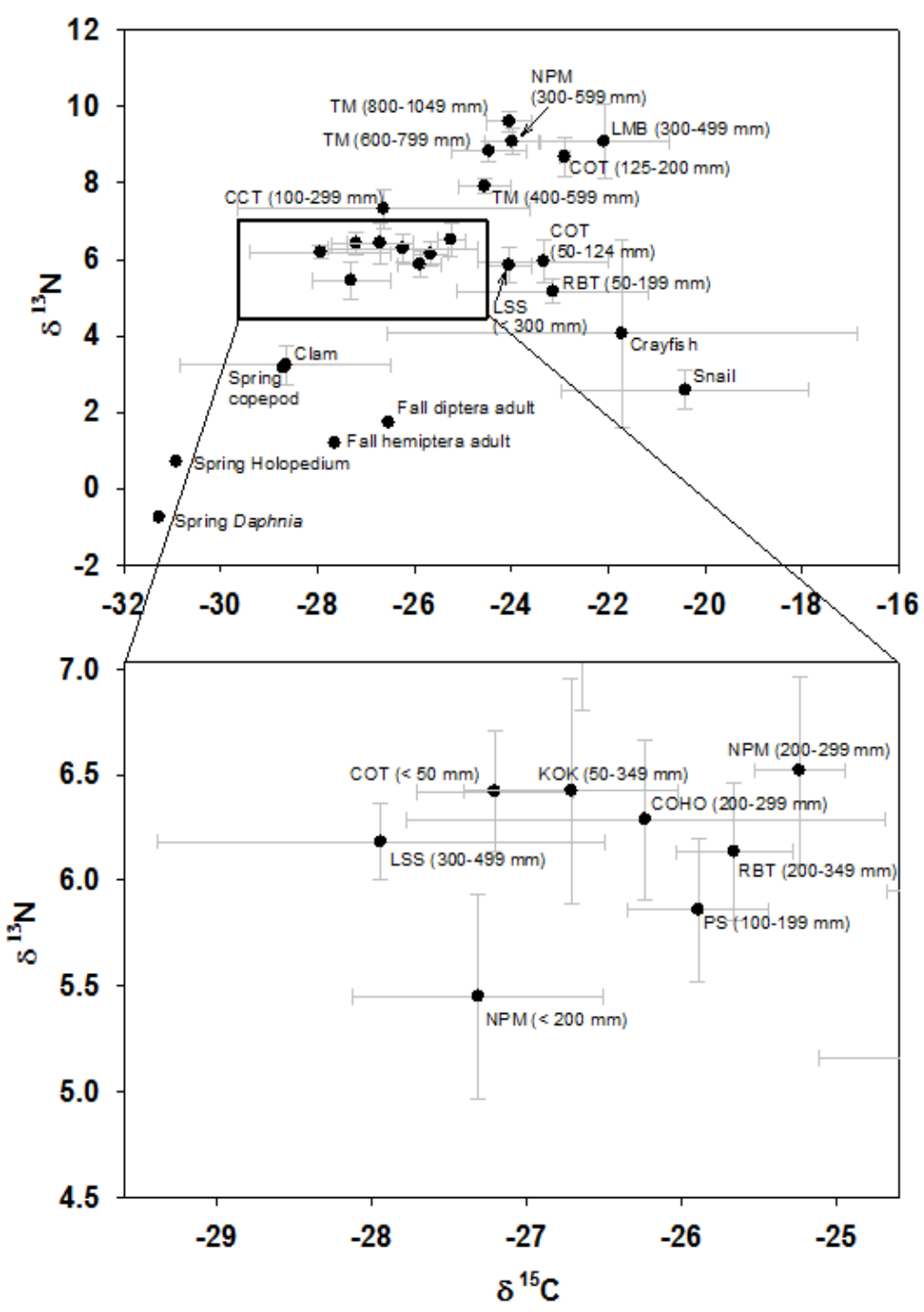
Task 5: Results-Tiger Muskie diets



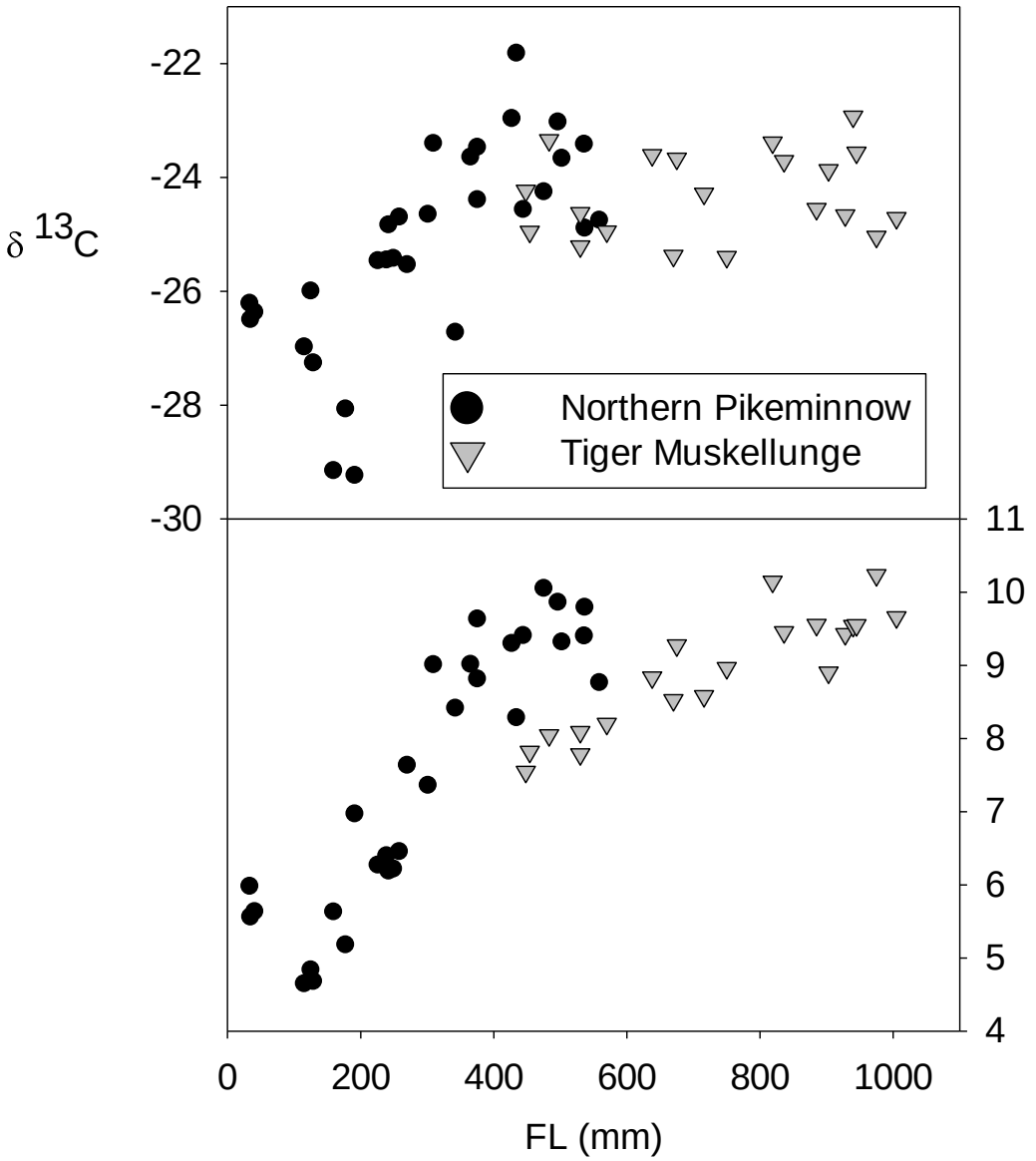
- Diets
  - Largest proportion of diets
  - Year-round predation on NPM
  - Very few Kokanee
    - Shift under anadromous reintroductions?



Task 5: Results

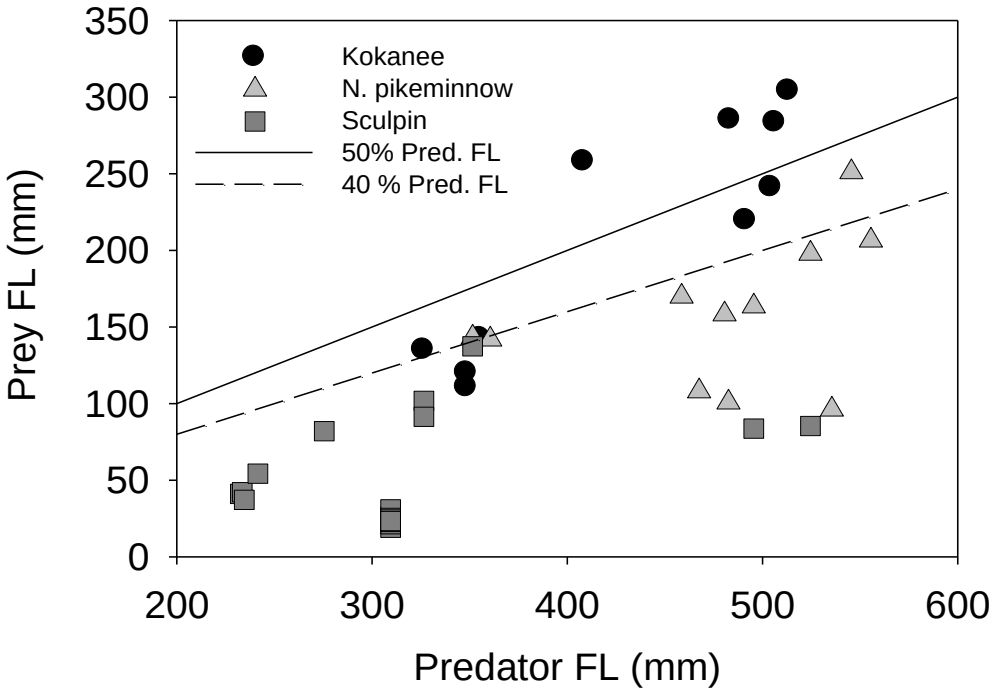
- Stable isotope data
  - Substantial differences in trophic level and forage
    - NPM
      - >300 mm
      - <300mm
    - Tiger Muskie

Task 5: Isotope results



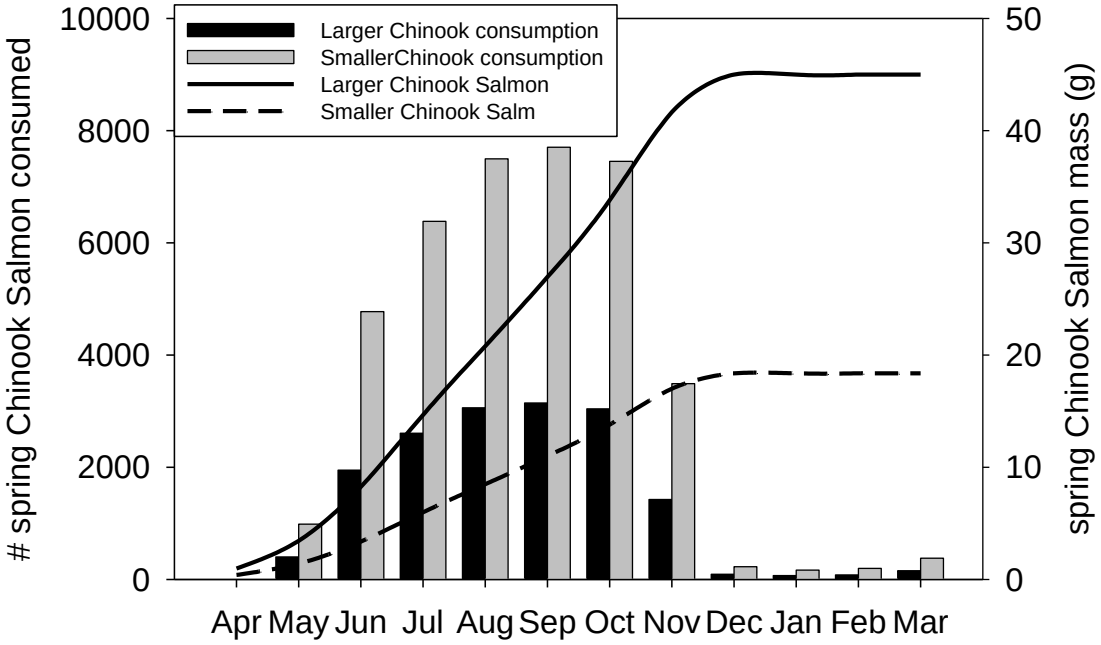
- Size relationships
- NPM
  - Shift in carbon source (more pelagic)
  - Shift to piscivory
- Tiger-Muskie
  - Consistent carbon
  - Increasing trophic level

Task 5: Results-NPM piscivory



- Primarily sculpin <300 mm
- Shift to salmonids and cannibalism
  - >300 mm

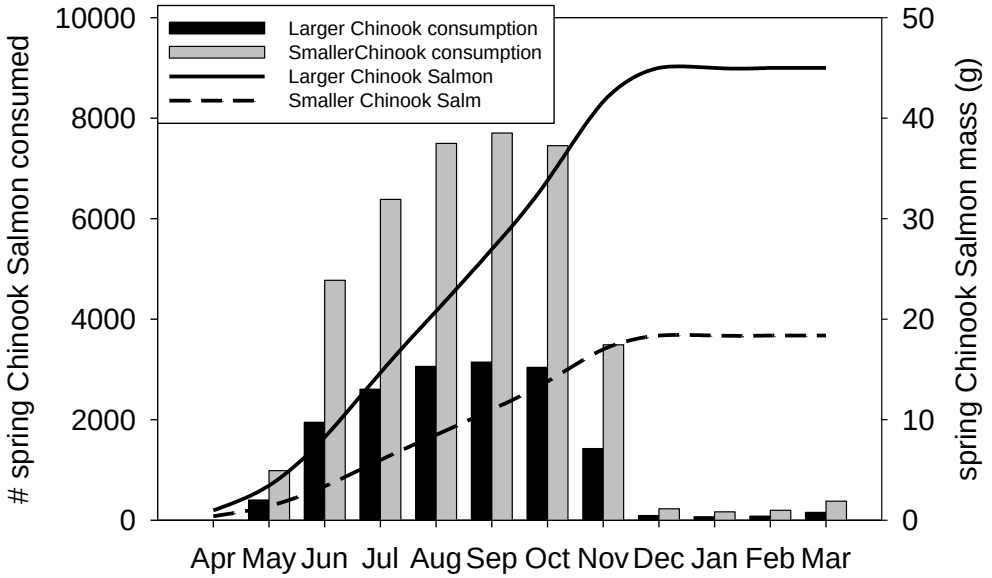
Task 5: Results-NPM piscivory



- Bioenergetics results
  - Per 1,000 NPM
- Annual estimates
  - 18 g juvenile Chinook
    - 39,250
  - 45 g juvenile chinook
    - 16,022

Task 5: Results-NPM piscivory

Per 1,000 NPM



- Abundance estimates
  - ~11,000 NPM > 300 mm
  - Annual consumption at the population level
    - 18 g →>431,000
    - 45 g→176,242
- Rearing time
  - 2-3 months?
    - 40,000 – 110,000
  - Fry

Conclusions-Task 5

- Tiger Muskellunge appear to have significant effect on size structure of NPM
- NPM population of piscivorous fish remains relatively large
- Estimates of juvenile Salmon predation, even seasonal appears to be high

Scope of Work: project tasks

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4. Assess juvenile production potential and emigration success
5. Evaluation of Lake Merwin predator impacts
6. **Assess anadromous/resident interactions**

Objectives

1. Potential influences of anadromous salmon reintroductions on bull trout populations
    1. Evidence of competition/overlap in resources
        1. Food resources
        2. Habitat
    2. Reservoir and tributaries

Study area: bull trout

- Adfluvial life-history
  - Tributary rearing (1-3 years)
  - Reservoir-growth and maturity

Photo: R. Al-Chokhachy, USGS

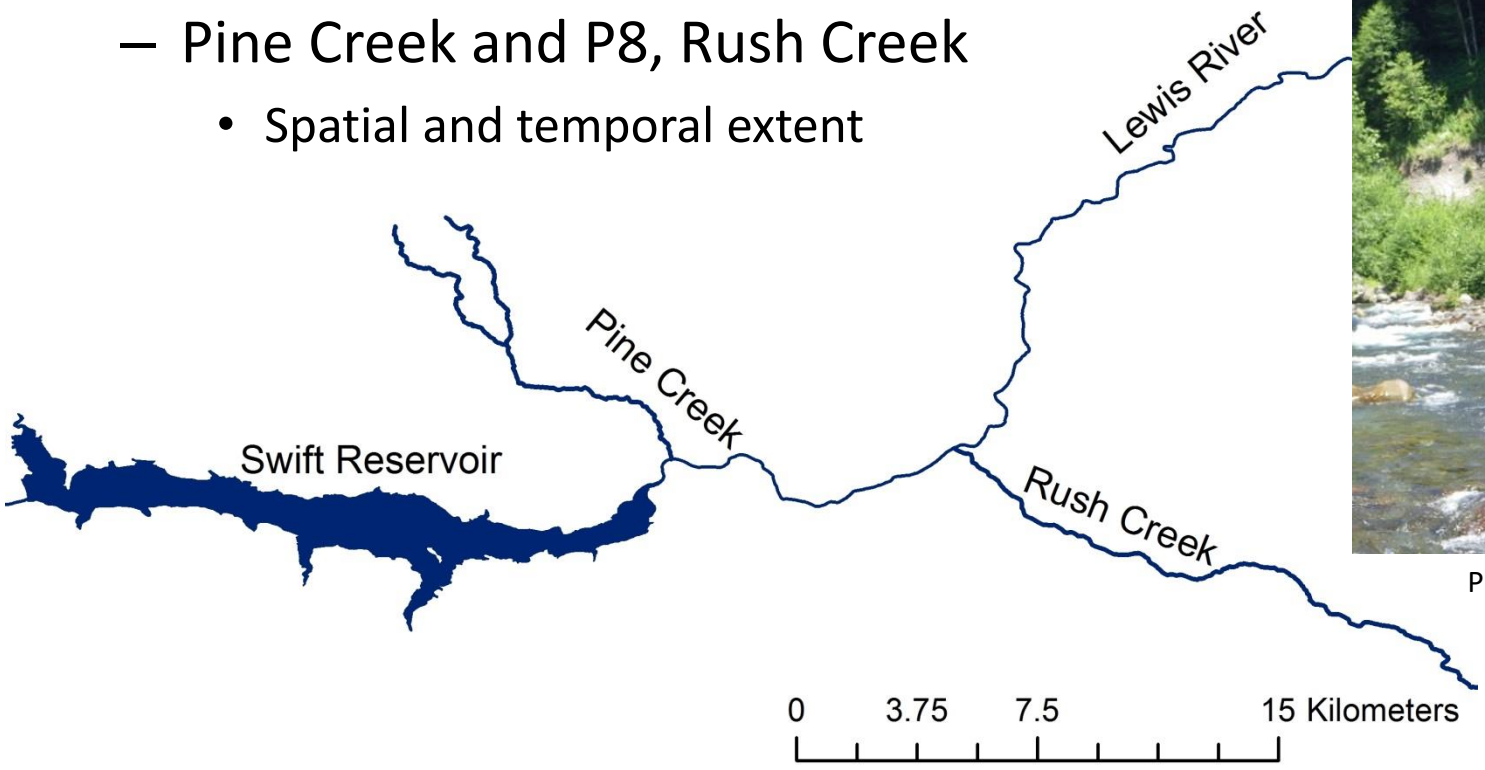
Photo: C. Muhlfeld, USGS

Methods

- Interactions across life-stages
  - Quantify distributional overlap in key bull trout spawning and rearing areas
  - Foodweb analyses to evaluate potential bull trout shifts in diet after reintroduction
  - Superimposition of coho on existing bull trout redds
  - Reservoir capacity

Methods: distributional overlap in tributaries

- Systematic snorkel surveys
  - Pine Creek and P8, Rush Creek
    - Spatial and temporal extent



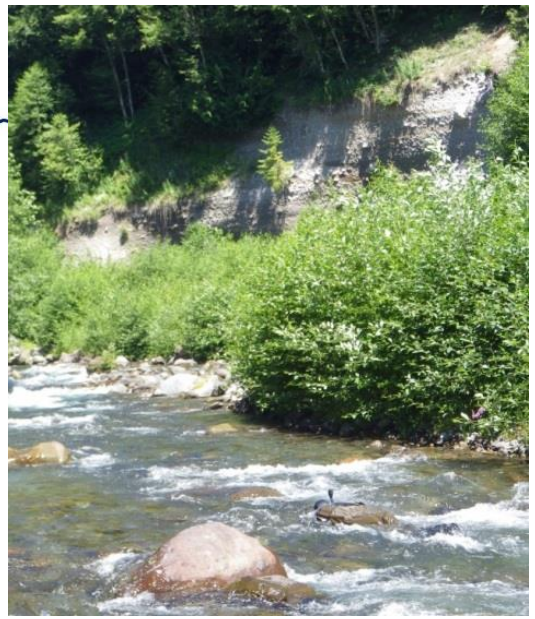


Photo: R. Al-Chokhachy, USGS

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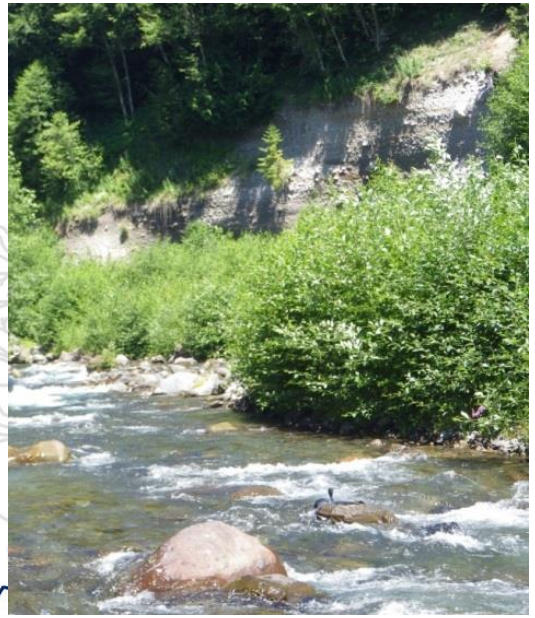

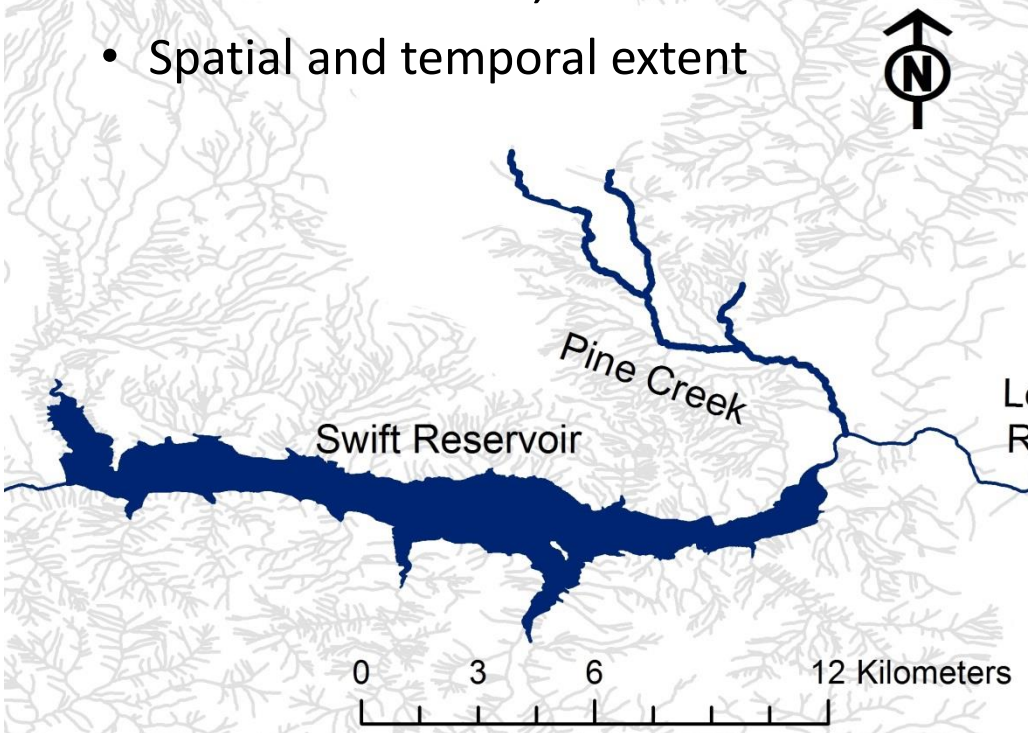

Methods

- Interactions across life-stages
  - Quantify distributional overlap in key bull trout spawning and rearing areas
  - Foodweb analyses to evaluate potential bull trout shifts in diet after reintroduction
  - Superimposition of coho on existing bull trout redds
  - Reservoir capacity

Methods: tributaries

Photos: R. Al-Chokhachy, USGS

- Tributaries
  - Shifts since reintroduction
  - Summer, fall
  - Coho and bull trout diet overlap
- Fin clips and macroinvert.
  - Stable isotopes
- Gastric lavage for diet data

Methods: diet overlap, foodweb, and trophic position in Swift Reservoir

- Trawl and gillnet data
- Diets and stable isotopes
- Trophic shifts

Photo: D. Beauchamp, USGS

Methods: coho superimposition and potential population effects

- Tributaries
  - Quantify distributional overlap in key bull trout spawning and rearing areas
  - Do juvenile bull trout and coho diets overlap and is there evidence of potential bull trout shifts in diet after reintroduction?
  - Superimposition of coho on existing bull trout redds
  - Reservoir capacity

Methods: superimposition

- Tributaries
  - All existing bull trout and coho redd data
  - Identify extent of temporal overlap of coho redds

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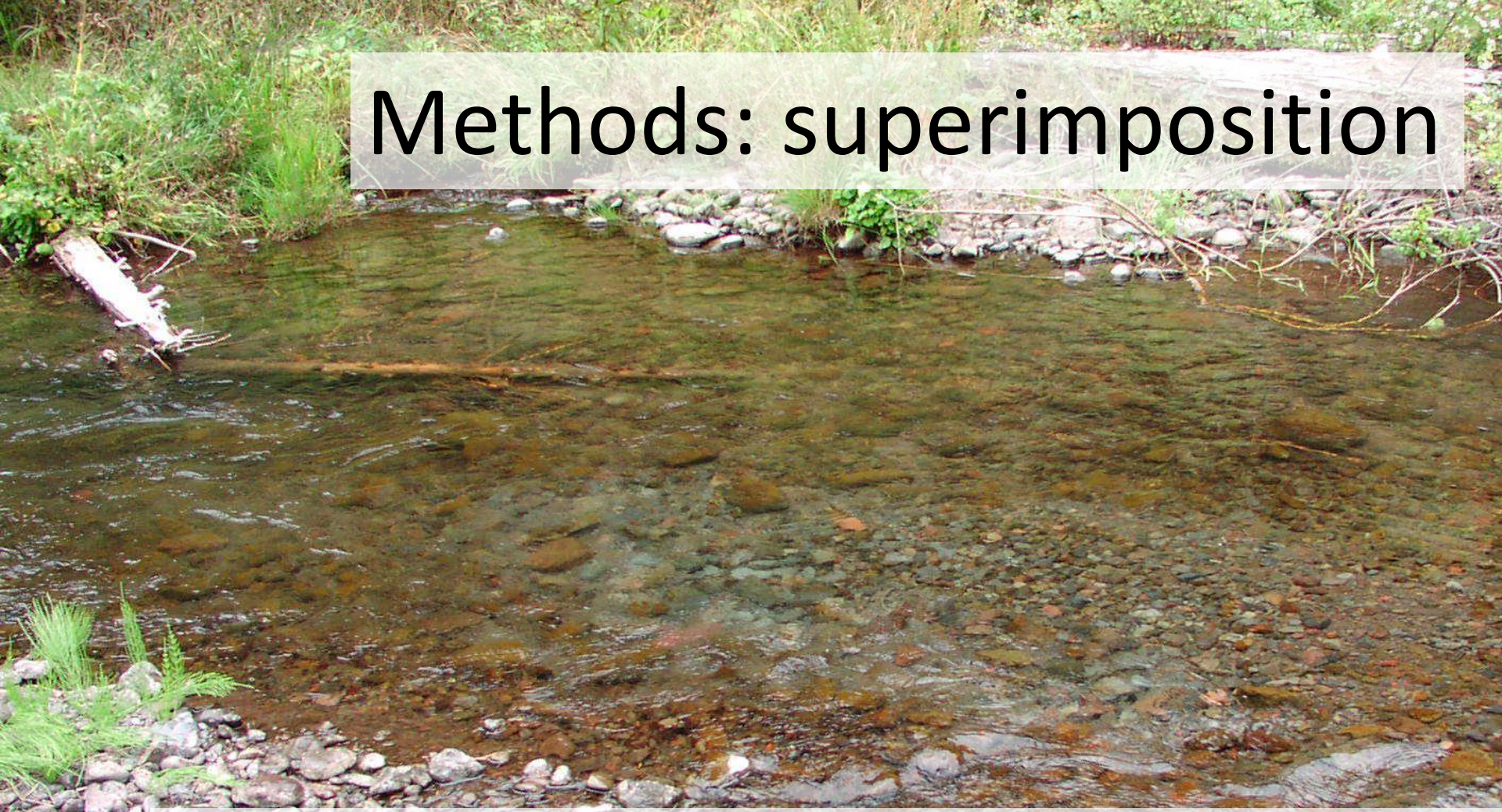
Photo: R. Al-Chokhachy, USGS

Methods: superimposition



- Superimposition
  - Identified bull trout redds—minimize sampling error
  - Superimposition of coho on existing bull trout redds

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Photo: R. Al-Chokhachy, USGS

Methods: superimposition

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Photo: R. Al-Chokhachy, USGS

Methods: coho superimposition and potential population effects

- Tributaries
  - Quantify distributional overlap in key bull trout spawning and rearing areas
  - Do juvenile bull trout and coho diets overlap and is there evidence of potential bull trout shifts in diet after reintroduction?
  - Superimposition of coho on existing bull trout redds
  - Reservoir capacity

Reservoir carrying capacity

- Estimate juvenile Salmon capacity
  - Add to information from habitat, predation, collection
  - Interactions with resident salmonids

Reservoir carrying capacity

- Depth-distributions of fishes across seasons
  - Gill nets
  - Hydroacoustics
- Depth-thermal profiles and thermal experience

Reservoir carrying capacity

- Depth-distributions of fishes across seasons
- Depth-thermal profiles and thermal experience
- Zooplankton-seasonally
  - Clarke-Bumpus sampler
  - Forage by depth
  - Biomass
  - Production-egg development

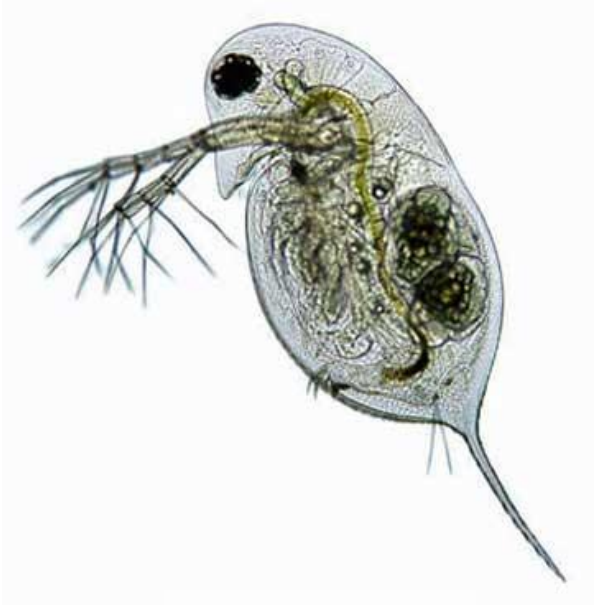
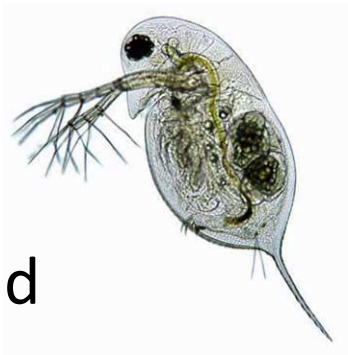


Photo: P. Budy, USGS

Reservoir carrying capacity

- Depth-distributions of fishes across seasons
- Depth-thermal profiles and thermal experience
- Zooplankton-seasonally
- Diets, stable isotopes, growth



- Bioenergetics modeling→consumption demand
  - Reservoir environment
  - Seasonally
    - Thermally excluded from epilimnion (summer)
  - Swift
    - Rainbow trout: (biomass + production) - demand
    - Forage to support juvenile Salmon

Photo: P. Budy, USGS

Task 6: Results

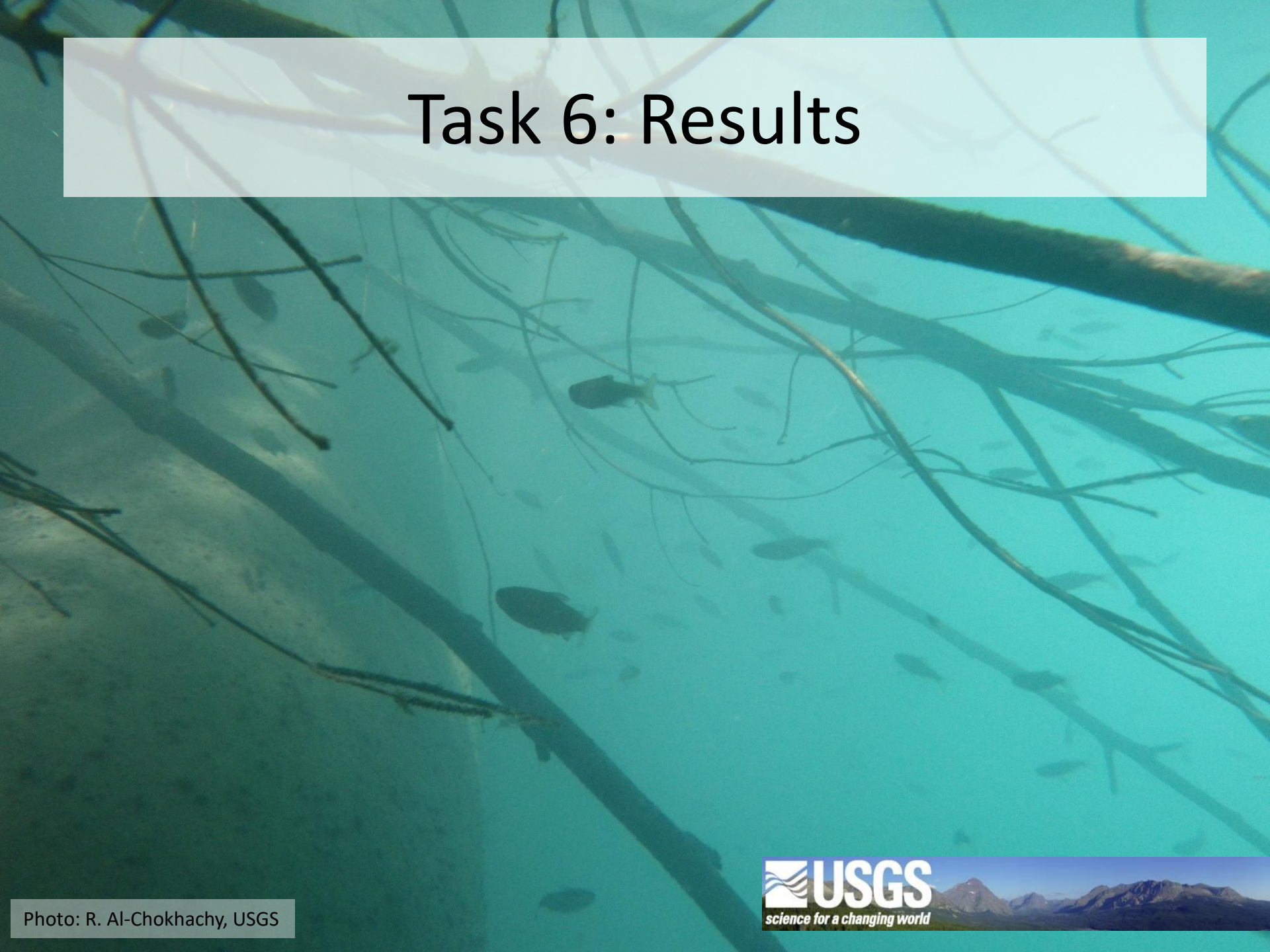


Photo: R. Al-Chokhachy, USGS

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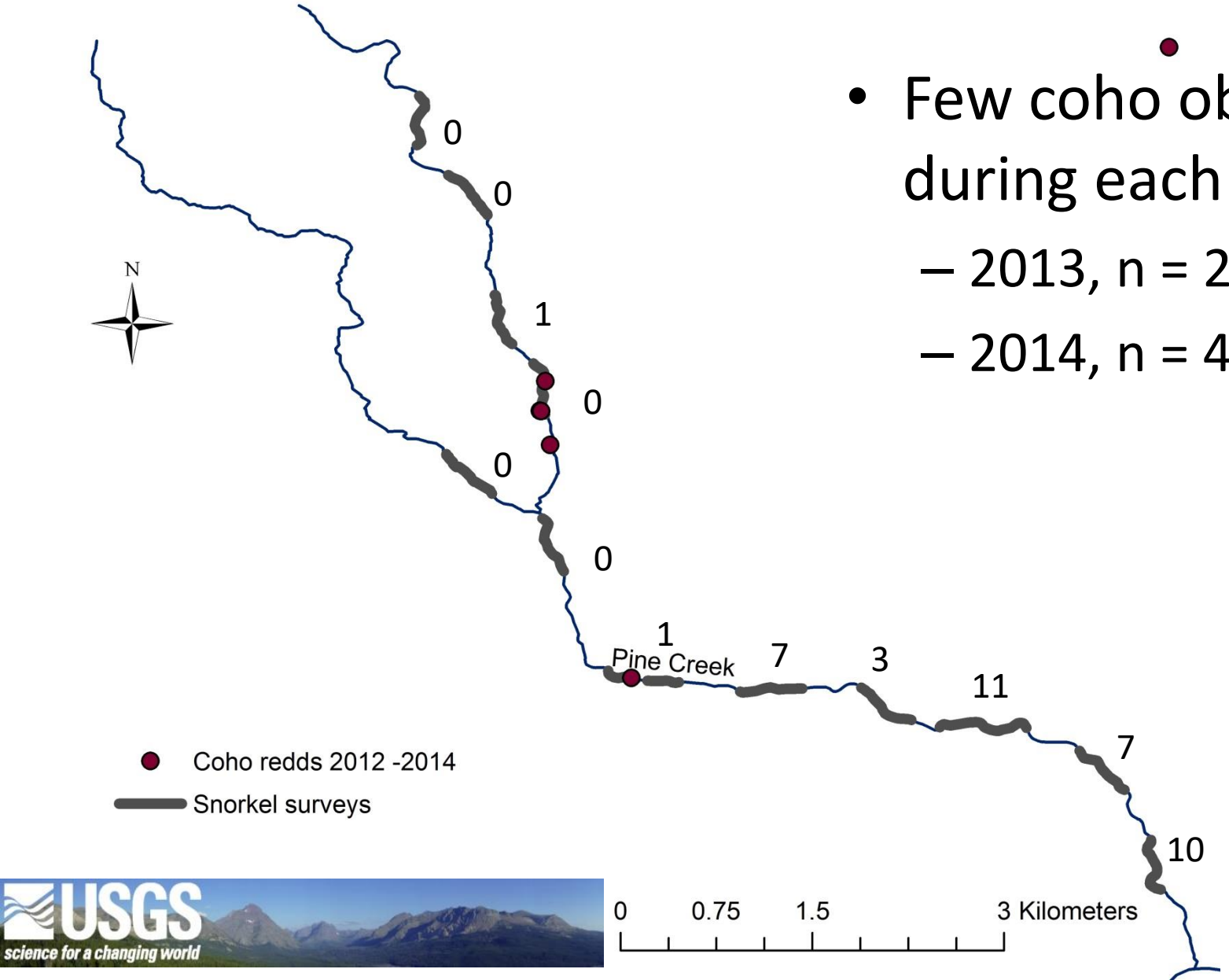
Snorkel surveys 2013-2014



- Few coho observed during each year
  - 2013, n = 2
  - 2014, n = 40

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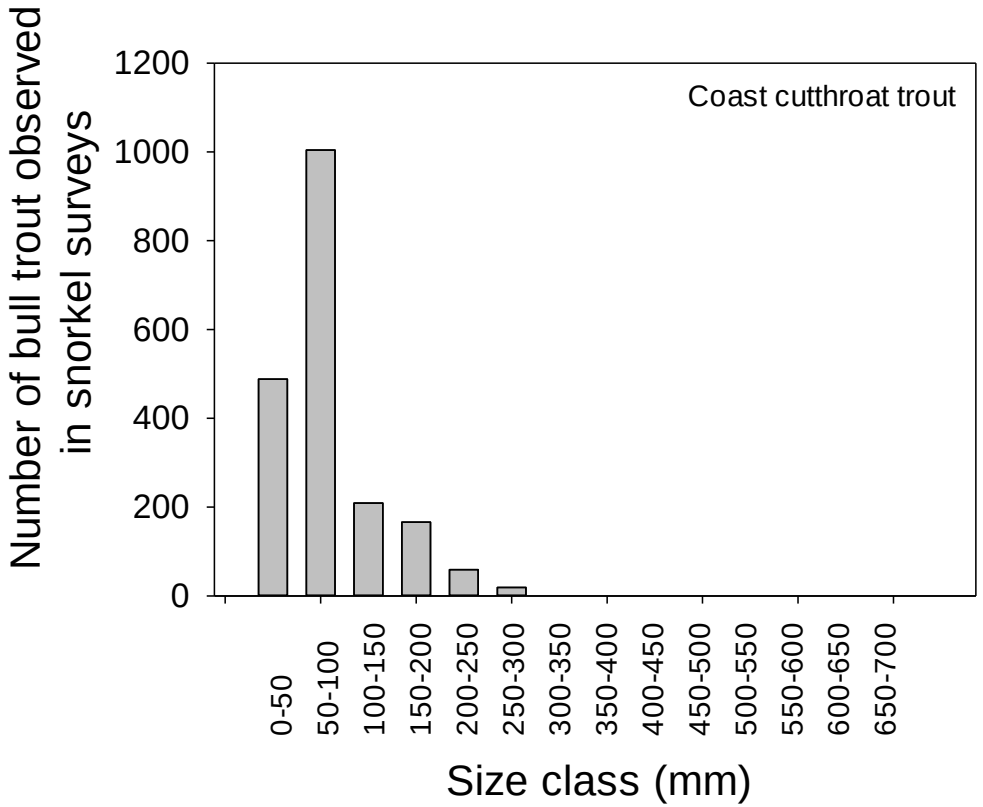
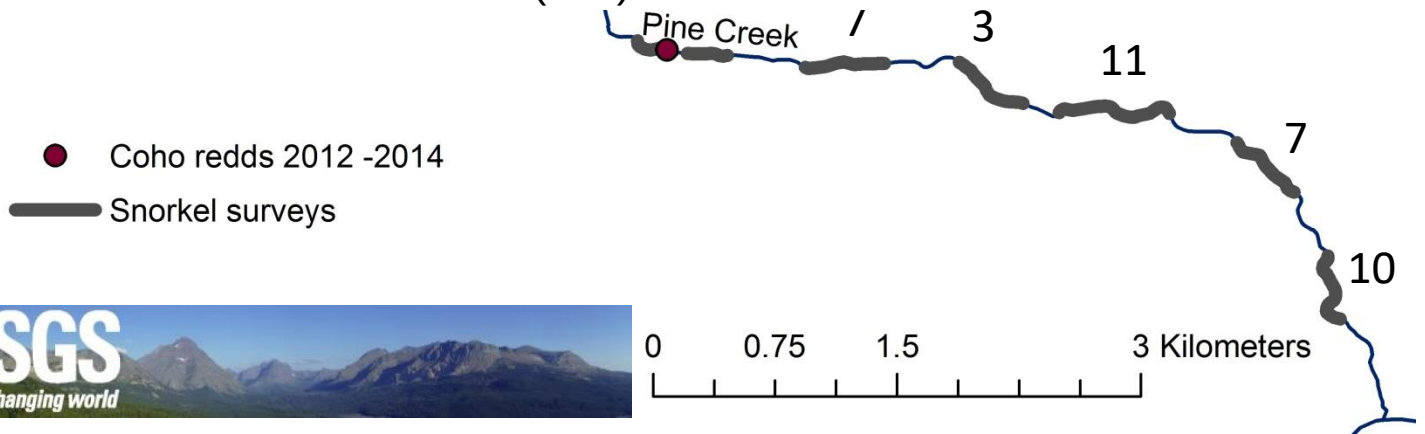
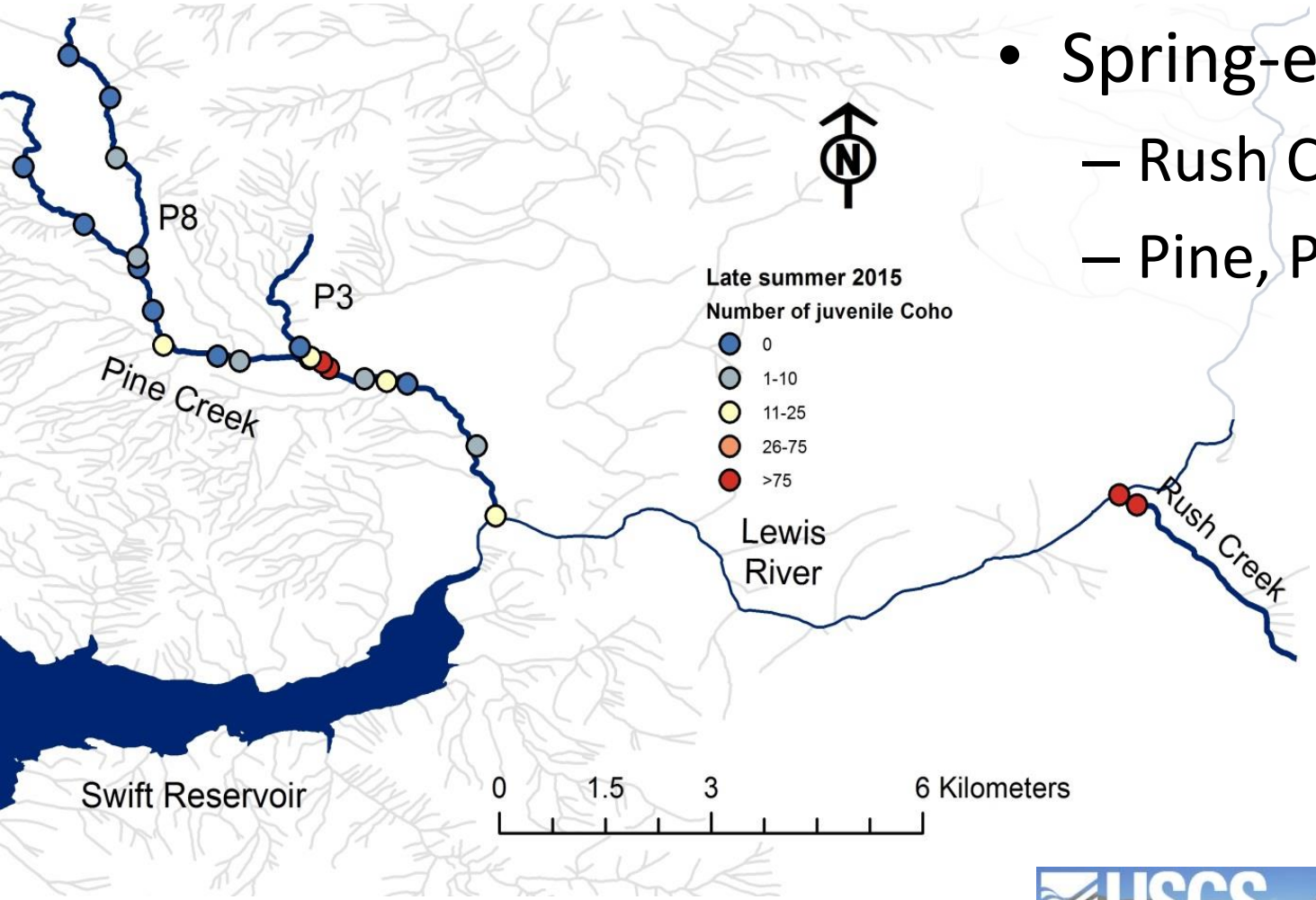
Snorkel surveys 2013-2014



- Few coho observed during each year
- Relatively low abundance compared to coastal cutthroat trout (10 - 100x higher)



Snorkel surveys 2015: expanded surveys



- Spring-early summer
  - Rush Creek
  - Pine, P8, P3

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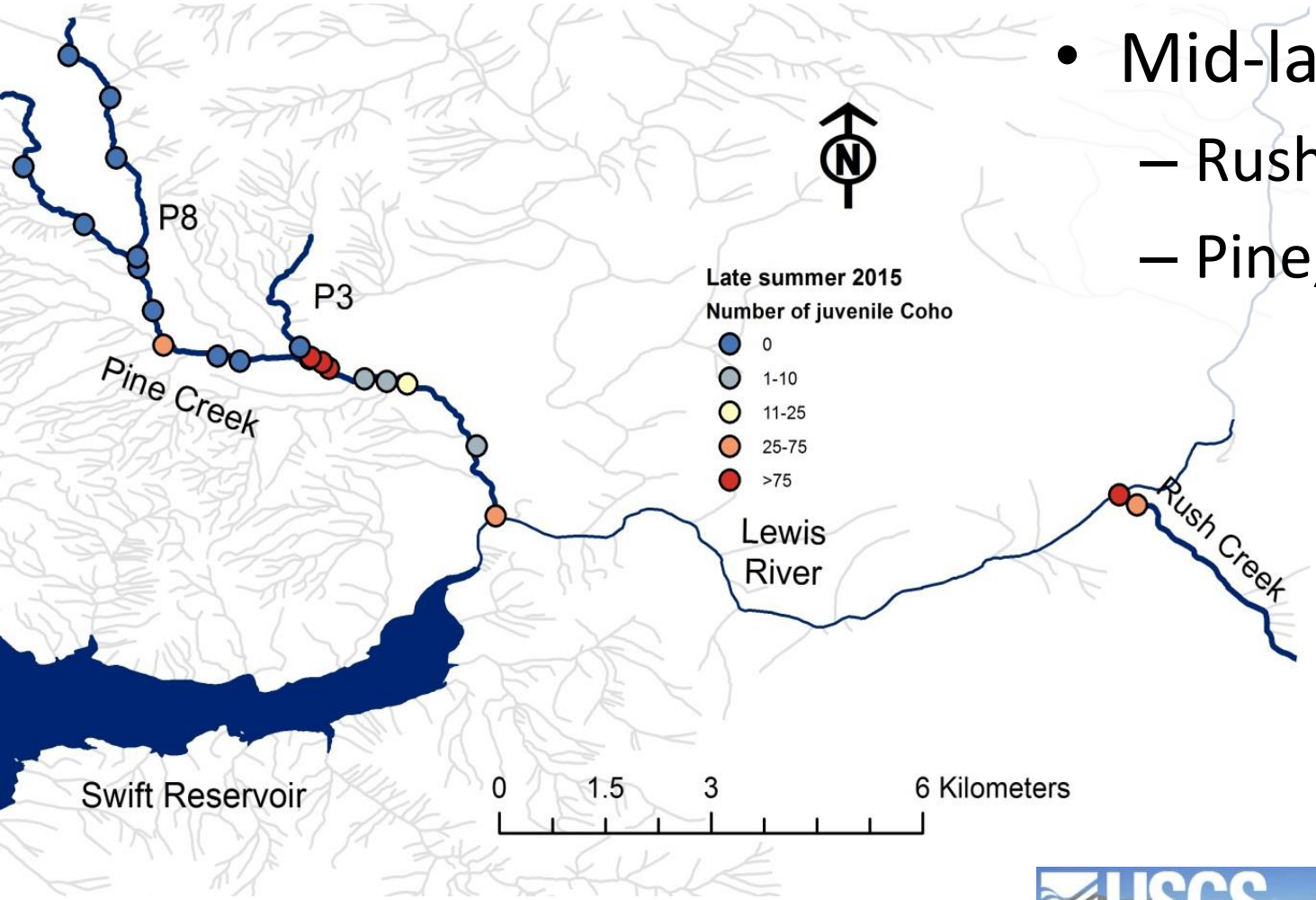
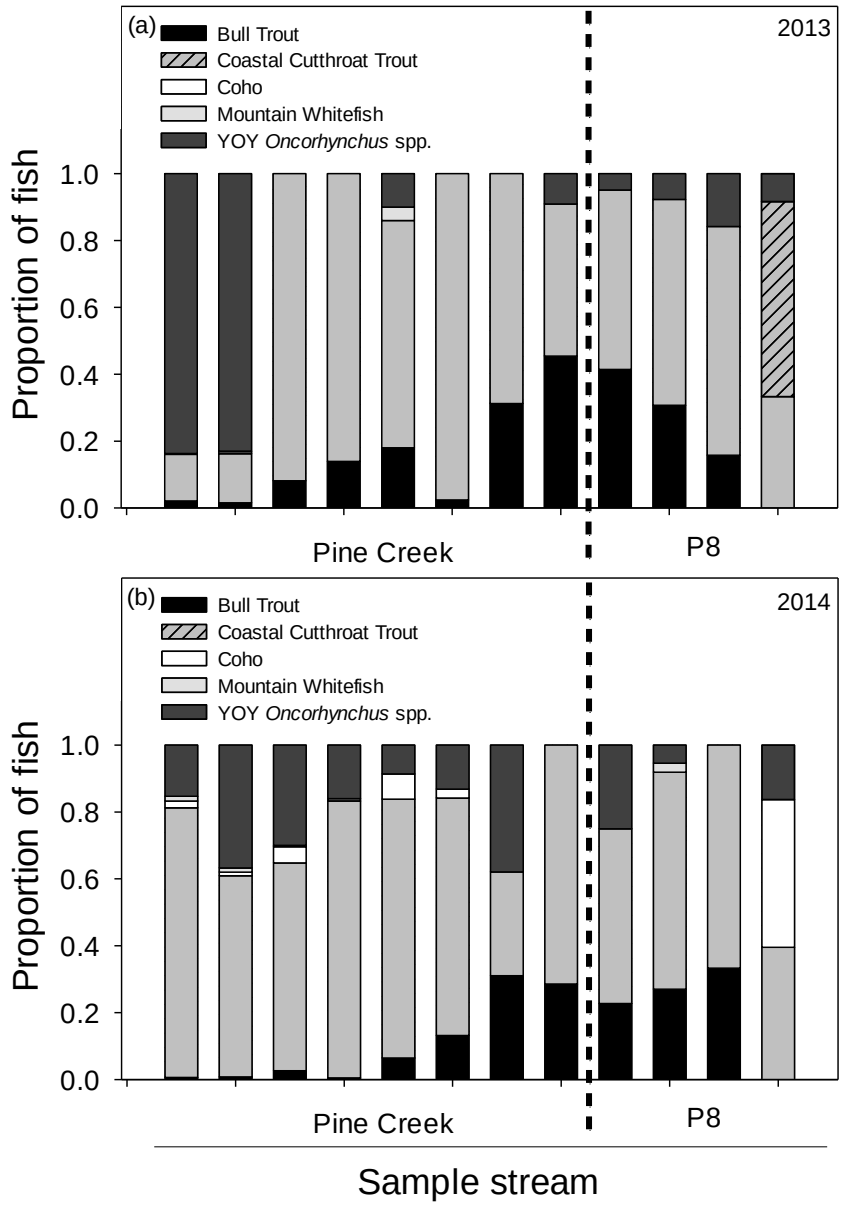
Snorkel surveys 2015: expanded surveys



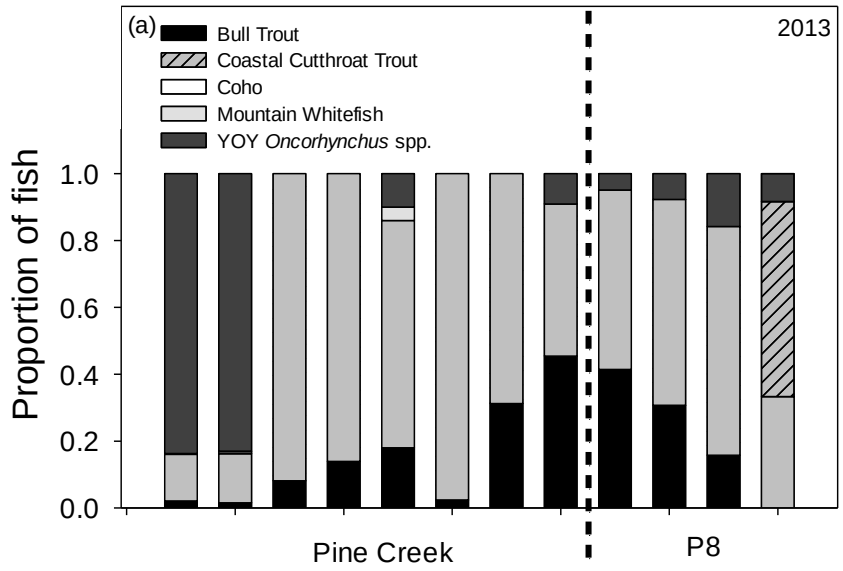
- Mid-late summer
  - Rush Creek
  - Pine, P8, P3

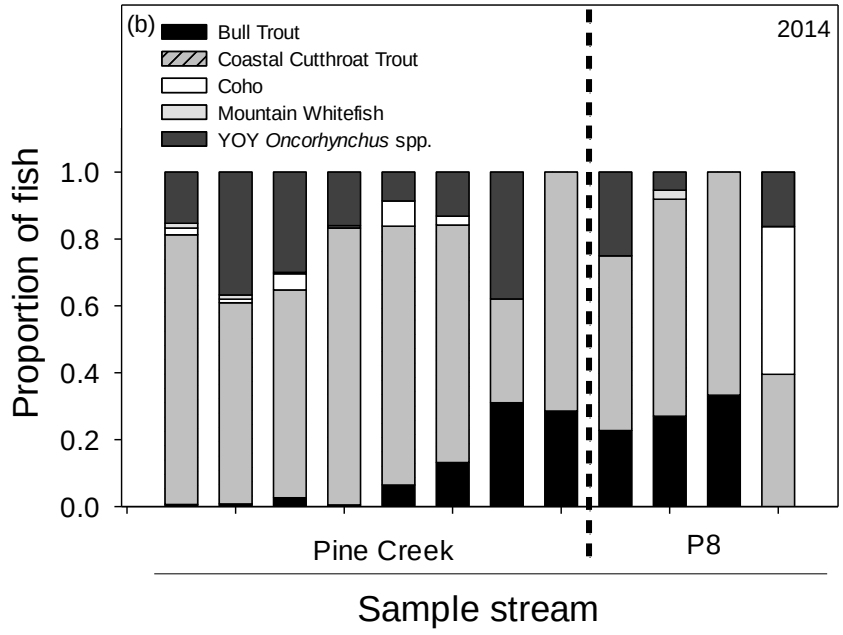
Snorkel surveys 2013-2014

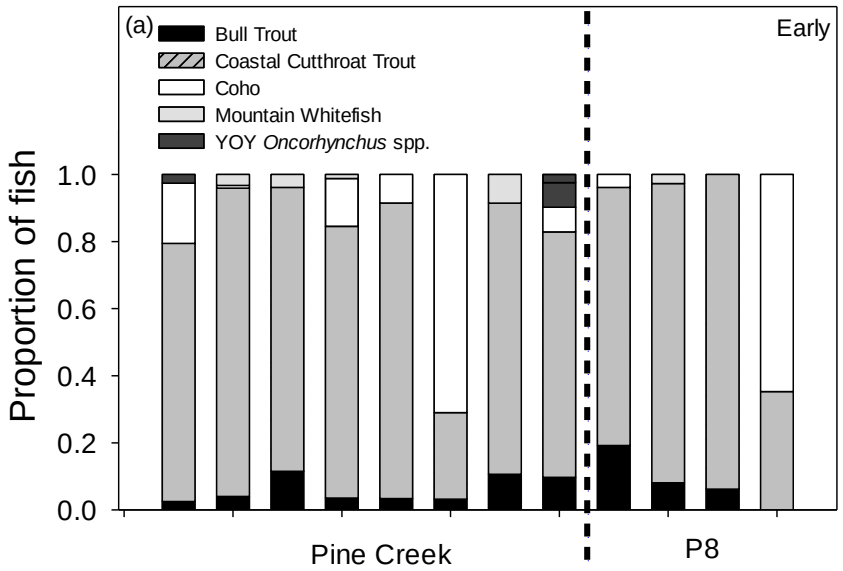


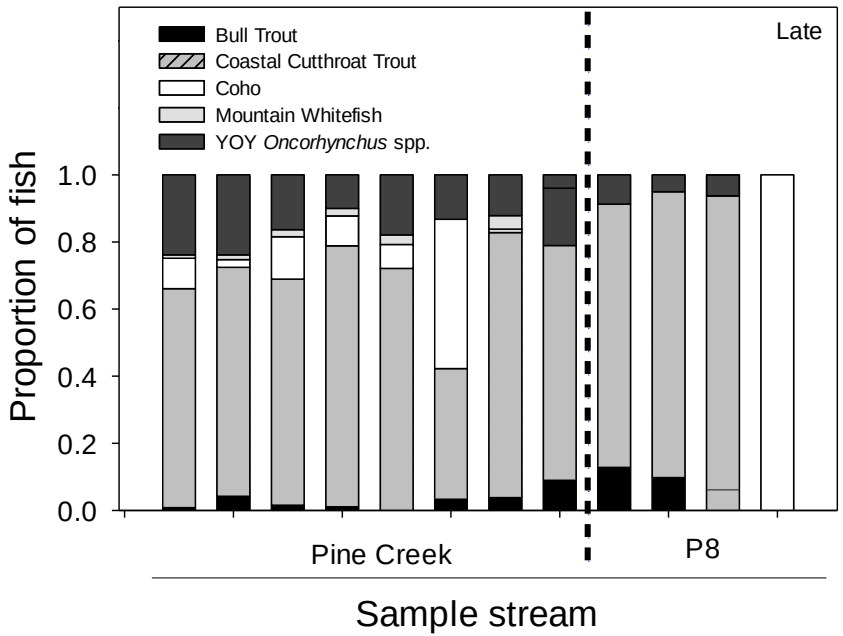
- Coho
  - Relatively low abundance
  - Coastal cutthroat trout

Snorkel surveys 2013-2015

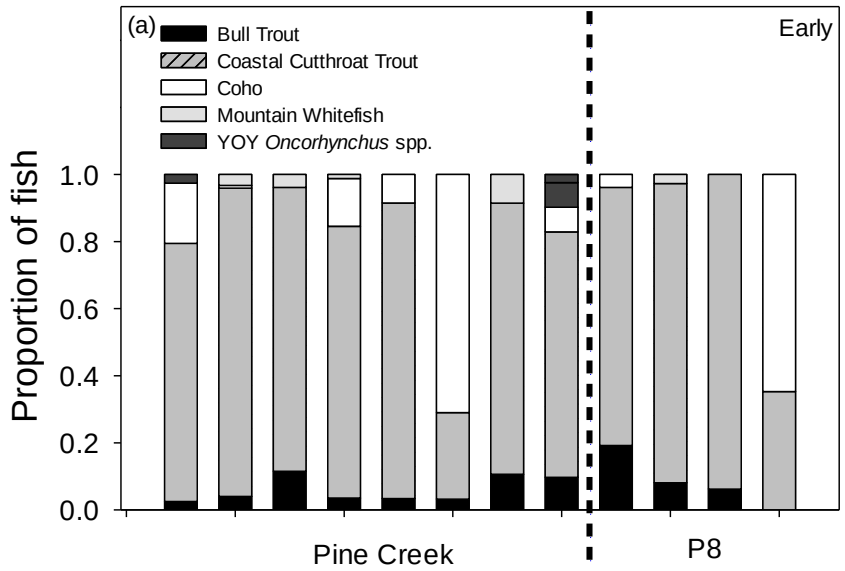


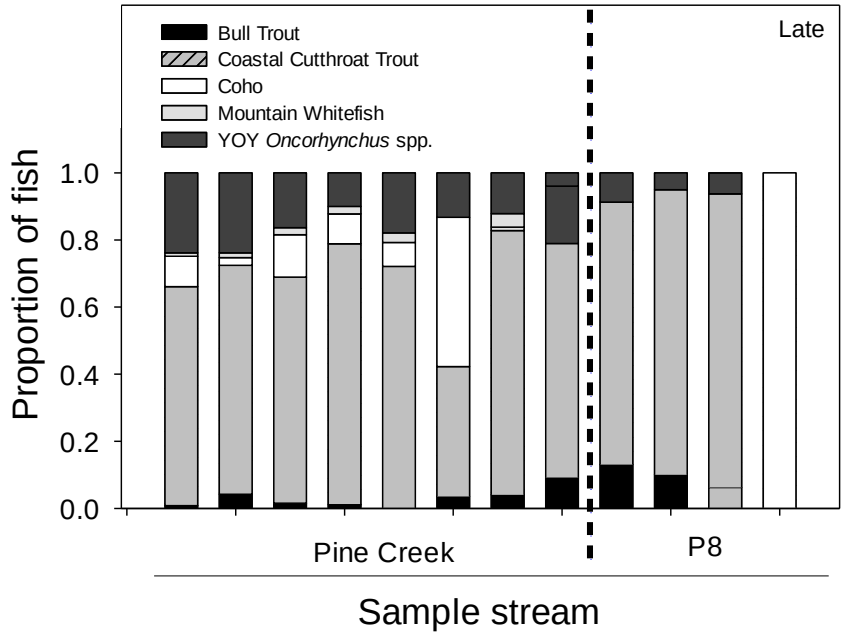


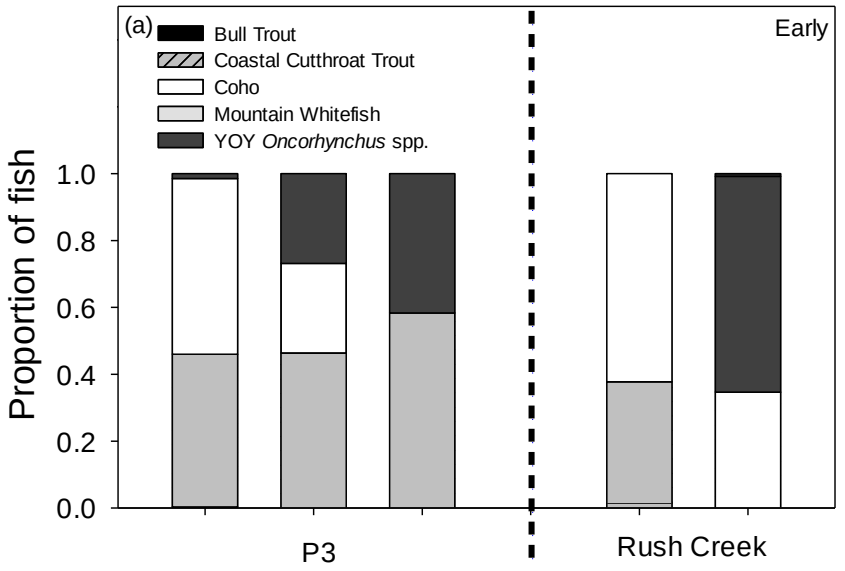


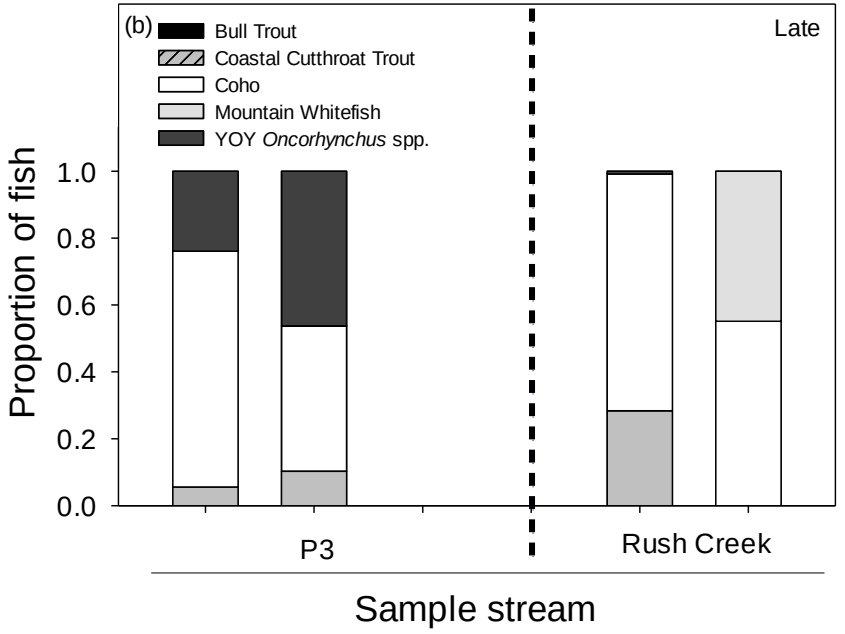


Snorkel surveys 2013-2015

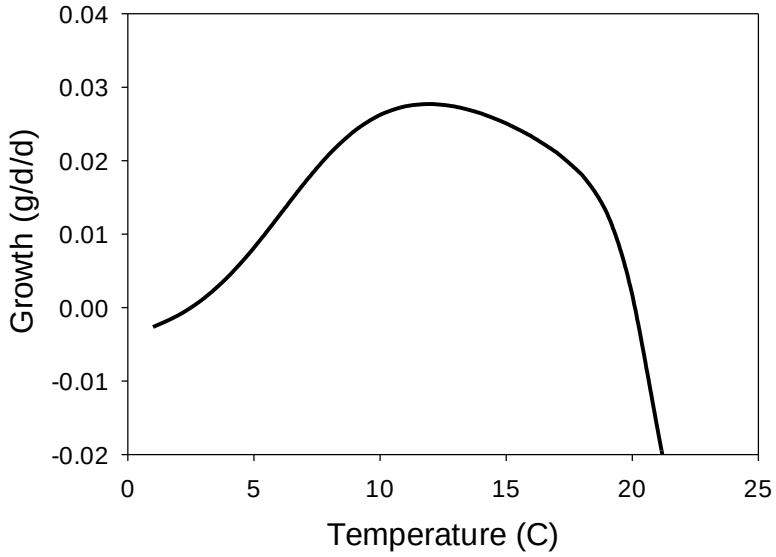


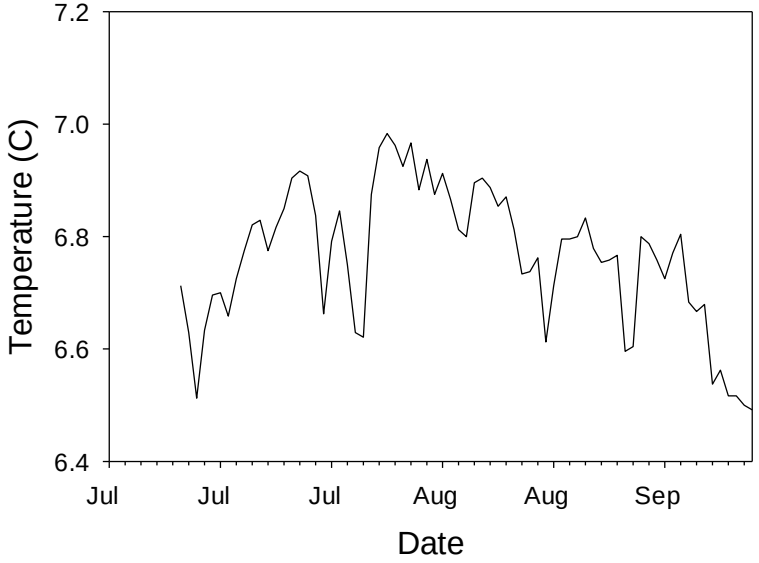






Snorkel surveys: Coho





- Outmigration due to thermal limitations for growth?
- Habitat

Photo: R. Al-Chokhachy, USGS

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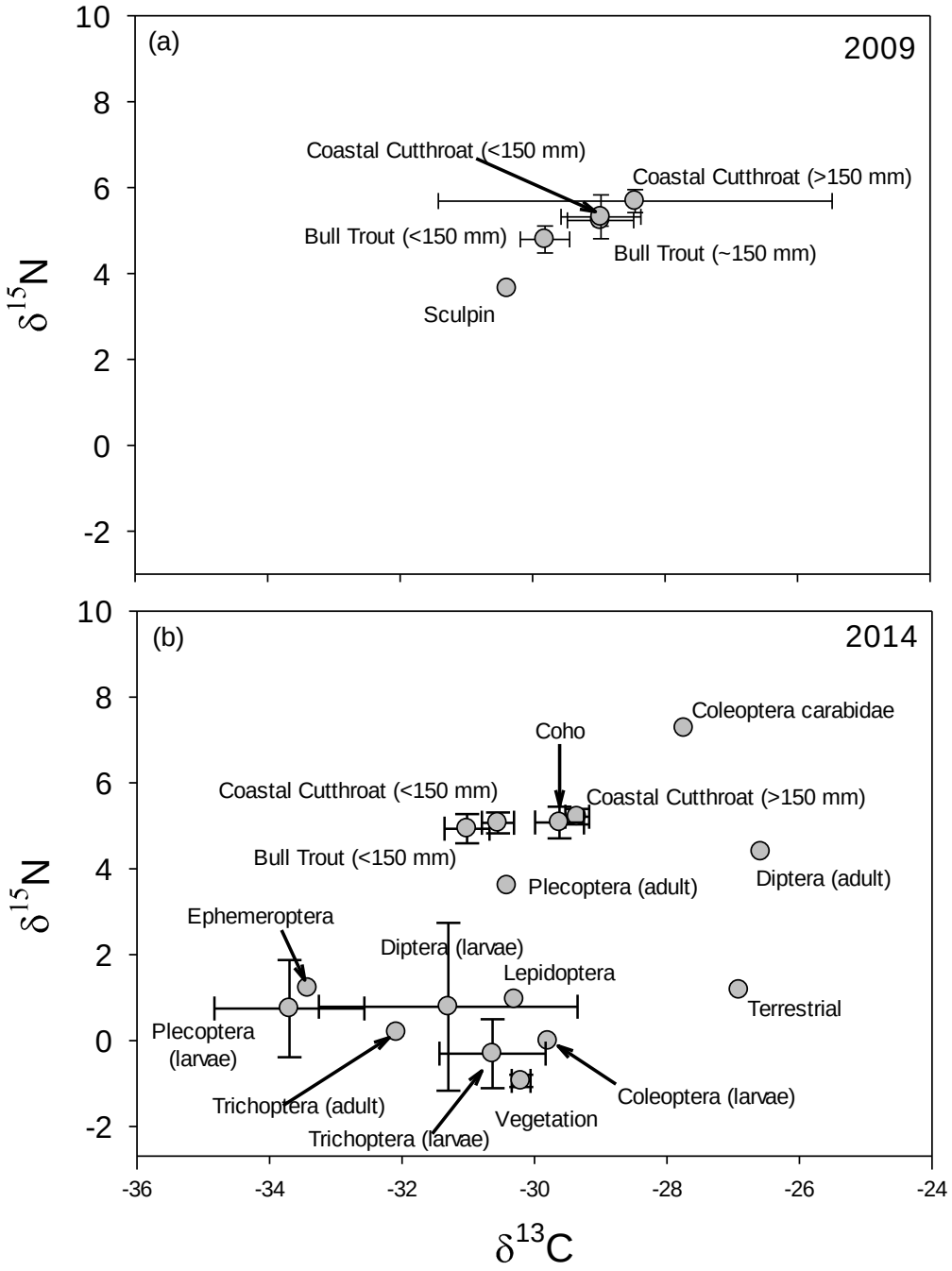

Tributary trophic interactions

- δ ^{15}N and δ ^{13}C
- P8
- Bull trout and coho
  - Similar trophic level
  - ~similar food resources

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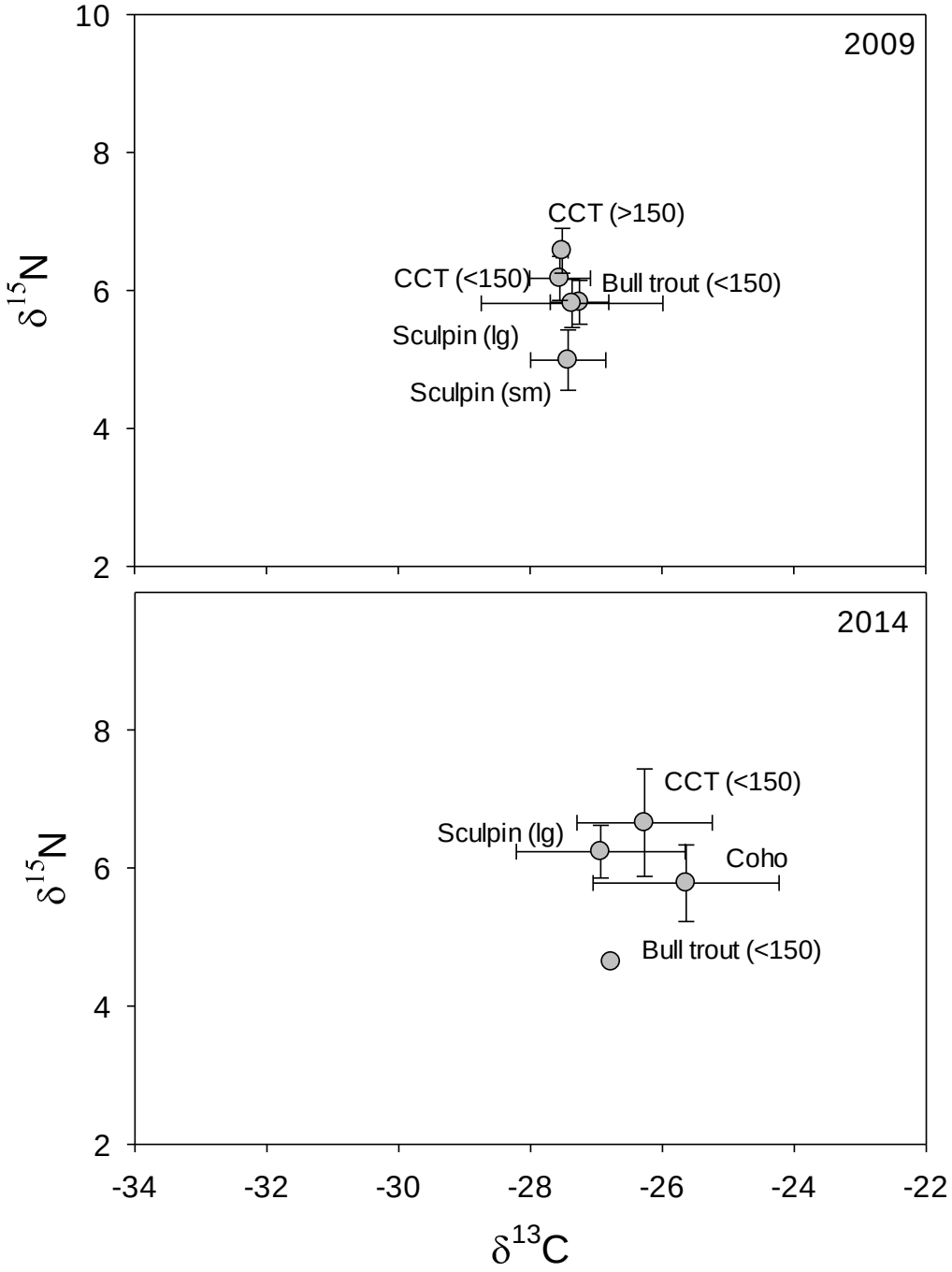

Tributary trophic interactions

- Rush Creek
- Consistent pattern with P8
- Bull trout and coho
  - Similar trophic level
  - ~similar food resources

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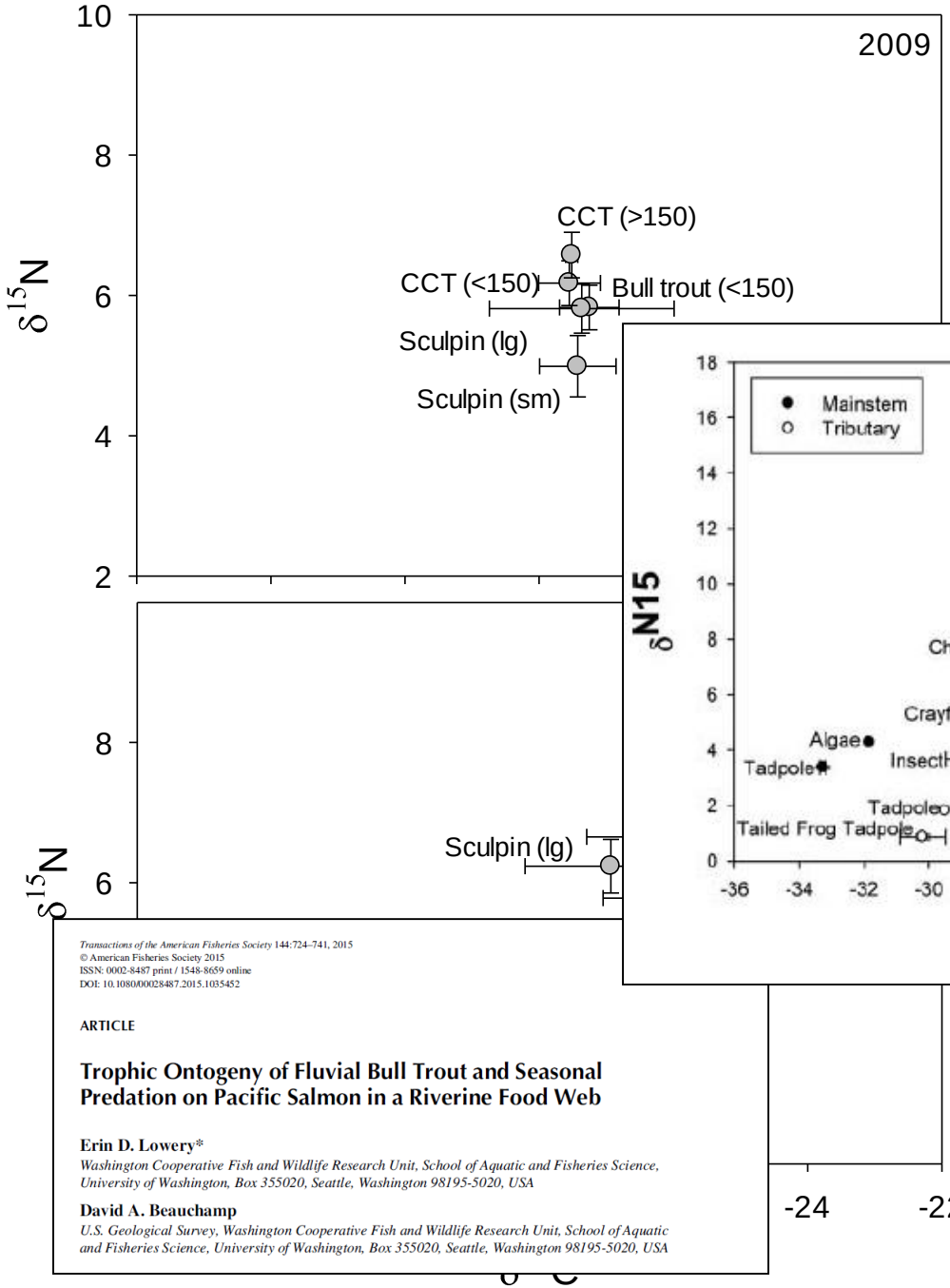
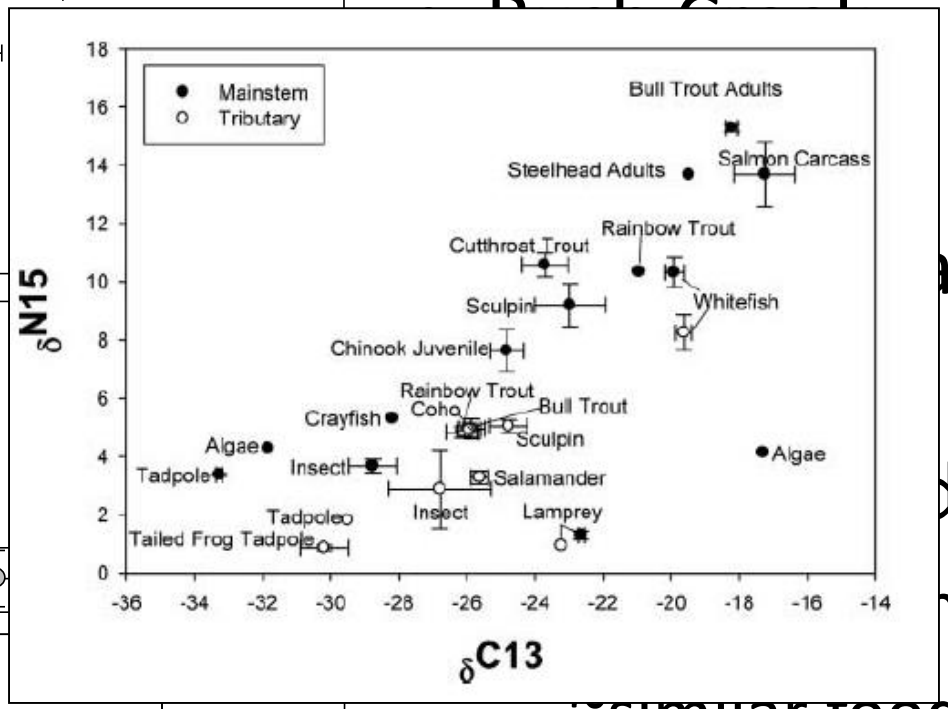
Tributary trophic interactions





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ARTICLE

Trophic Ontogeny of Fluvial Bull Trout and Seasonal Predation on Pacific Salmon in a Riverine Food Web

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David A. Beauchamp
U.S. Geological Survey, Washington Cooperative Fish and Wildlife Research Unit, School of Aquatic and Fisheries Science, University of Washington, Box 355020, Seattle, Washington 98195-5020, USA

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d coho

hic level

similar food resources

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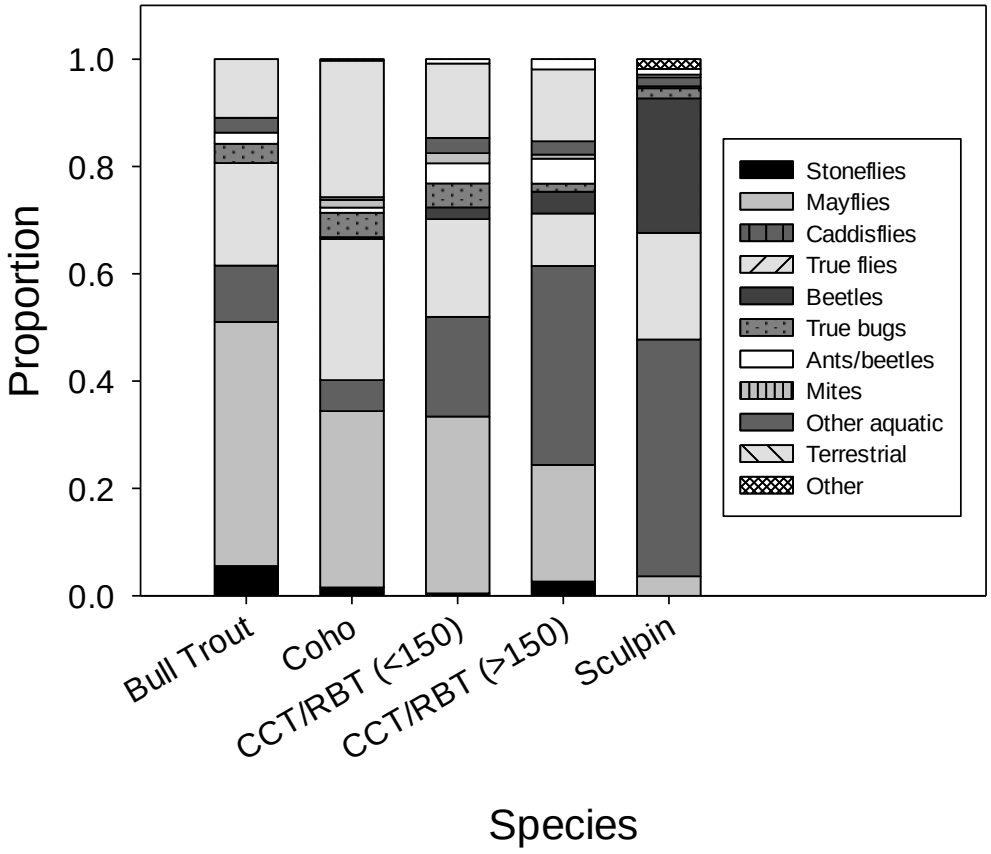
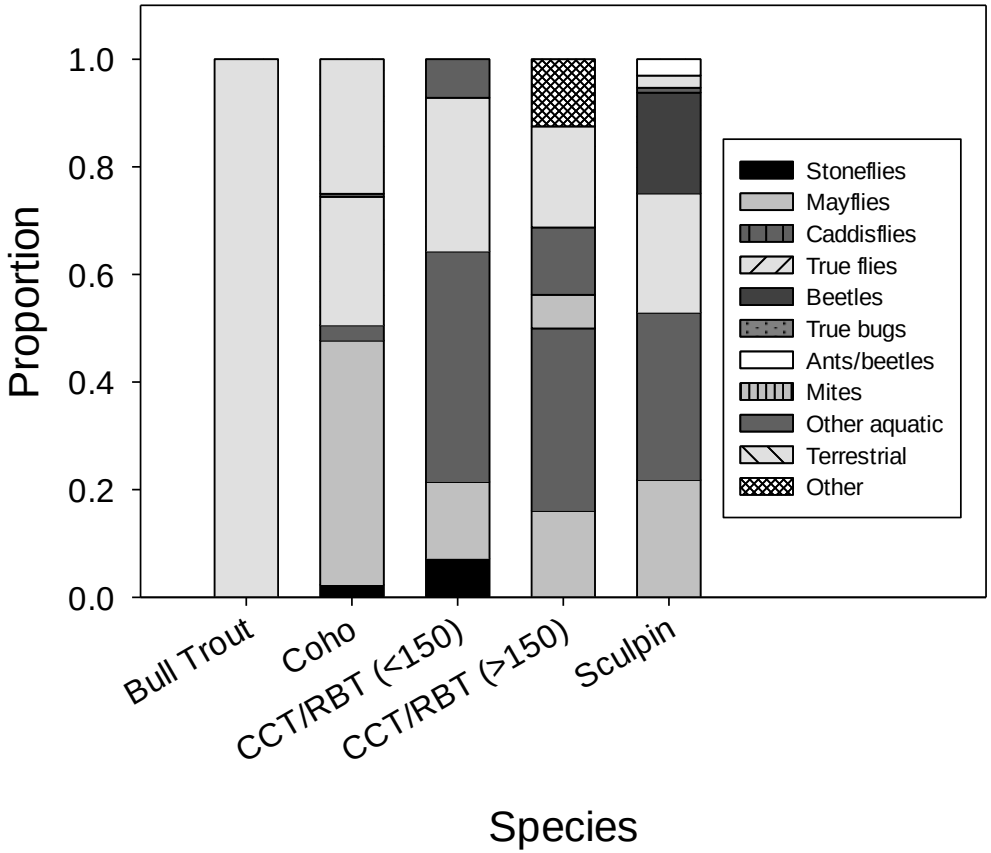
Tributary trophic interactions



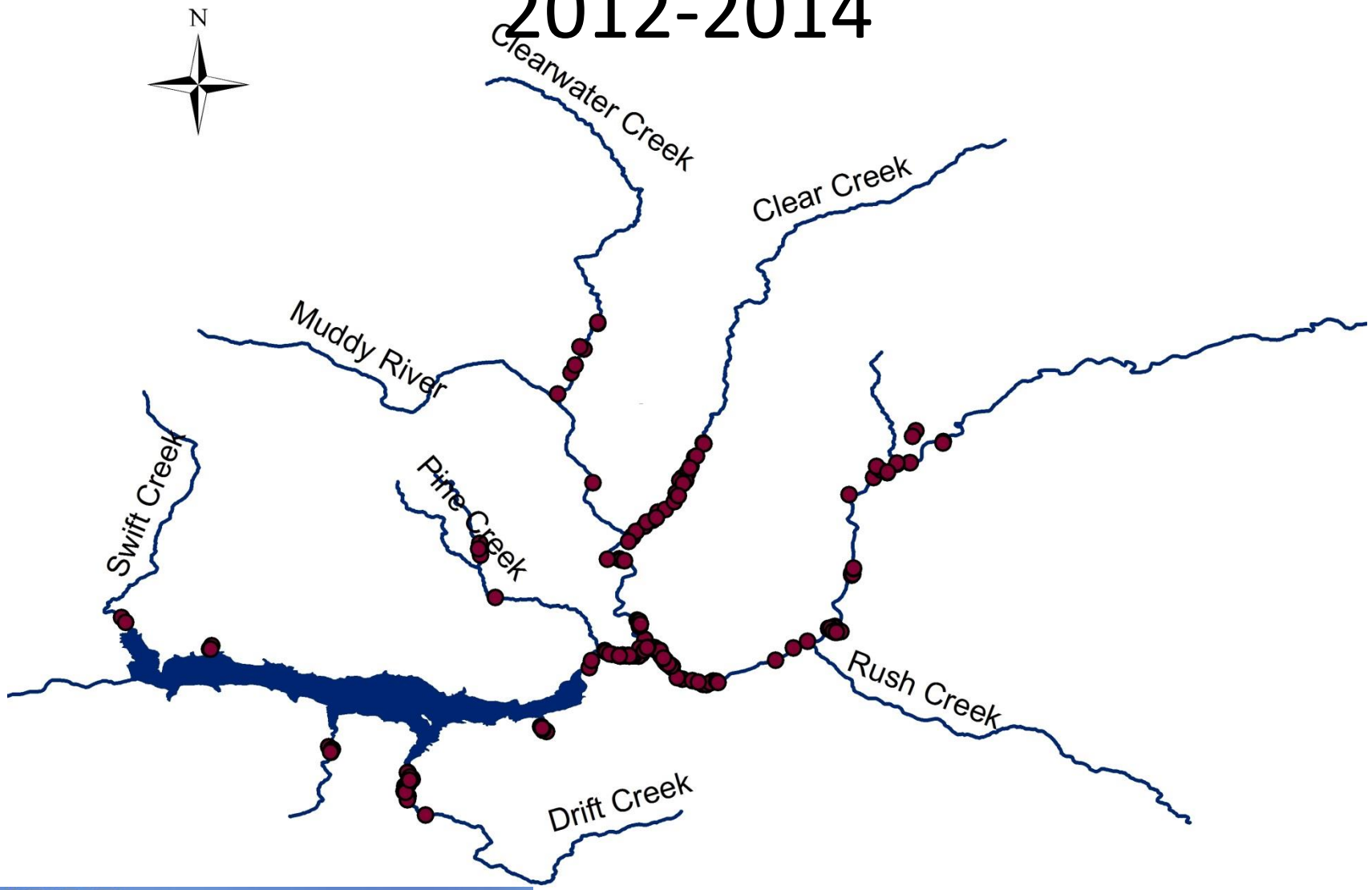
- Summer diet data
- Consistent results with isotope data
  - High overlap
    - Mayflies
    - True flies
    - Caddisflies

Tributary trophic interactions



- Fall diet data
- Shifts in fall

Redd superimposition: Coho redds 2012-2014



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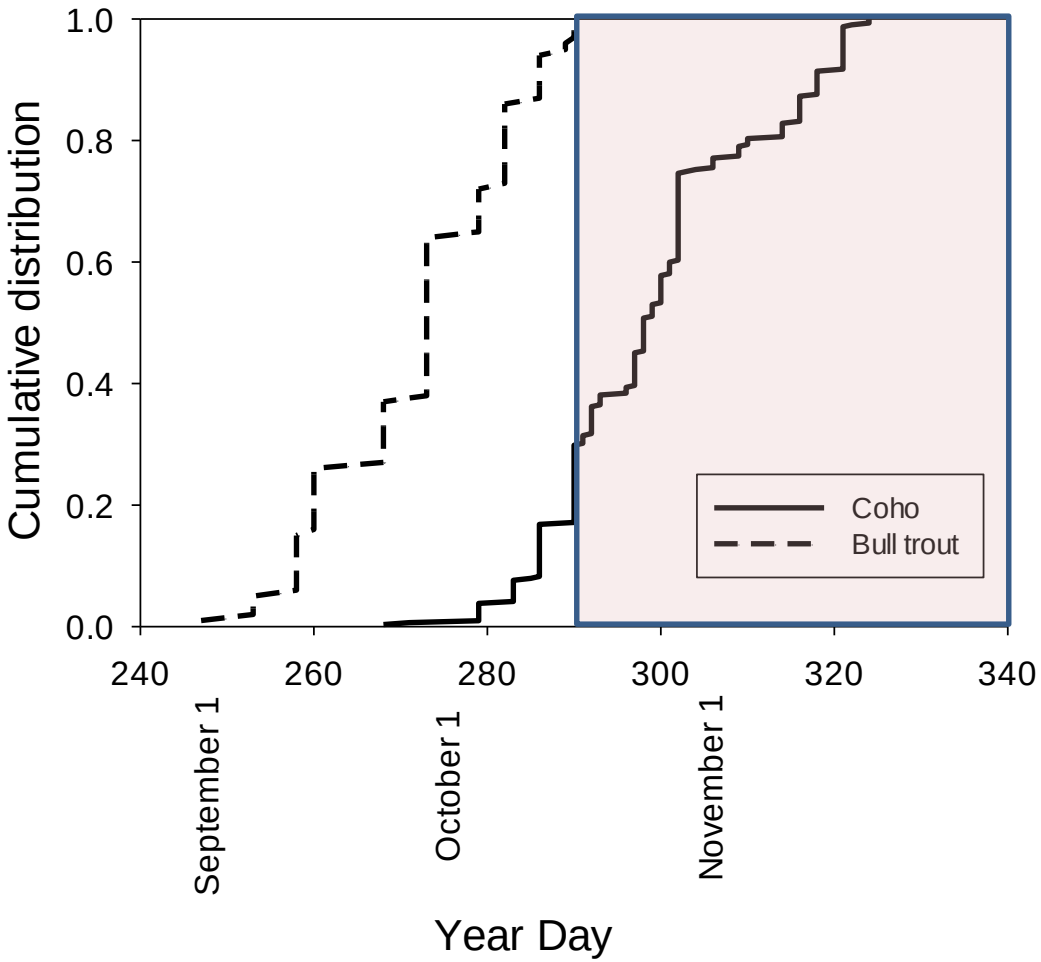
Temporal overlap: superimposition



- Bull trout redds
  - 2012 – current
  - Pine/P8
- Coho redds
  - 2012 – present
  - All tributaries above swift
- 80% of coho spawning occurs after bull trout
  - Hatchery individuals

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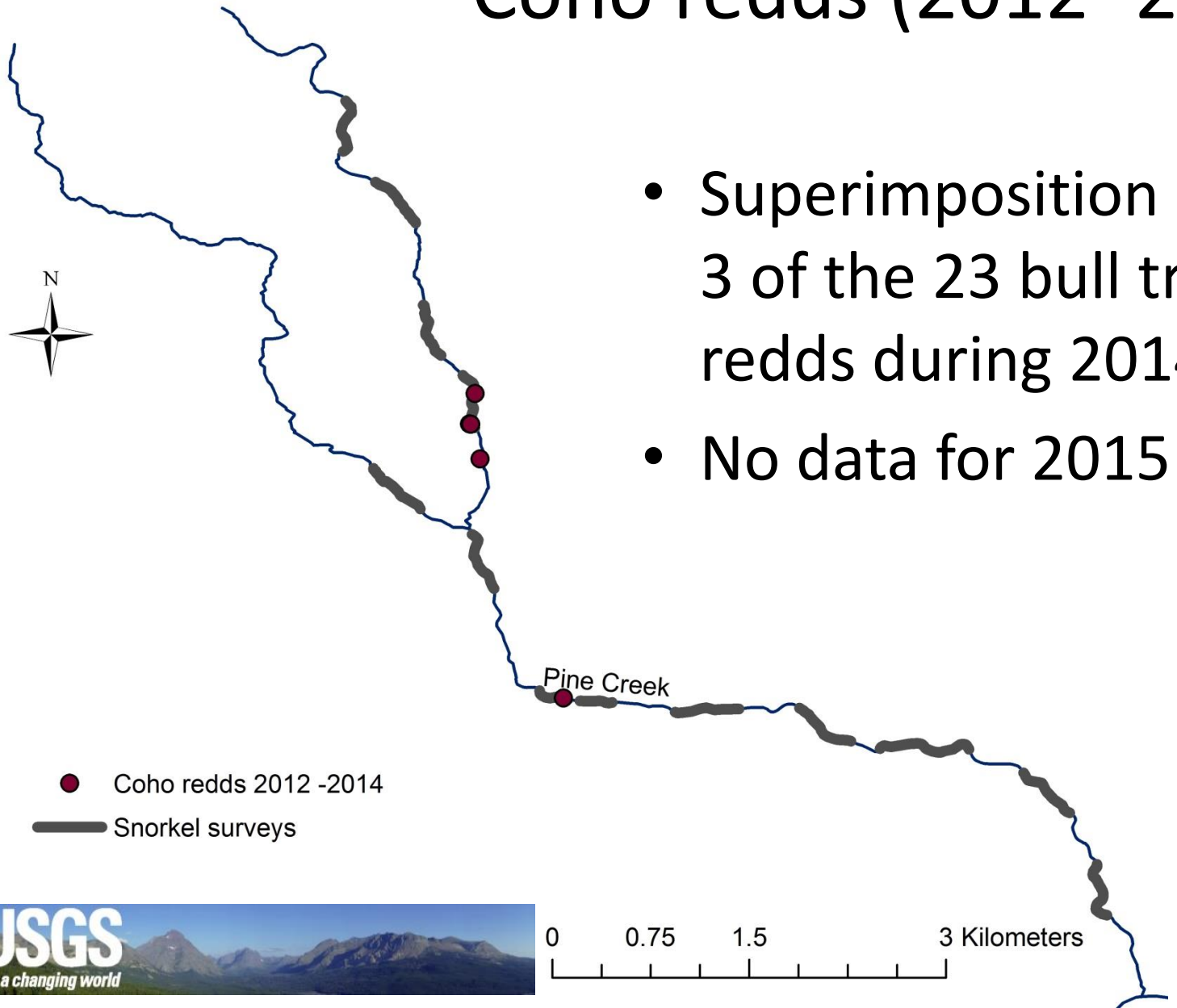
Coho redds (2012 -2014)



- Superimposition found on 3 of the 23 bull trout redds during 2014
- No data for 2015

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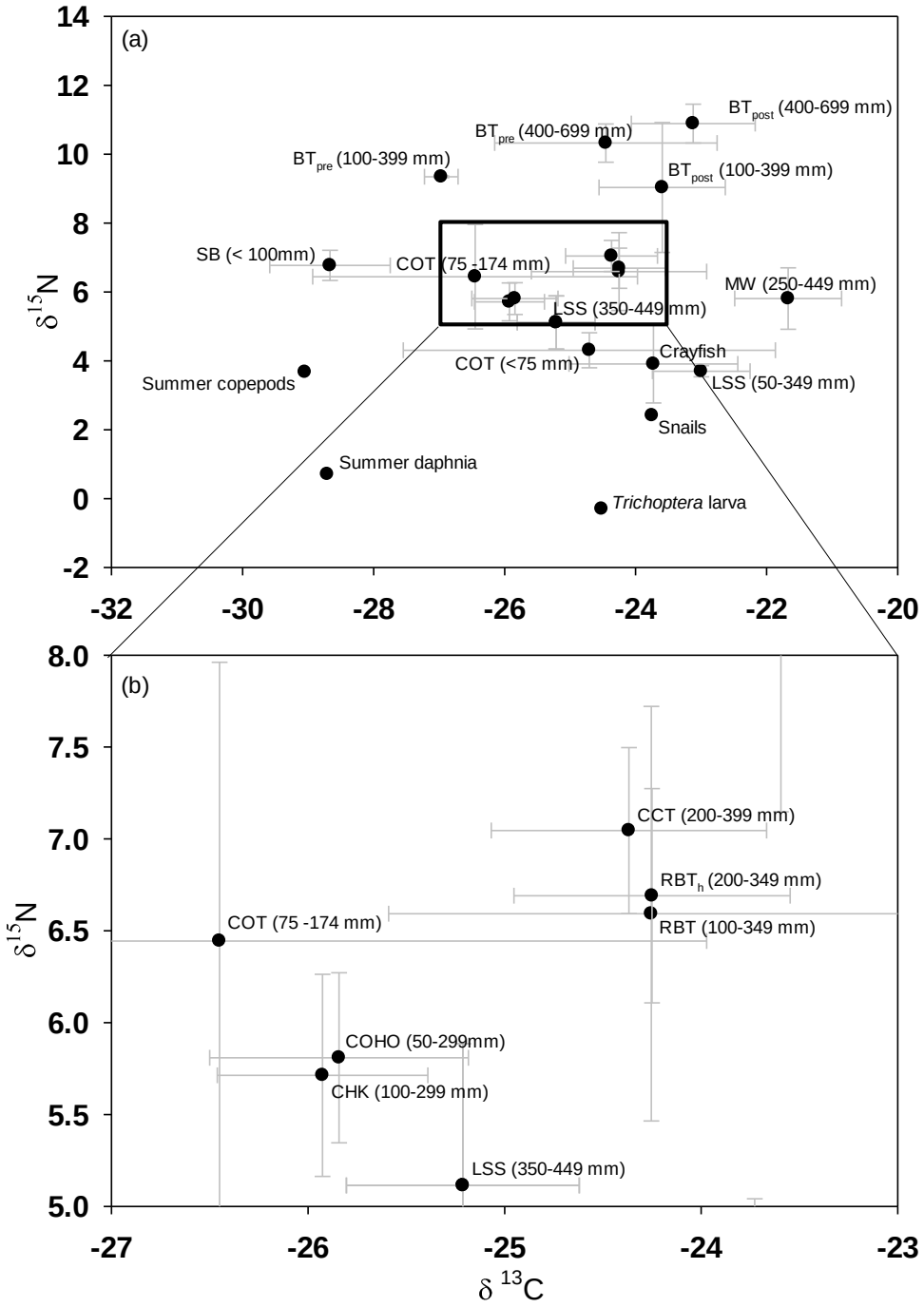
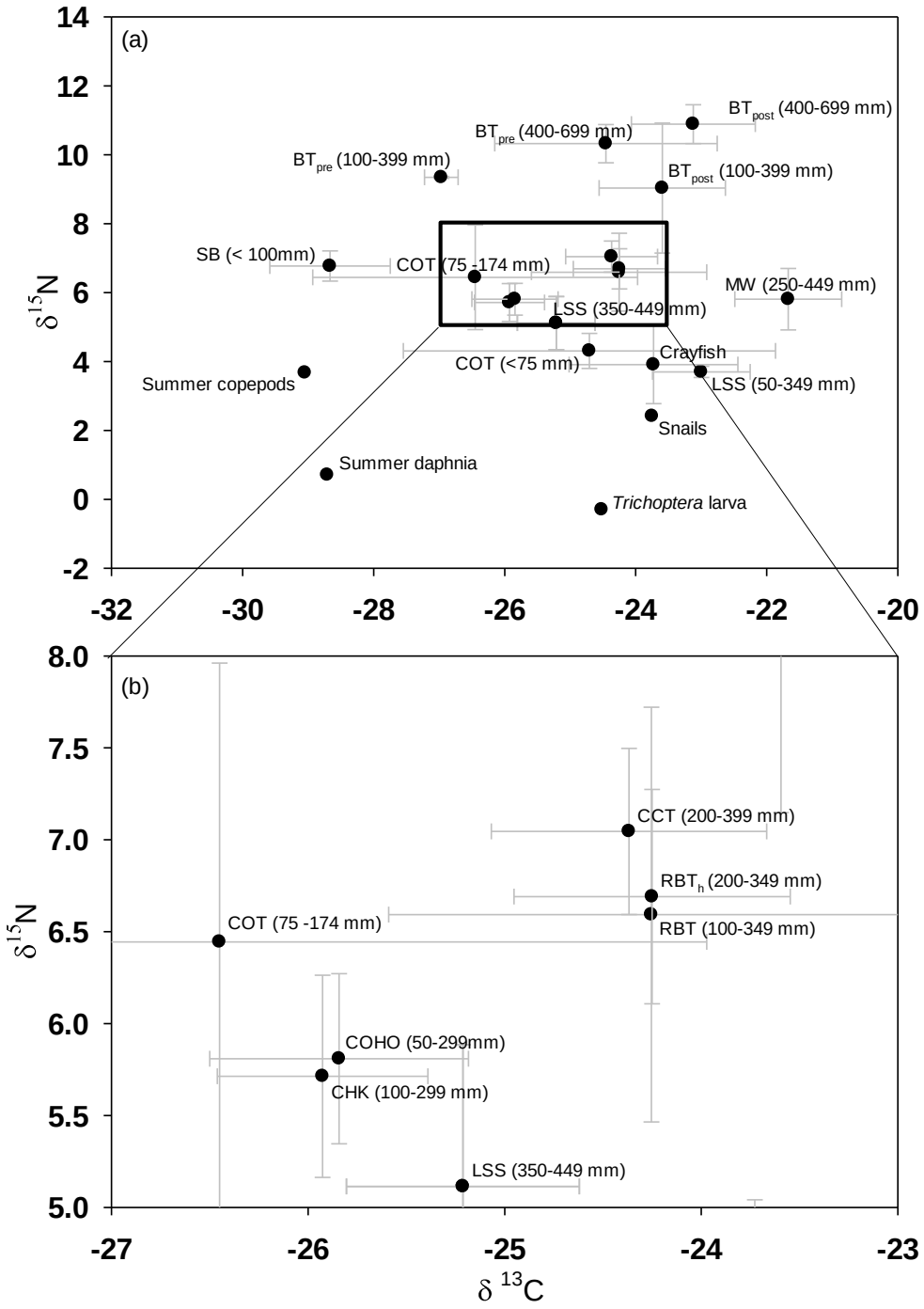


Reservoir trophic interactions

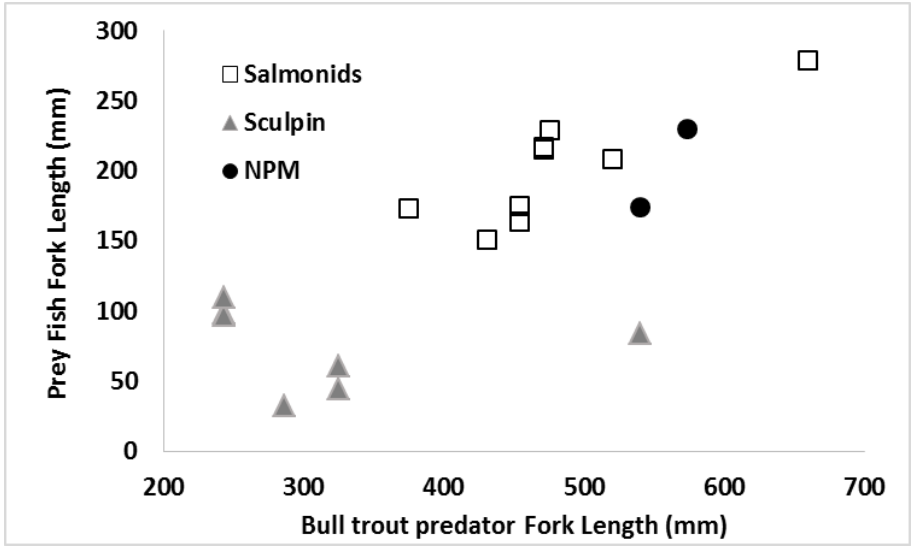
- Bull trout >400mm – top predator
  - Slightly higher trophic position
  - Slight shift in sources



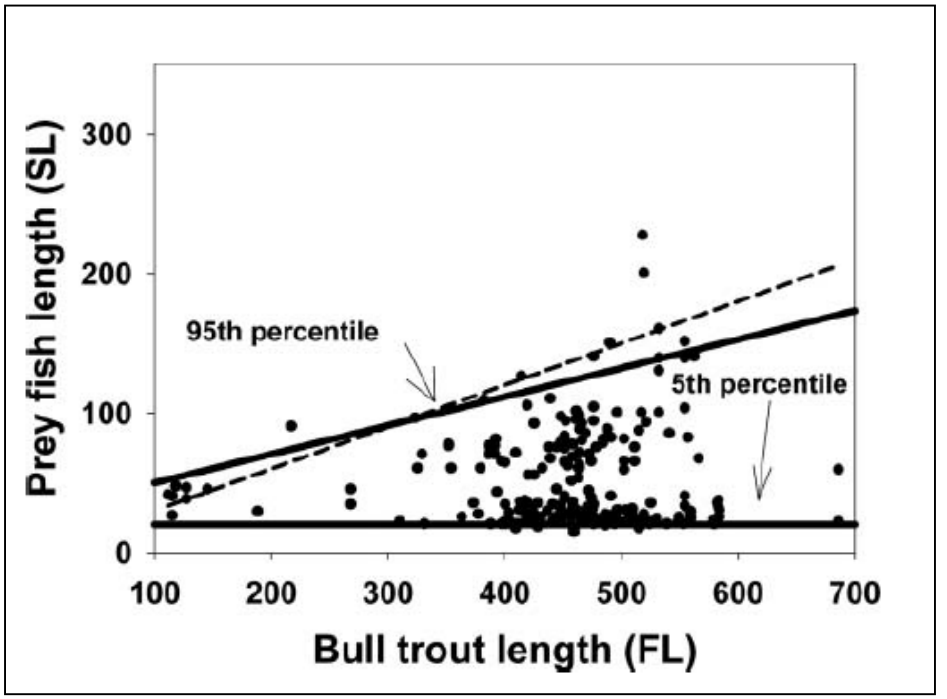
Reservoir trophic interactions

- Bull trout <400mm
  - High trophic position
    - Consistent across periods
  - Substantial shift in forage sources

Bull trout gape limitations/foraging patterns

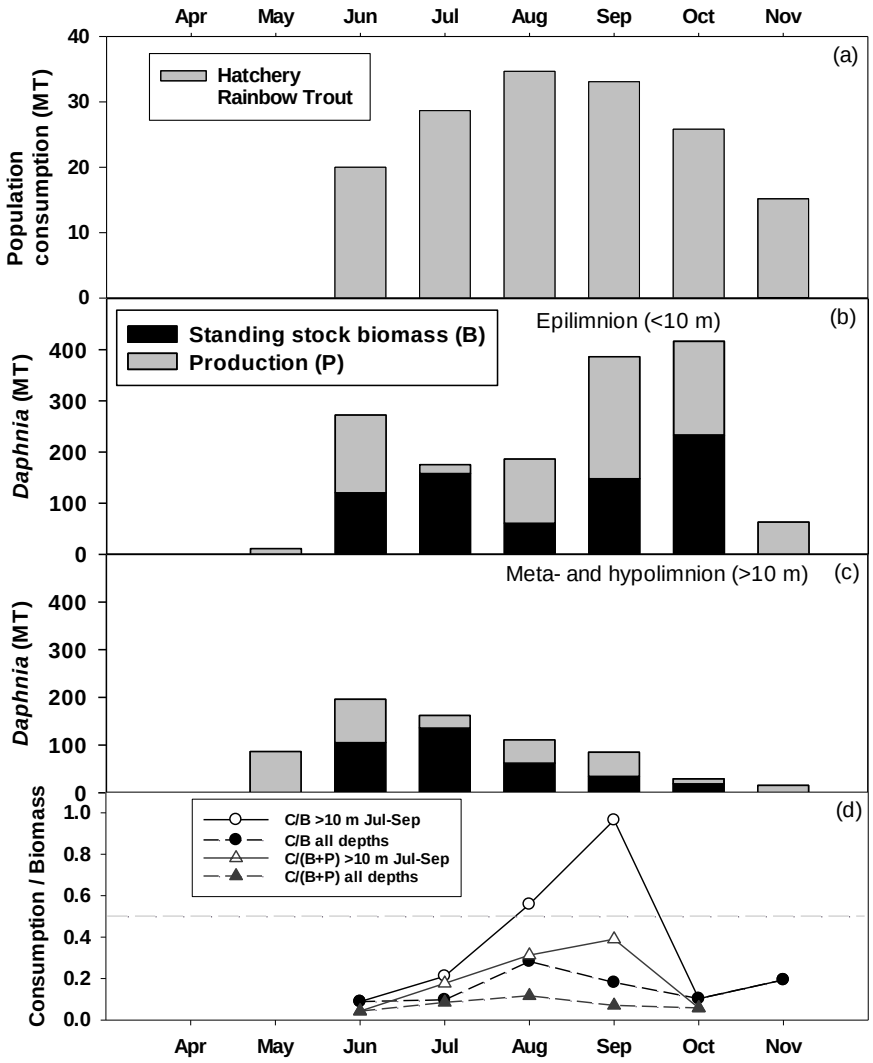


Lowery and Beauchamp 2015



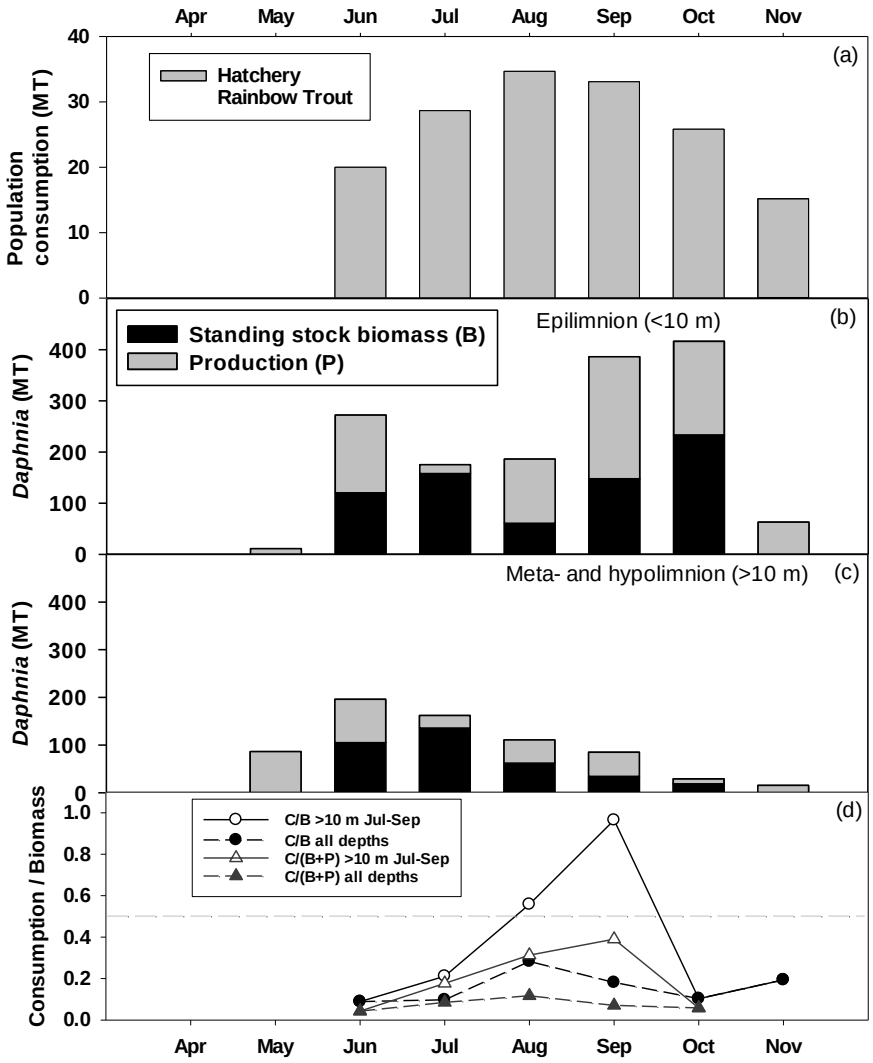
- Length-foraging patterns
- Finding prey
- Shift with increasing prey and size classes?

Reservoir carrying capacity



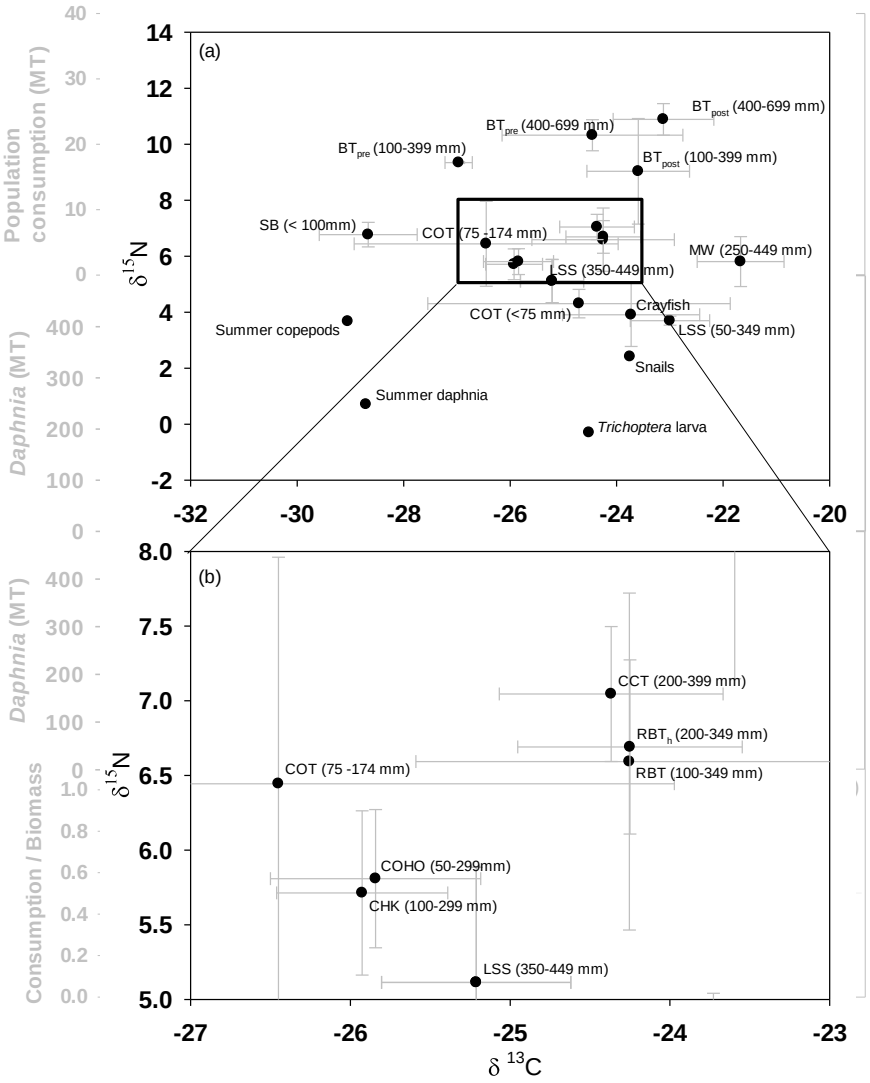
- Swift
  - RBT demand
  - Biomass + production
- Consumption/(B+P)
  - Support ~150,000 spring Chinook

Reservoir carrying capacity



- Swift
  - RBT demand
  - Biomass + production
- Consumption/(B+P)
  - Support ~150,000 spring Chinook
- Other fishes?
  - Coho
    - Fry ~6 months to year
    - Parr/smolts
  - Residualized salmon
    - Low collection rates

Reservoir carrying capacity



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  - Support ~150,000 spring Chinook
- Other fishes?
  - Coho
    - Fry ~6 months to year
    - Parr/smolts
  - Residualized salmon
    - Low collection rates

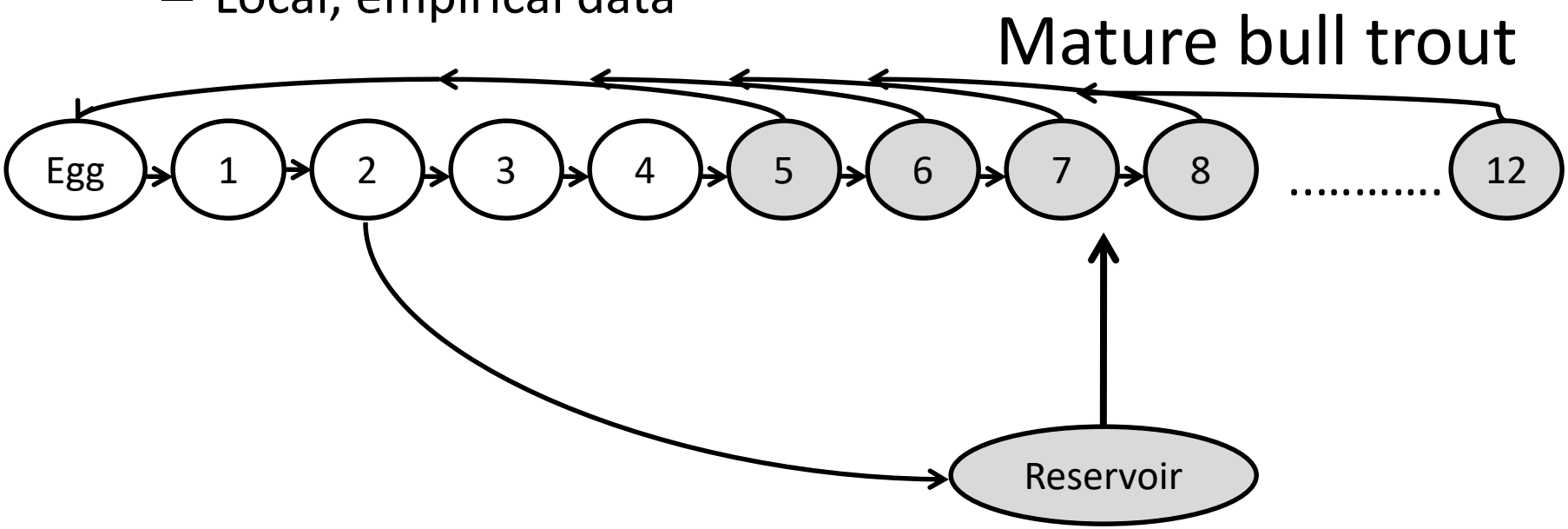
Integrating field data: potential effects on bull trout

- Field data into a modeling framework
- Integrate results with local data from WDFW, USFS, PacifiCorp

Photo: R. Al-Chokhachy, USGS

Individual-based model

- Small population in Swift/Yale
  - Enables tracking of individuals
  - Averages for small populations not applicable (e.g., matrix models)
  - Local, empirical data



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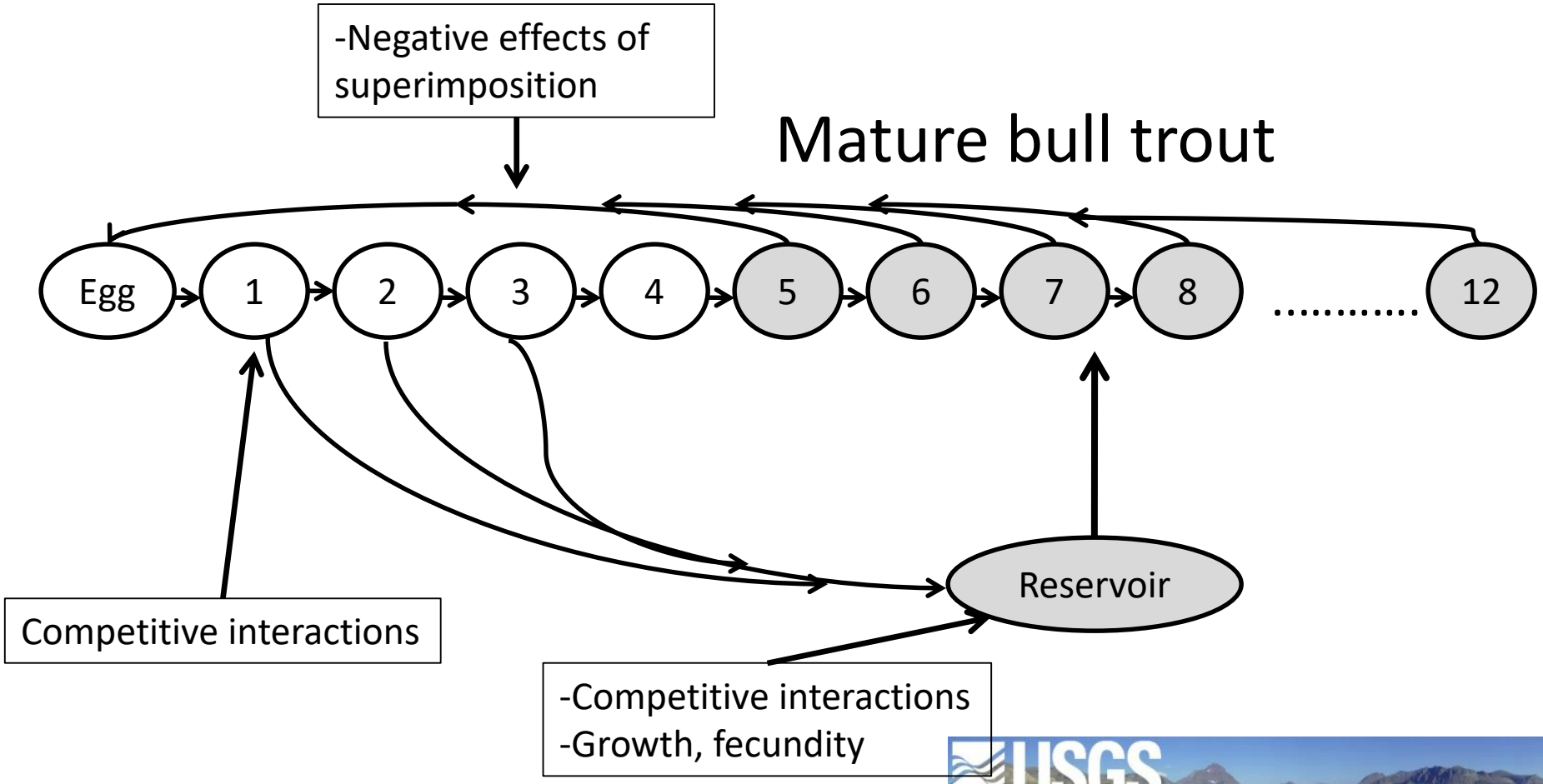
Individual-based model

- Small population in Swift/Yale



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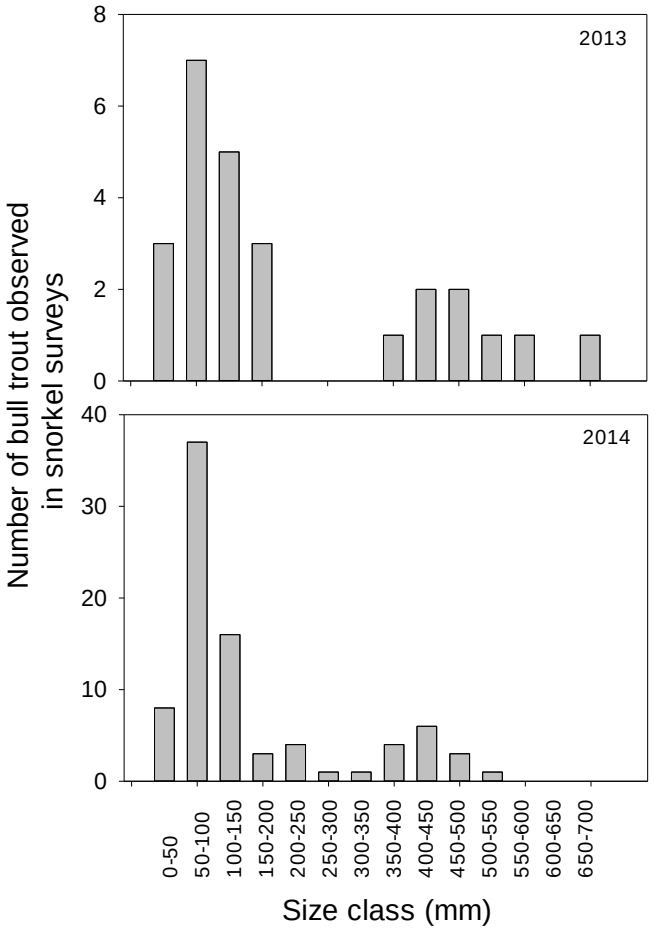
Bull trout adfluvial life history

- Adfluvial life-history
  - Majority of emigration occurs at age-2
- Sexual maturity
  - Literature-ages 4-6



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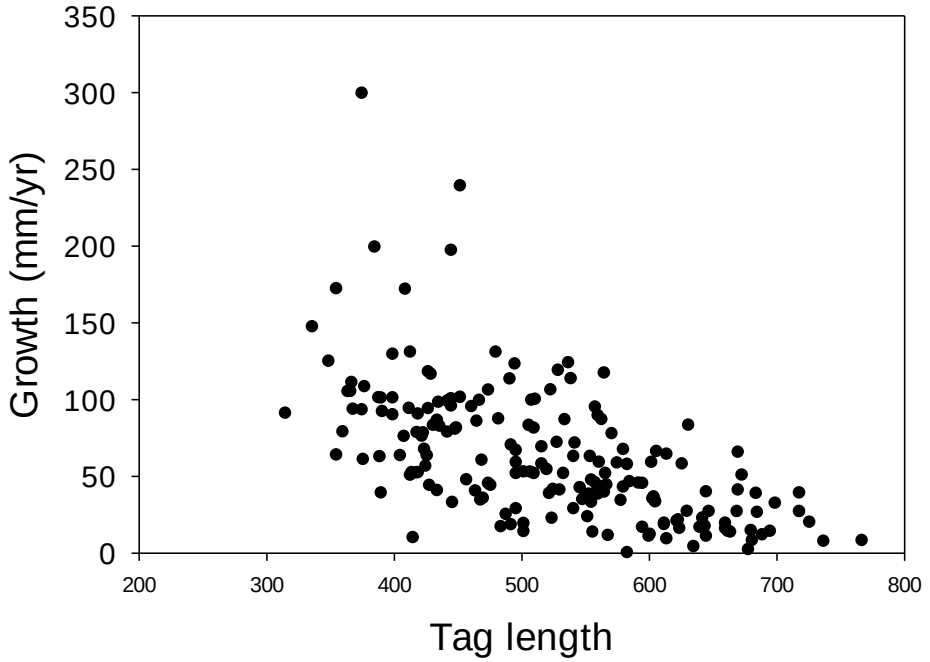
- Growth information
  - PIT-tag data (J. Doyle, J. Byrne)

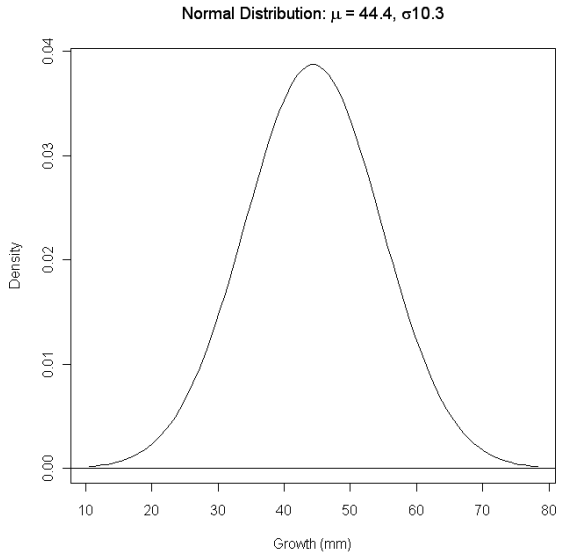


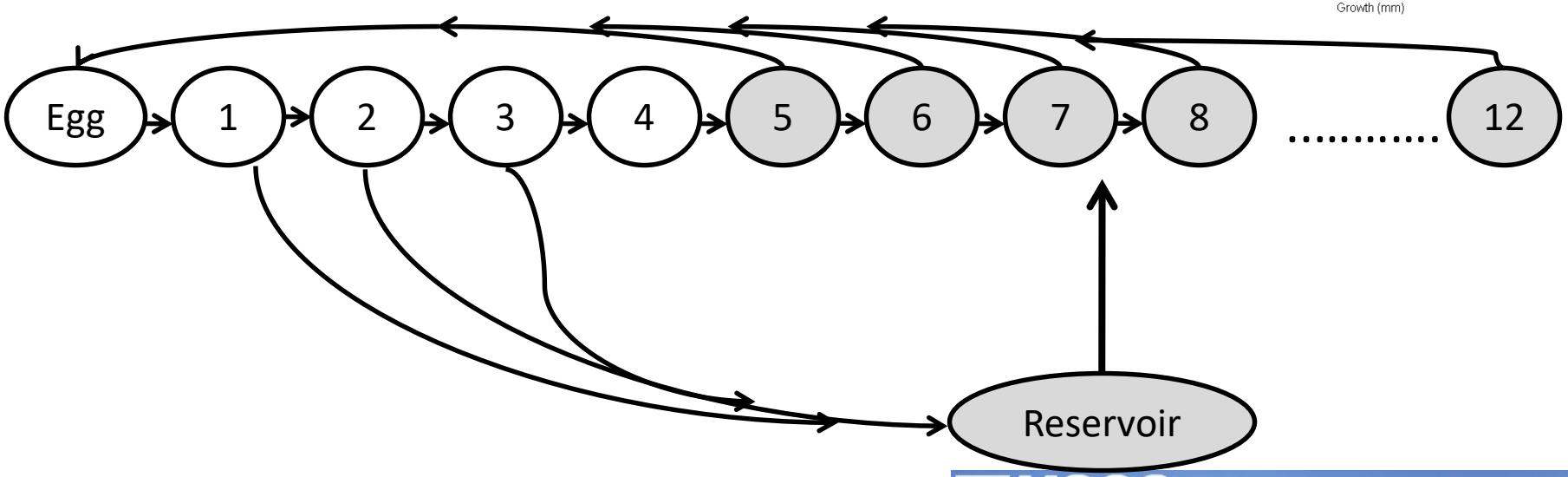
Bull trout adfluvial life history

- Adfluvial life-history
  - Majority of emigration occurs at age-2
- Sexual maturity
  - Literature-ages 4-6
- Growth information
  - PIT-tag data (J. Doyle, J. Byrne)
- Survival
  - Literature values-early life stages
  - Stillwater Sciences
    - Adult survival estimates

Individual-based model

- Likely risk to populations





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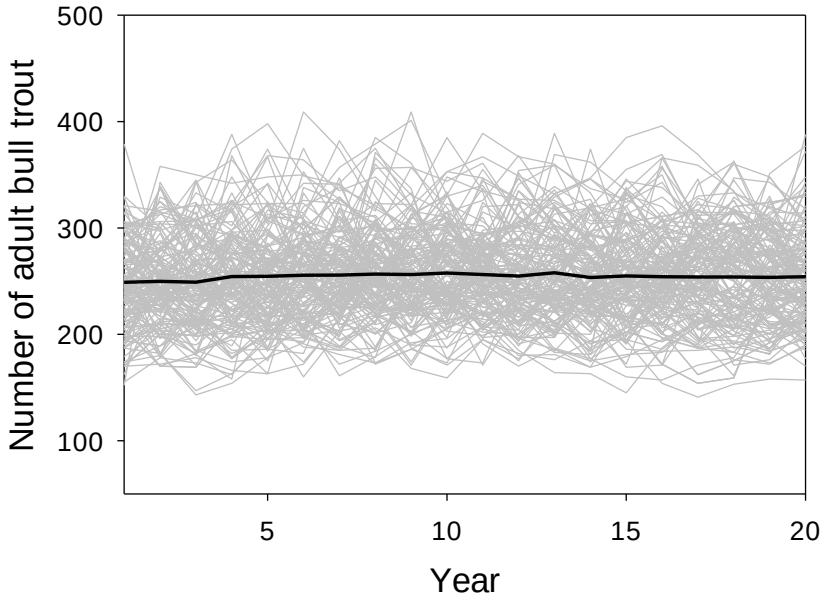
Individual-based model

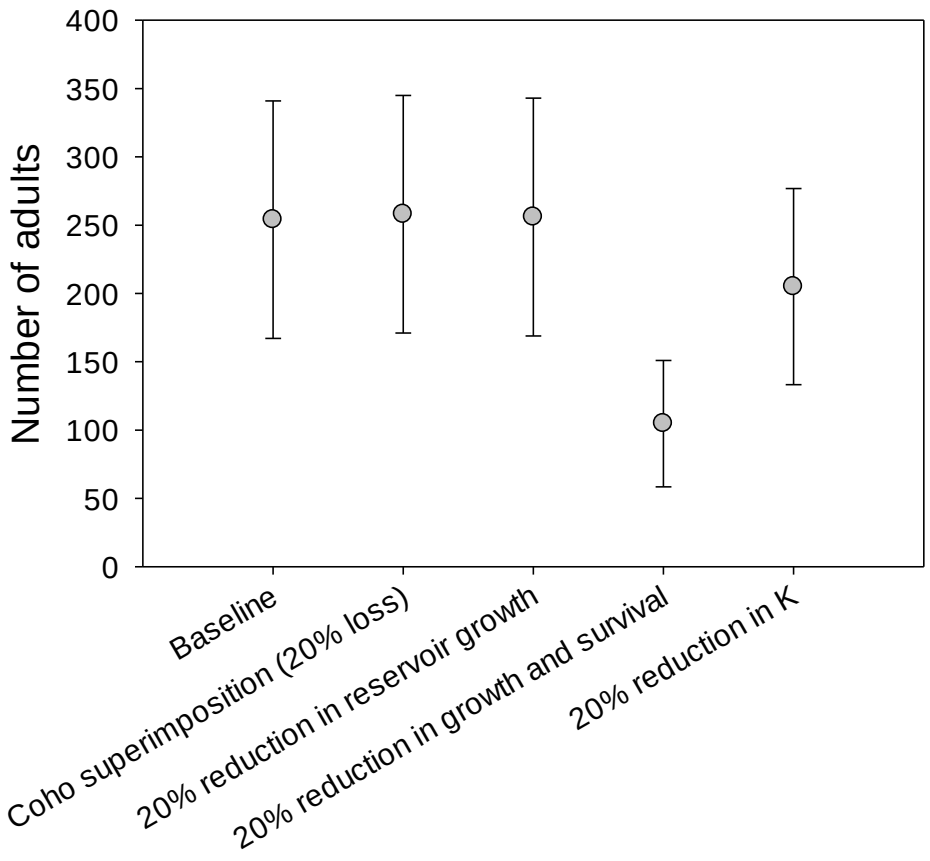
- Likely risk to populations
  - Scenarios
    1. Reductions in rearing carrying capacity
       1. Distributional overlap
       2. Diet overlap
    2. Redd superimposition
       1. Field data-timing, superimposition
       2. Literature-habitat similarities, similar body sizes
       3. Hatchery stock and natal homing and historical changes in the Lewis
    3. Reductions in reservoir carrying capacity
       1. Task 4-collection efficiencies
       2. Literature and regional evidence of “landlocked” populations
       3. Density-dependent effects on bull trout growth, survival (Johnston and Post 2009)

Risk assessment results



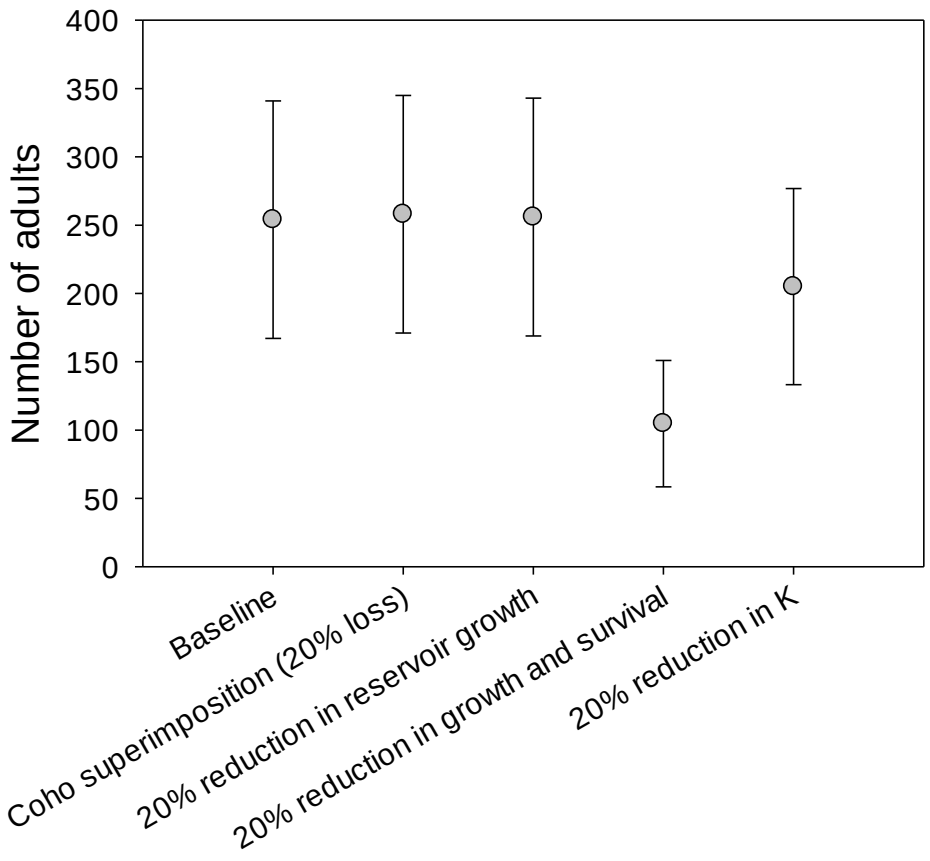
- Baseline population model
  - Absolute abundance not critical

Risk assessment results



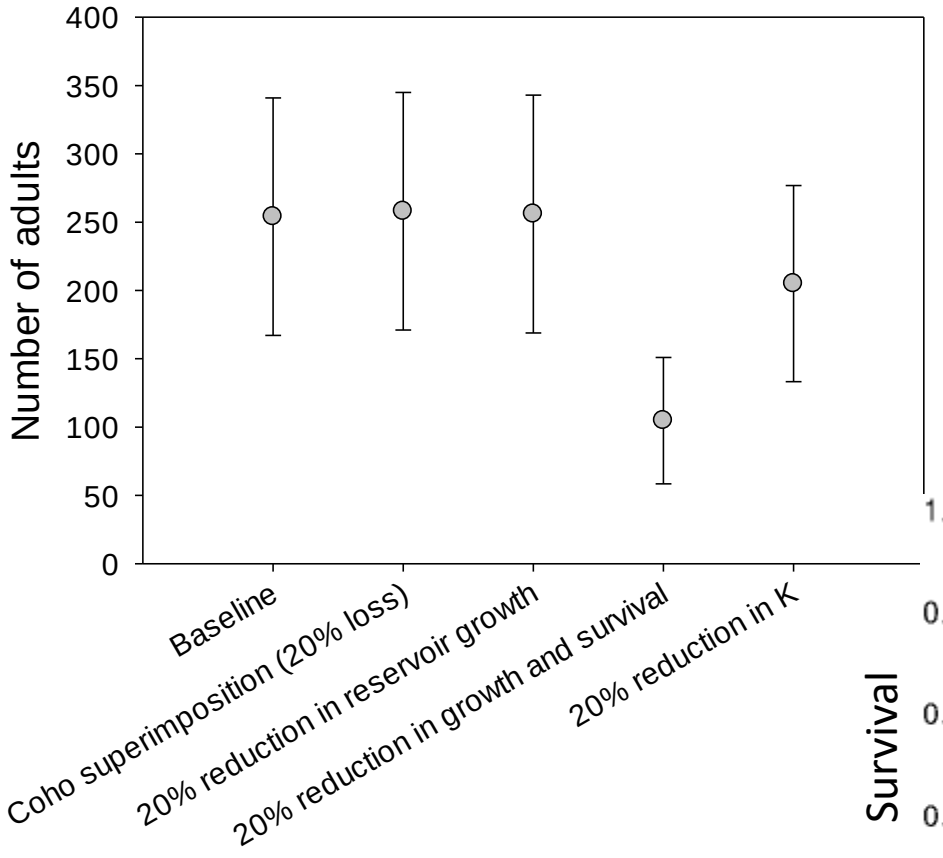
- Perturbations
  - Superimposition and reservoir growth
    - No real effect

Risk assessment results



- Perturbations
  - Superimposition and reservoir growth
    - No real effect
  - Reductions in reservoir survival
    - Largest effect on bull trout

Risk assessment results



- Perturbations
  - Superimposition and reservoir growth
    - No real effect
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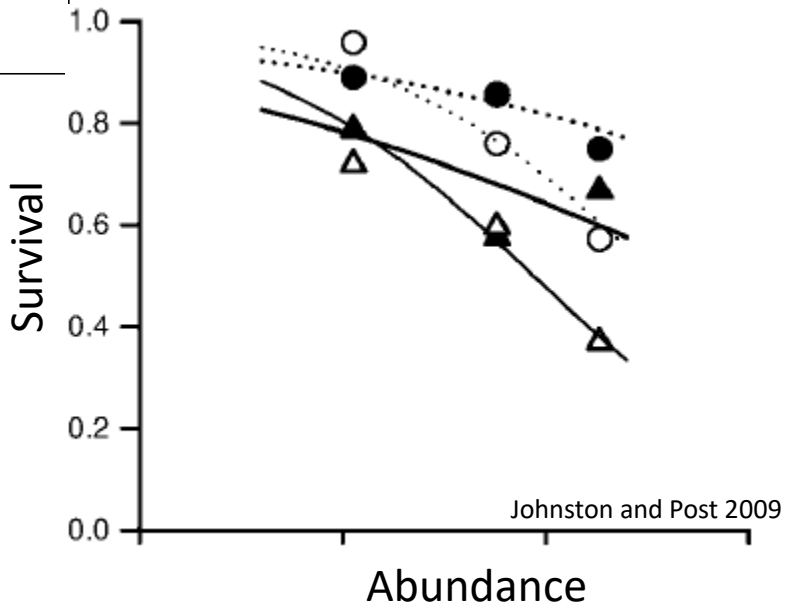
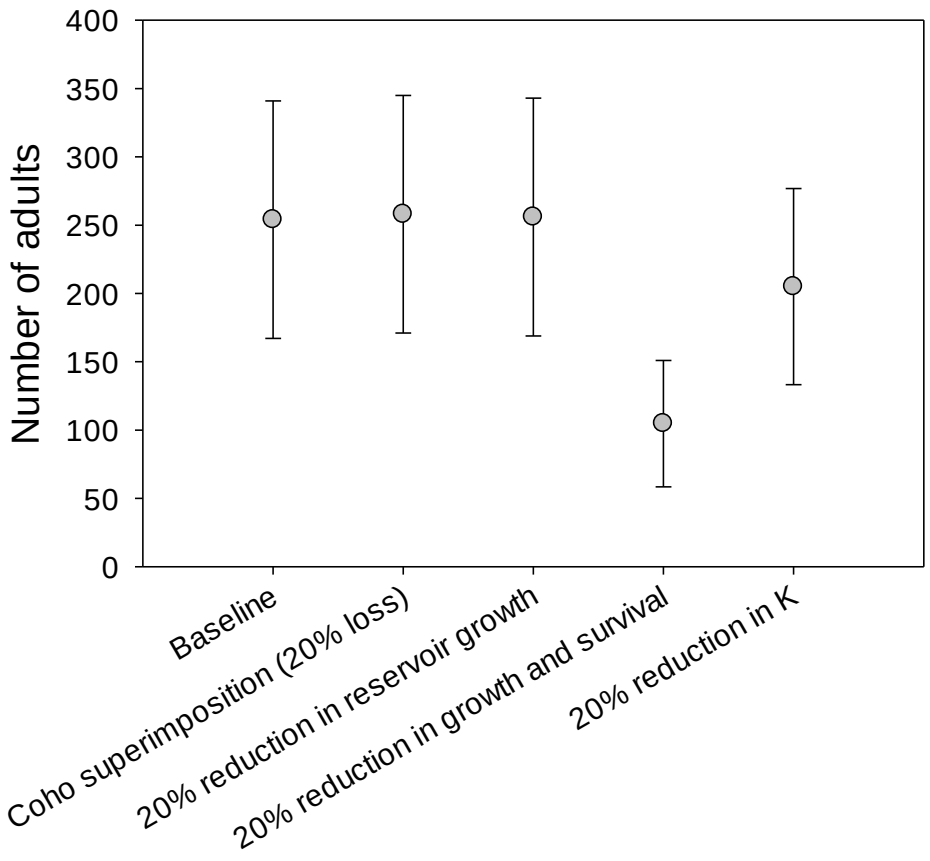
    - Largest effect on bull trout



Johnston and Post 2009

Risk assessment results



- Perturbations
  - Superimposition and reservoir growth
    - No real effect
  - Reductions in reservoir survival
    - Largest effect on bull trout
  - Reductions in carrying capacity
    - Negatively effect on bull trout

Conclusions

Aerial image: Google Earth

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science for a changing world

Questions

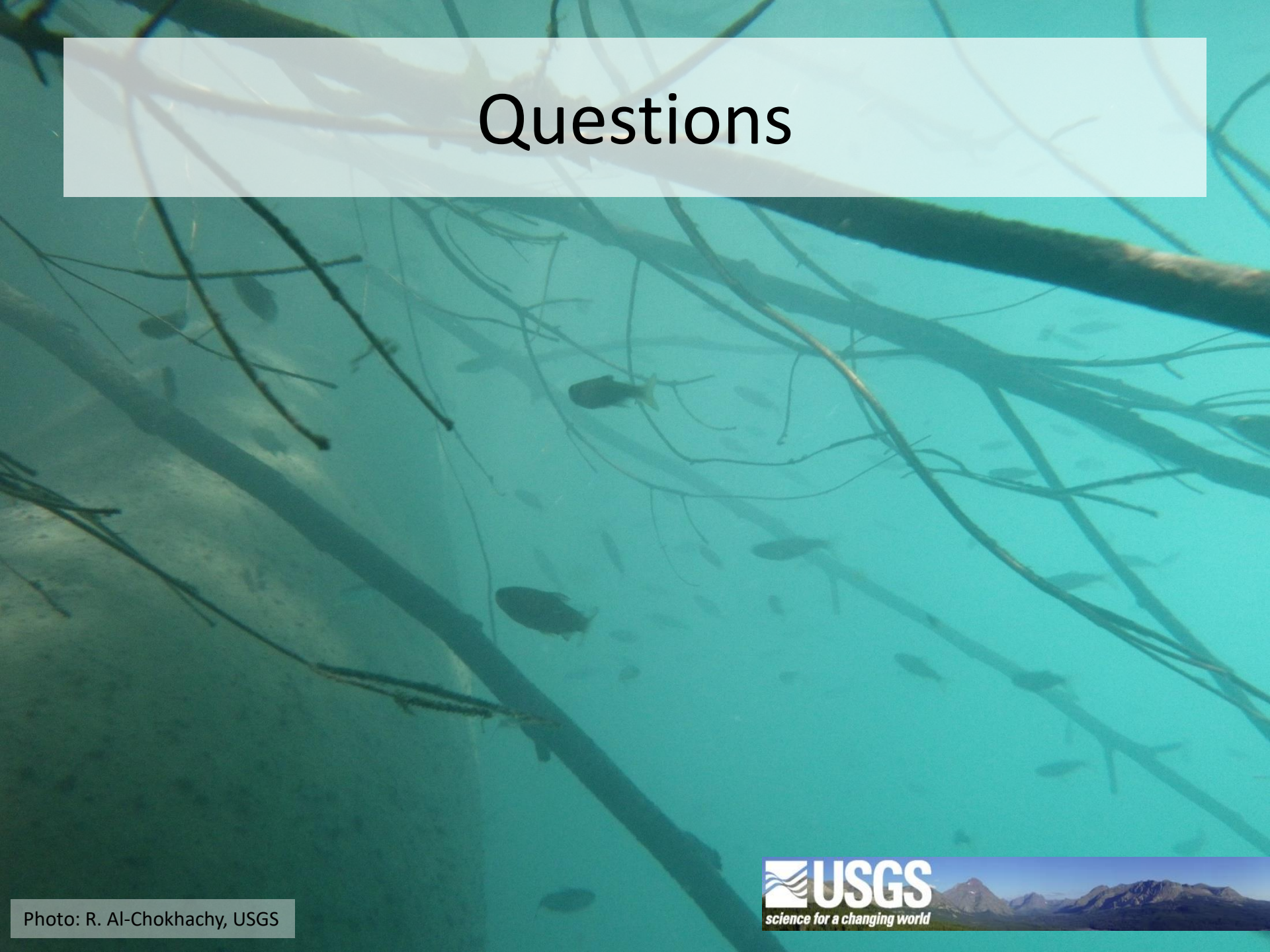

Photo: R. Al-Chokhachy, USGS

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