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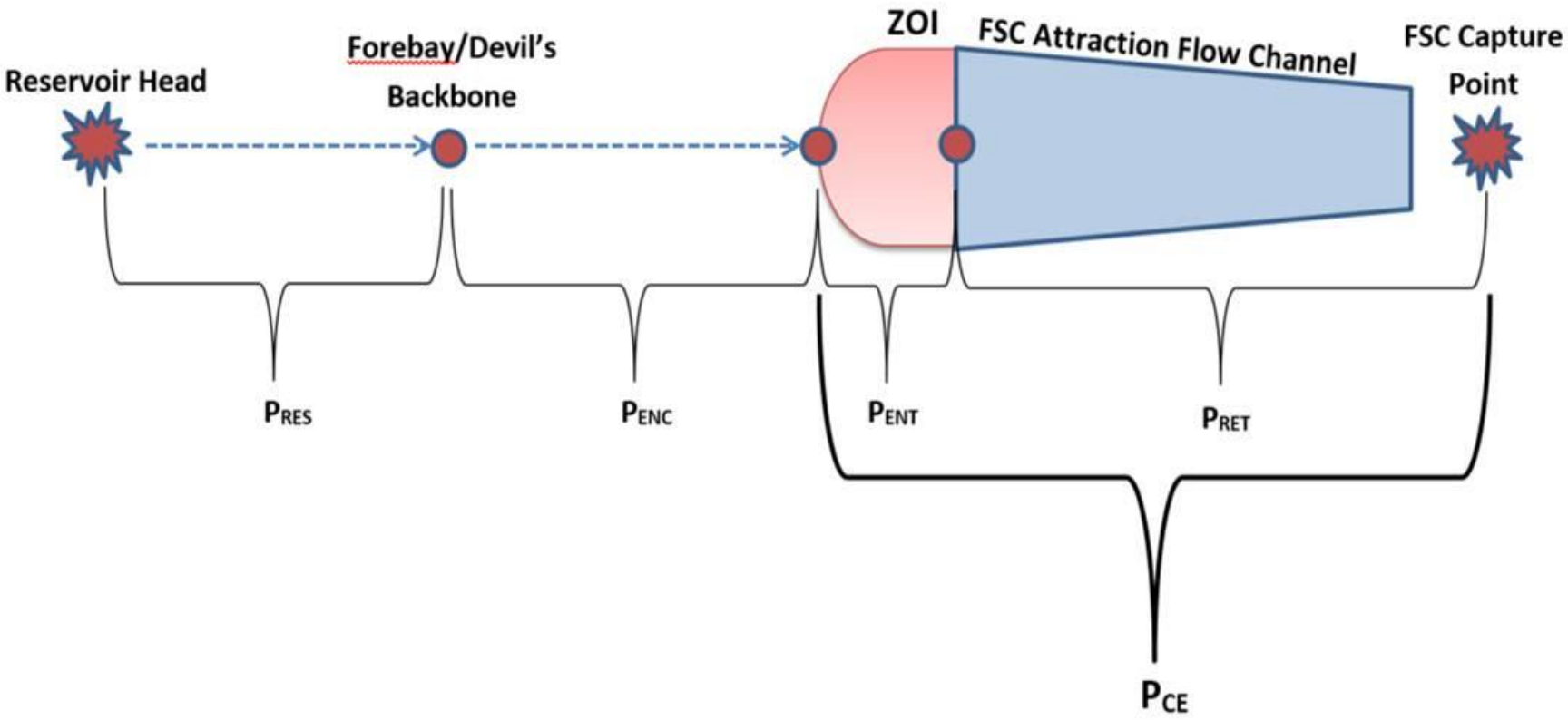
Swift Reservoir 2019 Floating Surface Collector Efficiency Evaluation

Annual Report Review Meeting

2019 Study Objectives

- Evaluate how recent modifications to the floating surface collector (FSC) have influenced collection efficiency (P_{CE})
  - Reprogramming the FSC pumps to reduce vibration
  - Adjusting baffles along the primary screens to further reduce vibrations
  - Increasing the attraction flow velocity at the mouth of the collector
- Estimate passage metrics and investigate fish behavior in the forebay and collector

Passage Metrics

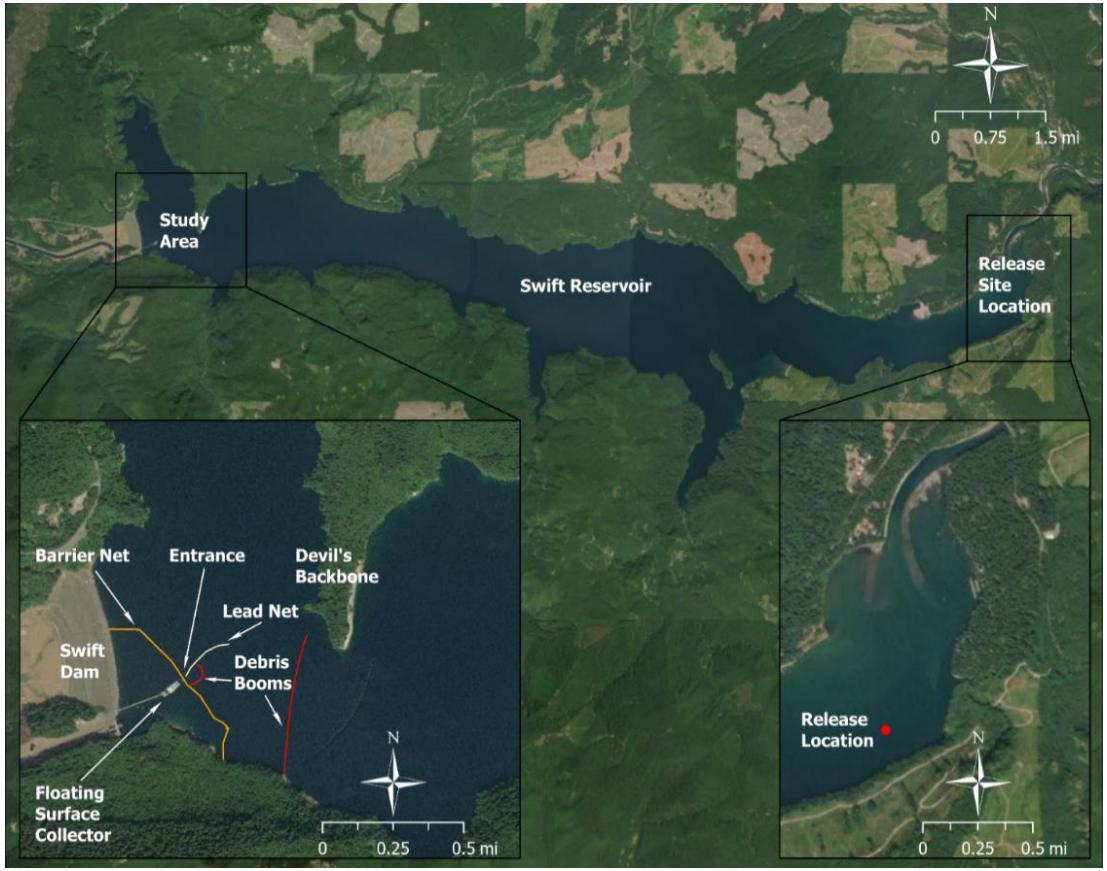


Methods Overview

- Use acoustic telemetry to track fish through the ZOI and into the collector
  - Estimate 2D position within the ZOI
  - Track fish through the ZOI and into the NTS
- Analyze the acoustic telemetry data to estimate passage metrics and investigate fish behavior in the forebay and collector
  - Use presence/absence data to determine when fish entered the forebay
  - Evaluate behavior in the ZOI using 2D position estimates
  - Analyze detection signatures to track fish in the NTS and collection channel

Field Study Overview

- 525 dual PIT/acoustic-tagged fish released 9 miles upstream of the FSC between 3/26 and 6/26
  - 300 Coho Salmon
  - 155 Chinook Salmon
  - 70 steelhead
- Fish tracked via acoustic telemetry from Devil's Backbone to the NTS
- Fish tracking continued until July 22
  - Each tag has an estimated 45 day battery life from time of release
- Collection confirmed with PIT tags



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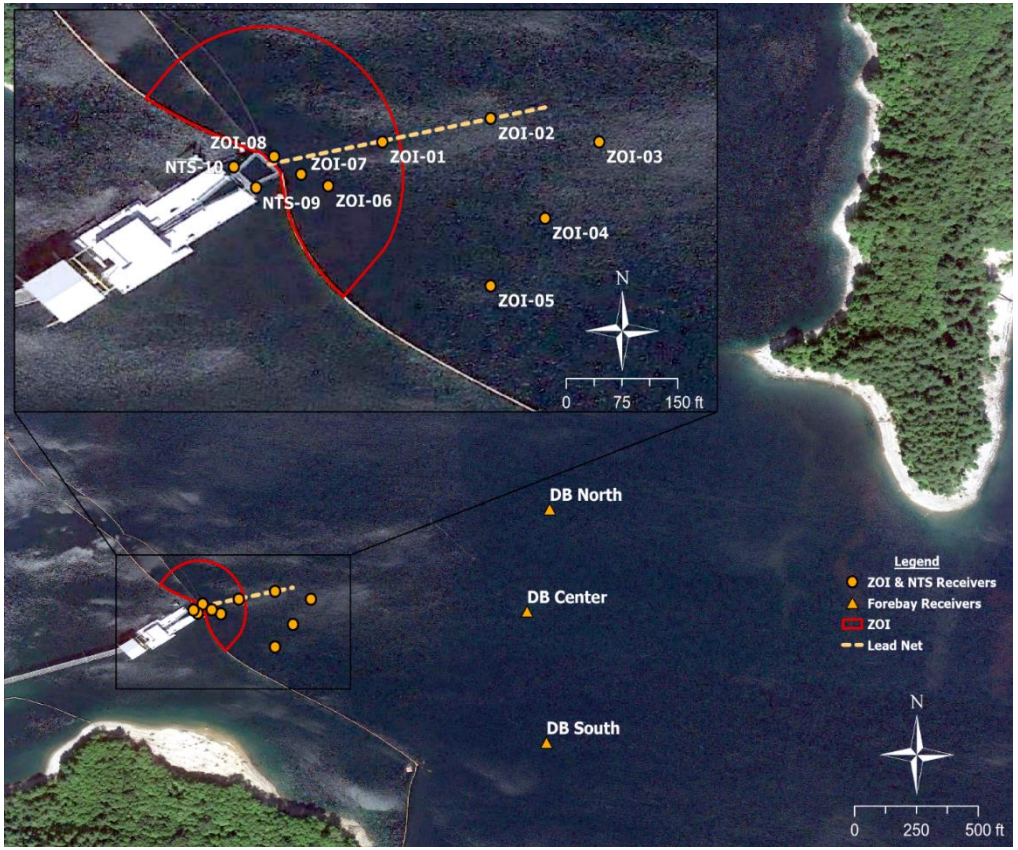
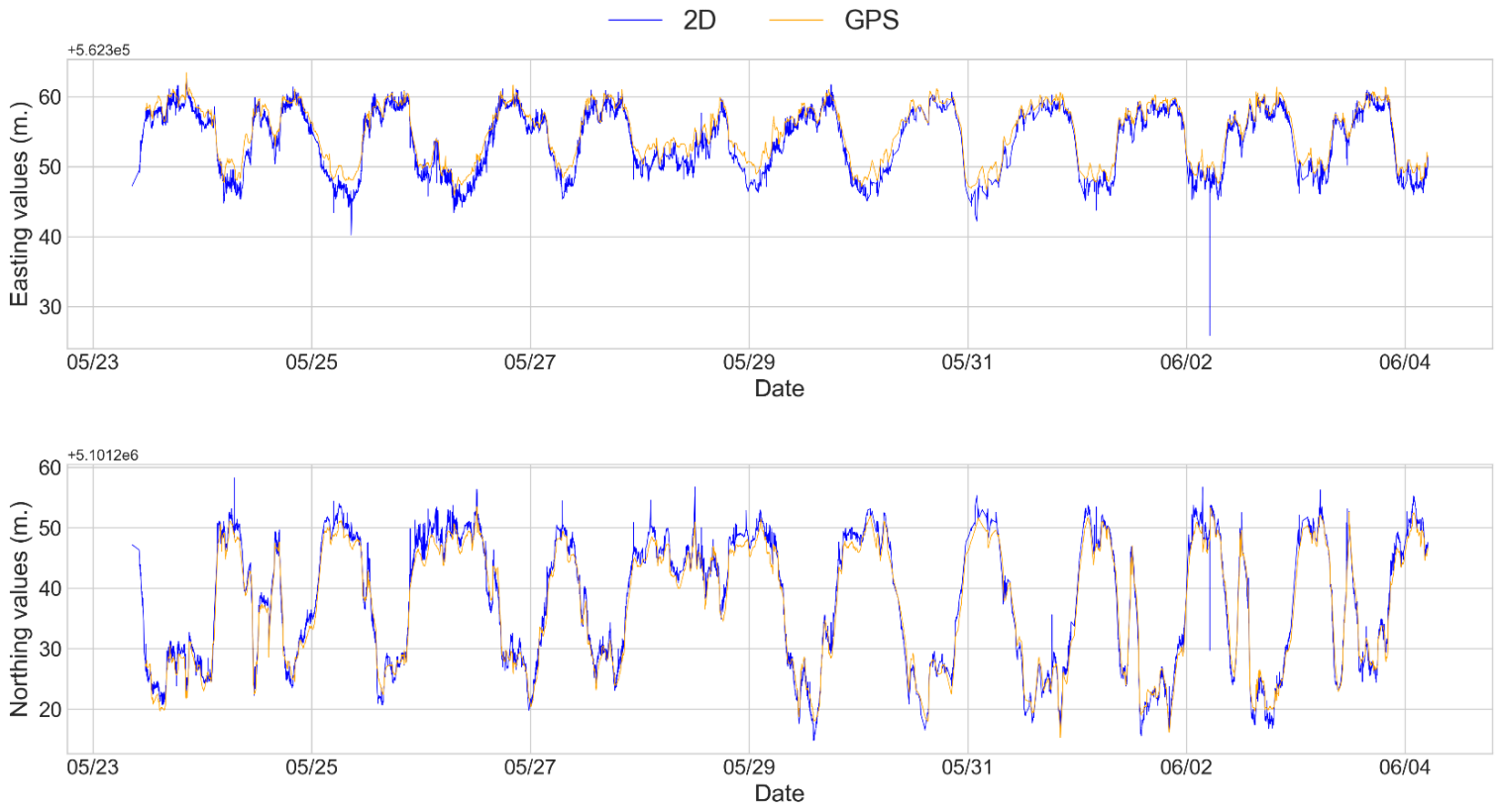
Acoustic Telemetry Arrays



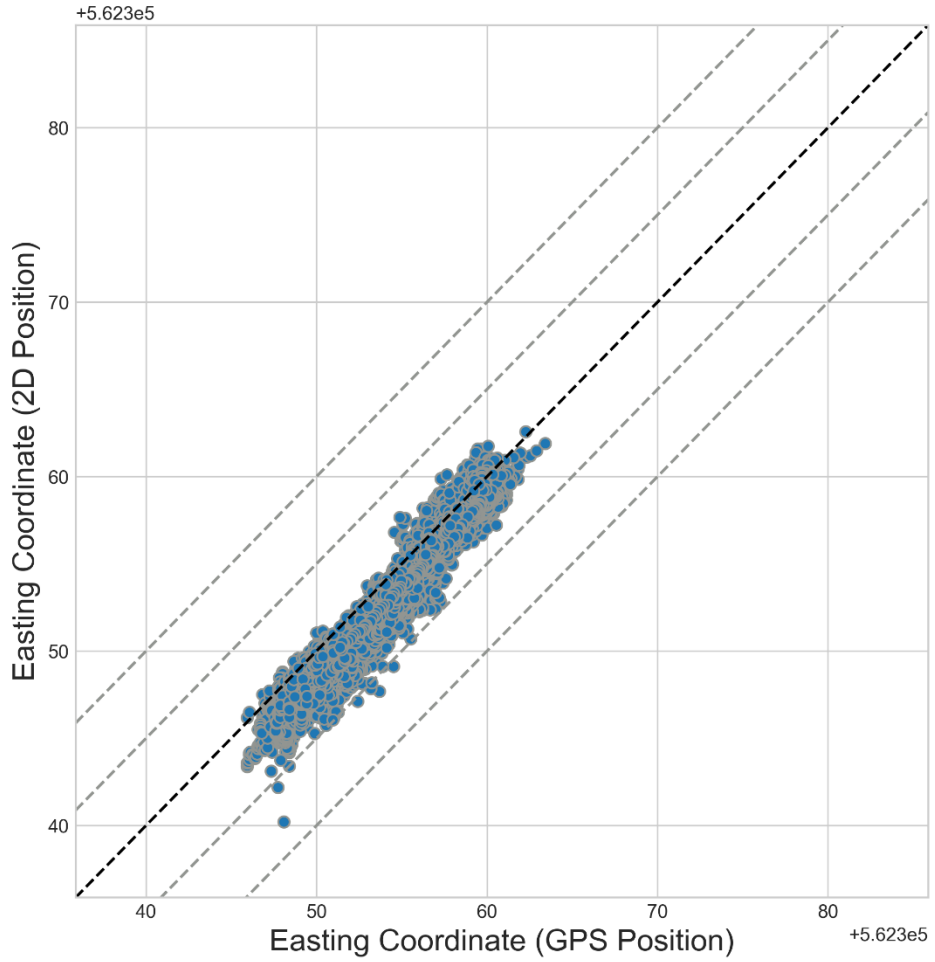
- 13 receivers
  - 3 presence/absence: monitor forebay entrance
  - 8 positioning with beacon tags: track fish in the zone of influence (ZOI)
  - 2 positioning: track fish through the NTS and into the collector
- 22-week deployment: February 18 to July 22
- Data downloaded and processed semi-monthly
  - Processing included computation of 2D position estimates and passage metrics

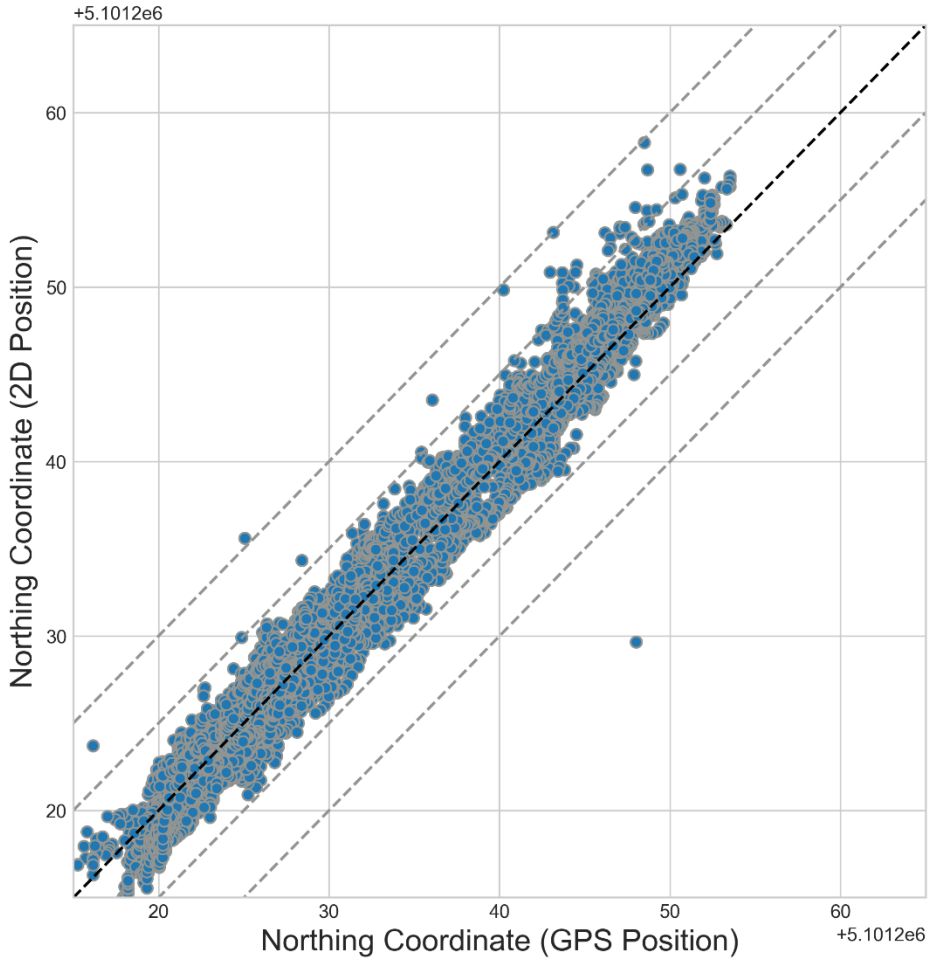
2D Tracking Accuracy

Evaluated by comparing beacon tag position estimates with receiver GPS data



2D Tracking Accuracy (continued)





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Detection/Tracking Efficiency

Species	Forebay Array (%)	ZOI Array (%)	Missed on ZOI	NTS Array (%)	Missed on NTS
Chinook Salmon	100	100	0	97 (84, 100)	1
Coho Salmon	100	100	0	98 (93, 100)	2
Steelhead	100	100	0	100	0
All	100	100	0	98 (94, 99)	3

Metric Calculations

Metric	Calculation (uncorrected)	Calculation (corrected)
Rate of Reservoir Passage (P_{RES})	$P_{RES} = \frac{DET_{Swift}}{R}$	$\hat{P}_{RES} = \frac{(C/R)}{P_{ENC} \cdot P_{ENT} \cdot P_{RET}}$
ZOI Encounter Rate (P_{ENC})	$P_{ENC} = \frac{DET_{ZOI}}{DET_{Swift}}$	$\hat{P}_{ENC} = \frac{(DET_{ZOI}/D_{EFF-ZOI})}{DET_{Swift}}$
Entrance Efficiency (P_{ENT})	$P_{ENT} = \frac{DET_{ENT}}{DET_{ZOI}}$	$\hat{P}_{ENT} = \frac{(DET_{ENT}/D_{EFF-ENT})}{(DET_{ZOI}/D_{EFF-ZOI})}$
Retention Efficiency (P_{RET})	$P_{RET} = \frac{C}{DET_{ENT}}$	$\hat{P}_{RET} = \frac{C}{(DET_{ENT}/D_{EFF-ENT})}$
Collection Efficiency (P_{CE})	$P_{CE} = \frac{C}{DET_{ZOI}}$	$\hat{P}_{CE} = \frac{C}{(D_{ZOI}/D_{EFF-ZOI})}$

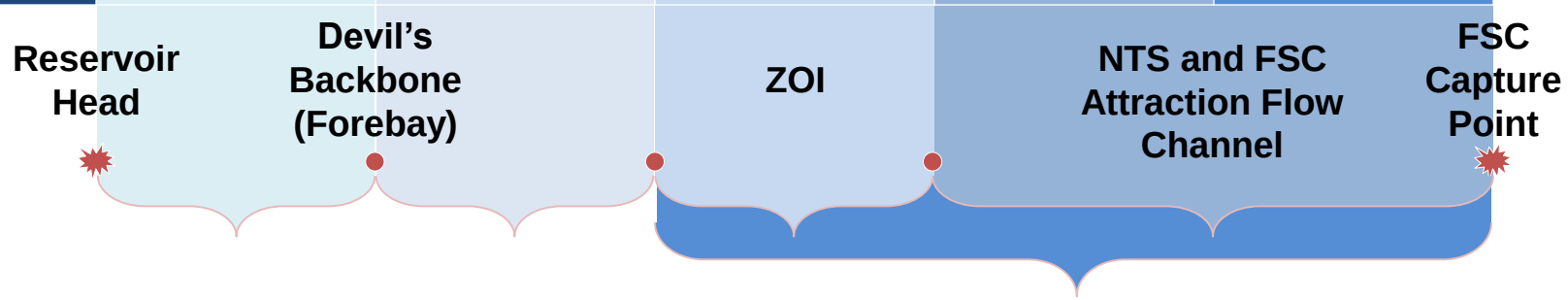
R = number of unique tagged fish released
DET_{Swift} = number of juveniles detected entering Swift Dam forebay (i.e., at any receiver in Swift forebay array)
$D_{EFF\text{-}Swift}$ = detection efficiency of the Swift forebay array
DET_{ZOI} = number of unique tagged fish identified in the vicinity of the floating surface collector (i.e., in the ZOI)
$D_{EFF\text{-}ZOI}$ = detection efficiency of the ZOI array
DET_{ENT} = number of tagged fish detected inside the entrance of the net transition structure
$D_{EFF\text{-}ENT}$ = detection efficiency of the net transition structure entrance array
C = number of unique tagged fish identified in the fish collection ponds inside the floating surface collector (i.e., collected)

Metric Calculation Methods

- DET_{SWIFT} determined using presence/absence on the forebay array
- DET_{ZOI} determined using 2D tracking through the ZOI
  - A minimum of 5 position estimates within the ZOI in a 10-minute window was used as the criteria for presence in the ZOI
- DET_{ENT} determined using time-of-arrival on NTS receivers with amplitude filtering
  - 2D position estimates used for verification of filter accuracy
- C determined using PIT detections in the collector (any array)

Passage Metrics

Species	P_{RES} (%)	P_{ENC} (%)	P_{ENT} (%)	P_{RET} (%)	P_{CE} (%)
Chinook Salmon	63	85	78	65	51
	(55, 70)	(76, 91)	(67, 86)	(53, 77)	(39, 62)
Coho Salmon	86	95	98	65	64
	(82, 90)	(91, 98)	(93, 100)	(57, 72)	(53, 74)
Steelhead	63	93	97	28	27
	(52, 74)	(79, 84)	(83, 100)	(13, 42)	(17, 37)
All	78	92	93	60	55
	(75, 82)	(89, 95)	(89, 96)	(53, 66)	(44, 67)



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Comparison to Past Studies

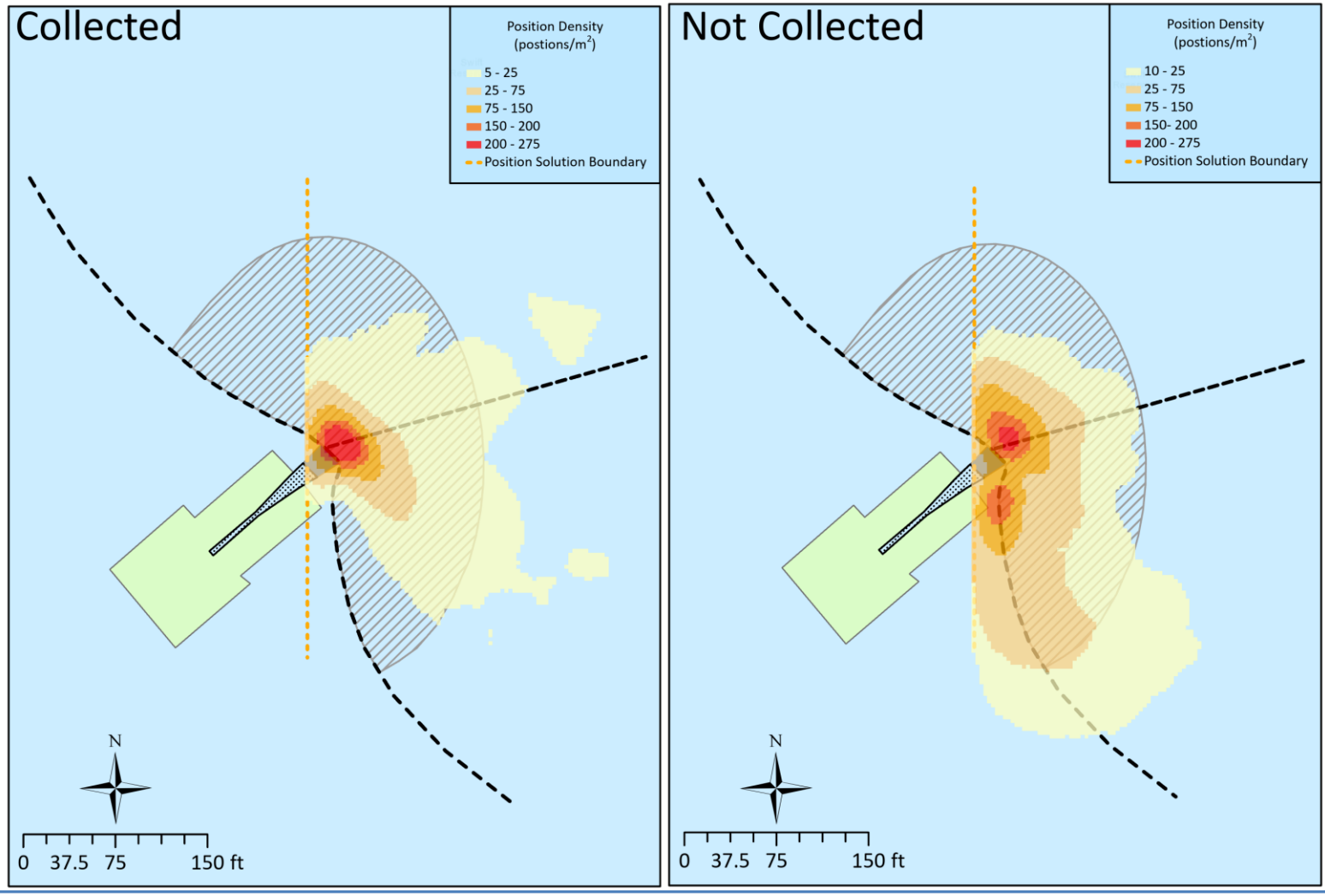
Year	Species	P_{RES} (%)	P_{ENC} (%)	P_{ENT} (%)	P_{RET} (%)	P_{CE} (%)
2017	Chinook Salmon	69.4	82.7	46.8	24.1	11.3
	Coho Salmon	81.0	91.6	65.1	41.1	26.7
	Steelhead	66.7	89.2	48.6	40.4	19.7
2018	Chinook Salmon	--	--	--	--	23.7*
	Coho Salmon	--	--	--	--	39.5*
	Steelhead	--	--	--	--	48.9*
2019	Chinook Salmon	62.8	85.2	78.1	64.9	50.7
	Coho Salmon	85.9	95.4	98.3	64.6	63.5
	Steelhead	62.8	92.5	97.3	27.8	27.0

* In 2018, survival probability through reservoir (S_{RES}) was used as a surrogate for collection efficiency

ZOI Position Analysis

- Investigate patterns in fish positions within the ZOI and NTS
  - Develop heat maps of all position estimates
  - Conducted in ArcGIS software using point density analysis routines (ESRI 2011)
- Comparison by species and collected versus non-collected fish
- Patterns indicate that all fish, whether collected or not, congregate at and immediately within the entrance of the NTS

Chinook Salmon Position Density



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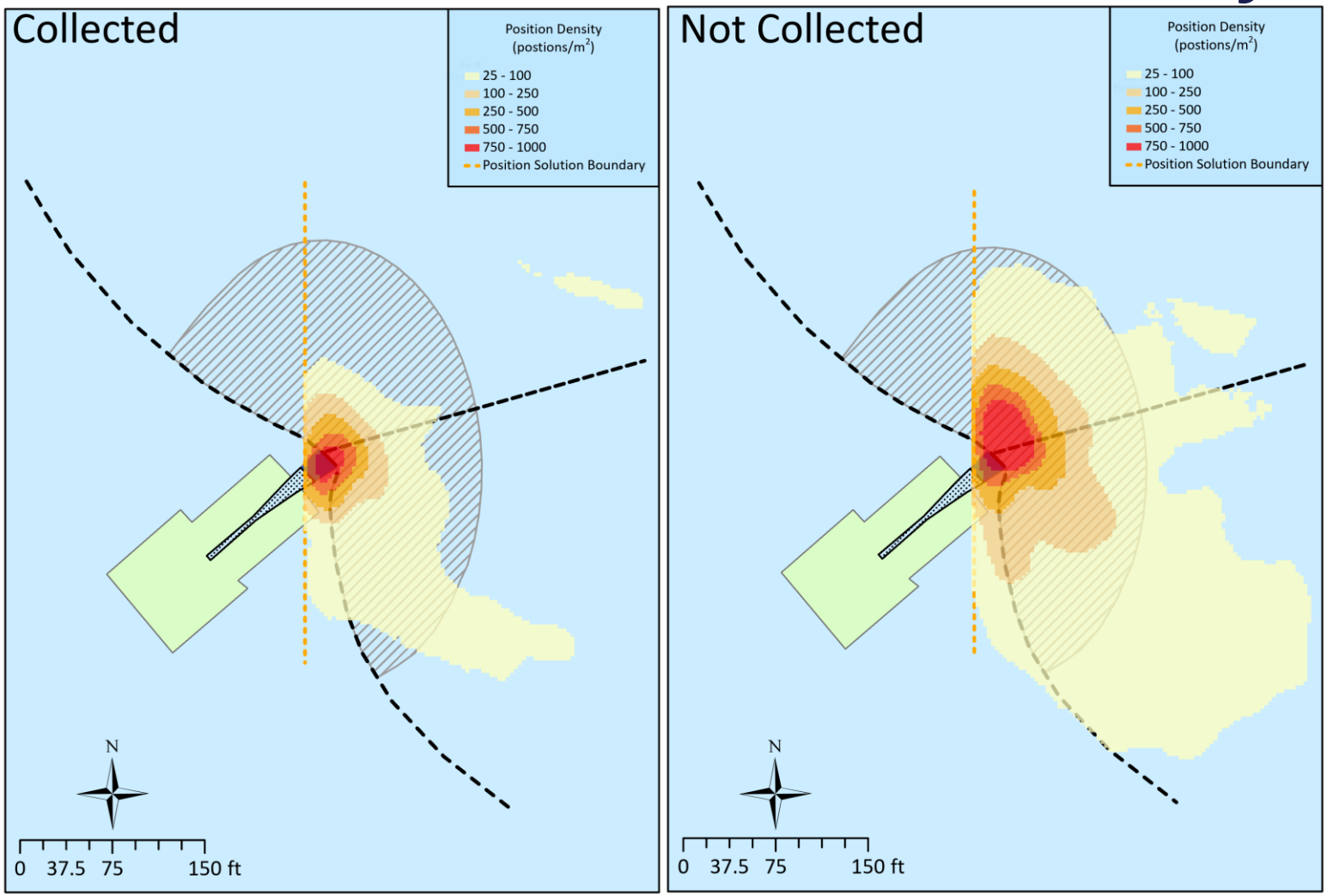
Coho Salmon Position Density



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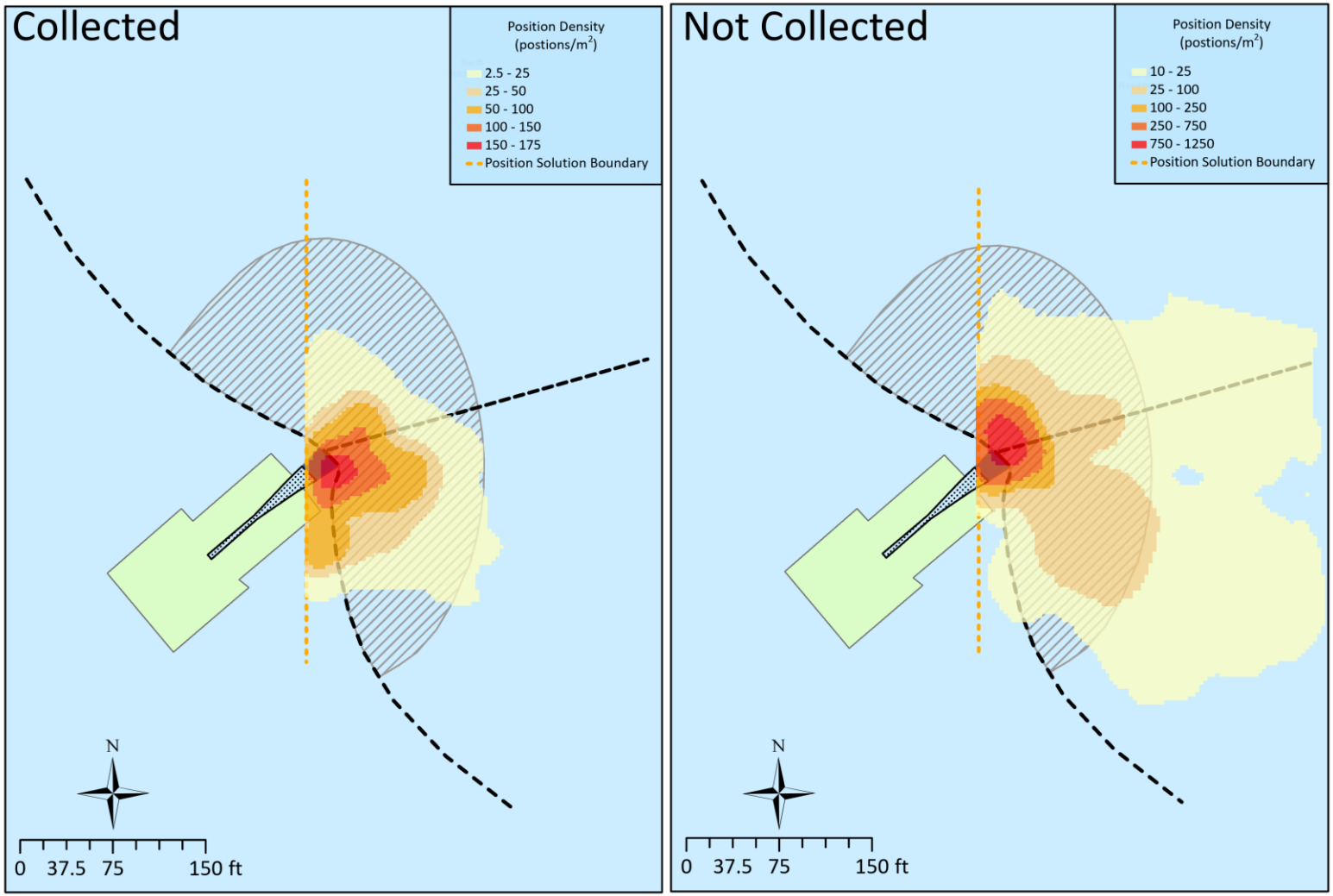
Steelhead Position Density



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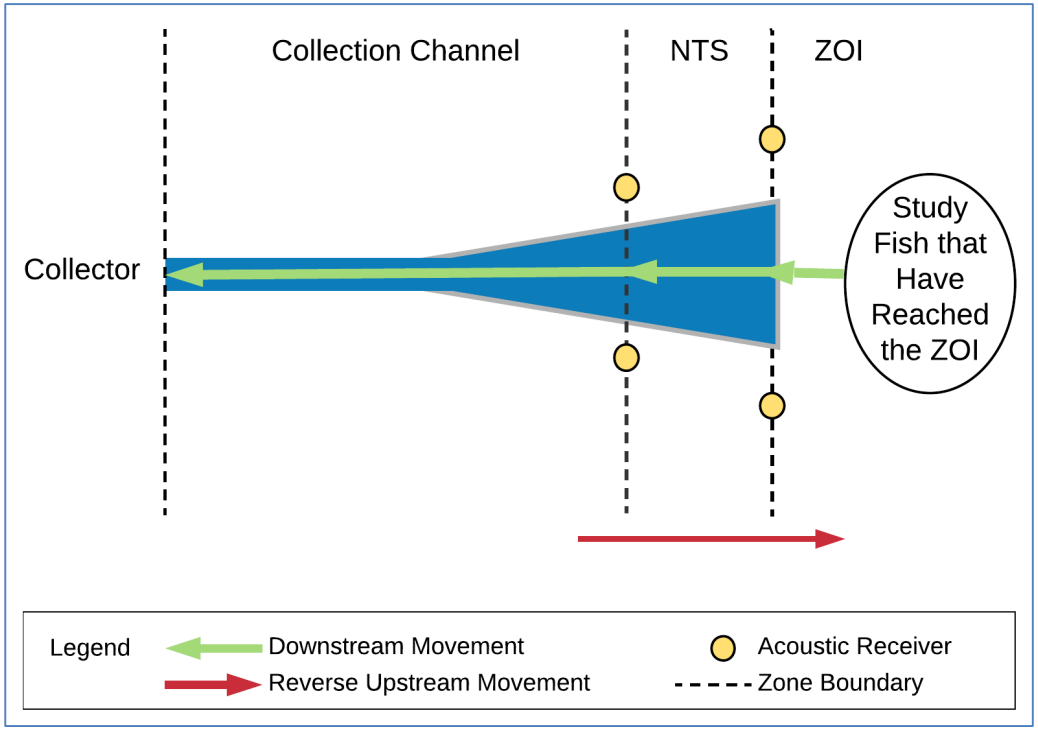
Time of Arrival Analysis

- ZOI approach timing
  - Steelhead that arrived at night more likely to be collected than those that arrived during the day
  - Unrelated to collection for both Chinook Salmon and Coho Salmon
- Collection timing

Species	Collection Timing	
	Day	Night
Chinook Salmon	13%	87%
Coho Salmon	61%	39%
Steelhead	56%	44%

Rejection Inside the Collector

- Investigate patterns in probability of fish exiting the collector after entering the collection channel
- Multivariate analysis included
  - Length
  - Species
  - Number of visits
  - Diel period
  - Release week
  - Last week detected



Rejection Analysis Results

- Time at large and length related to probability of rejection

Variable	P Value
Last Week Detected in Collection Channel	0.00001
Length	0.00013
Number of Visits to the Collection Channel	0.20
Species	0.24
Diel Period	0.26
Release Week	0.76

Summary

- Highest P_{CE} to date for Coho and Chinook
  - Steelhead P_{CE} highest of any acoustic study, though P_{CE} in 2018 PIT study was higher
- Gains observed in P_{ENT} since 2017 suggest that collector modifications have been effective at encouraging fish to enter the collector
- Retention within the collector (P_{RET}) currently the limiting factor to achieving P_{CE} targets
- Larger fish had a higher probability of rejecting the collector after entering the collection channel

Summary (Continued)

- Some steelhead metrics declined in 2019
  - P_{RET} lower than in 2017
  - P_{CE} lower than in 2018 (PIT only)
- Possible explanations
  - Low adult numbers taken upstream in 2017, so fewer out migrants
  - Fewer fish present overall (no “pied-piper” effect, higher risk of predation)
  - Differences in handling between 2018 (PIT only) and 2019 (acoustic + PIT)?

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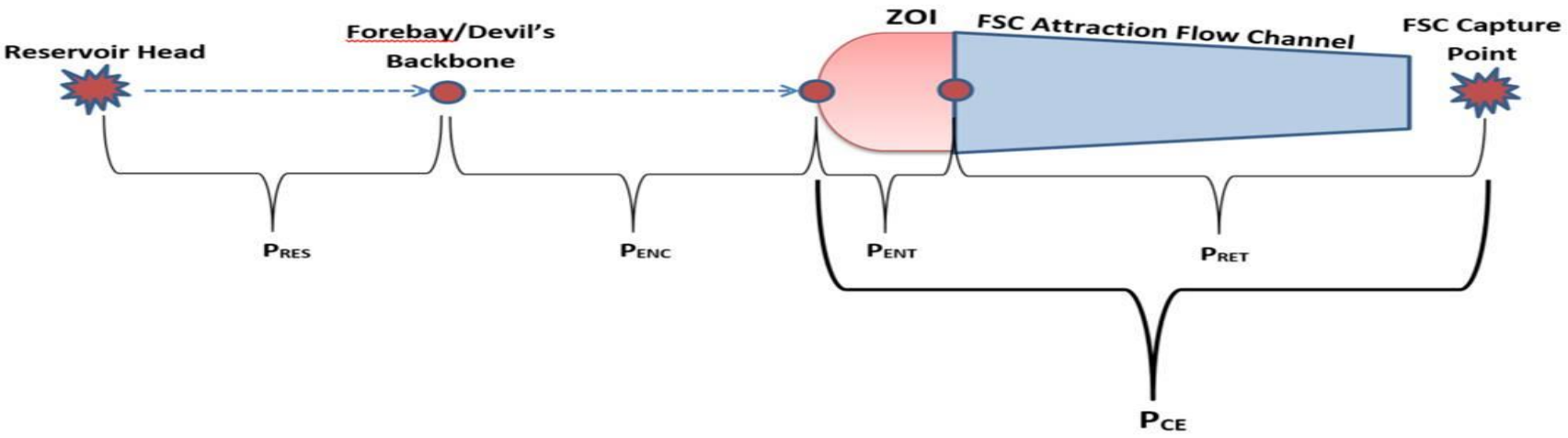
Backup Slides

Passage Metrics

Species	P_{RES} (%)	P_{ENC} (%)	P_{ENT} (%)	P_{RET} (%)	P_{CE} (%)
Chinook Salmon	63 (55, 70)	85 (76, 91)	78 (67, 86)	65 (53, 77)	51 (39, 62)
Coho Salmon	86 (82, 90)	95 (91, 98)	98 (93, 100)	65 (57, 72)	64 (53, 74)
Steelhead	63 (52, 74)	93 (79, 84)	97 (83, 100)	28 (13, 42)	27 (17, 37)
All	78 (75, 82)	92 (89, 95)	93 (89, 96)	60 (53, 66)	55 (44, 67)



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Passage Metrics

Metric	Definition
Rate of Reservoir Passage (P_{RES})	Proportion of released smolts that migrate to the forebay of Swift Dam
Encounter Rate (P_{ENC})	Proportion of released smolts that enter the forebay and are detected in the zone of influence (ZOI)
Entrance Efficiency (P_{ENT})	Proportion of released smots that enter the ZOI and the net transition structure (NTS)
Retention Efficiency (P_{RET})	Proportion of released smolts that enter the NTS and are successfully collected
Collection Efficiency (P_{CE})	Proportion of released smolts that enter the ZOI and successfully collected

Comparison to Past Studies

Study Attributes					Detection Estimates (Total)				
Year	Study Type	Capture Location	Release Location	Species	P_{RES} Estimate (%)	ZOI Detection Rate (%)	P_{ENT} Estimate (%)	P_{RET} Estimate (%)	P_{CE} Estimate (%)
2013	Radio Telemetry	FSC	<3.1 miles east of FSC	Chinook Salmon	--	79.3	--	--	0.0
				Coho Salmon	--	53.7	--	--	6.0
				Steelhead	--	--	--	--	--
2014	Radio Telemetry	FSC	2 miles east of FSC	Chinook Salmon	--	15.0	--	--	0.0
				Coho Salmon	--	19.7	--	--	29.0
				Steelhead	--	25.0	--	--	25.0
2015	Dual PIT/ Acoustic Telemetry	Eagle Cliff Rotary Screw Trap/Hook and Line	Eagle Cliff	Chinook Salmon	64.3	42.9	--	--	0.0
				Coho Salmon	90.6	79.1	--	--	11.8
				Steelhead	91.5	91.5	--	--	18.6
2016	Dual PIT/ Acoustic Telemetry	FSC and Eagle Cliff Rotary Screw Trap	Eagle Cliff	Chinook Salmon	33.3	33.3	--	--	0.0
				Coho Salmon	89.7	62.8	--	--	30.6
				Steelhead	70.0	42.5	--	--	23.5
2017	Dual PIT/ Acoustic Telemetry	FSC	Eagle Cliff	Chinook Salmon	69.4	82.7	46.8	24.1	11.3
				Coho Salmon	81.0	91.6	65.1	41.1	26.7
				Steelhead	66.7	89.2	48.6	40.4	19.7
2018	PIT	FSC	Eagle Cliff	Chinook Salmon	--	--	--	--	23.7*
				Coho Salmon	--	--	--	--	39.5*
				Steelhead	--	--	--	--	48.9*
2019	Dual PIT/ Acoustic Telemetry	FSC	Eagle Cliff	Chinook Salmon	62.8	85.2	78.1	64.9	50.7
				Coho Salmon	85.9	95.4	98.3	64.6	63.5
				Steelhead	62.8	92.5	97.3	27.8	27.0

Tag Activation Correction

- Unknown portion of tags appear to have not activated, biasing P_{RES}
- Remove bias in downstream metrics (P_{ENC}, P_{ENT}, P_{RET}, and P_{CE}) by considering only tags detected in the forebay as released in the mark/recapture model
- Solve for P_{RES}

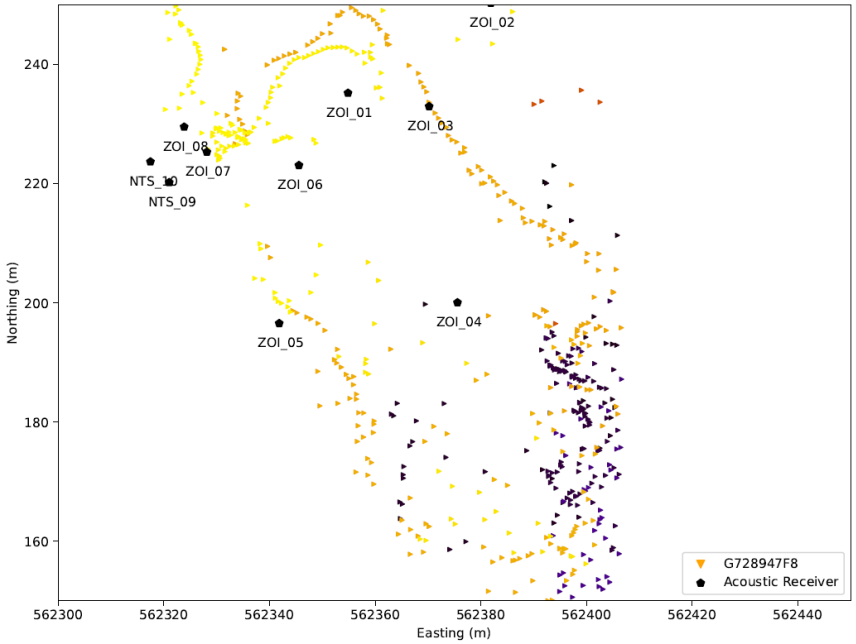
$$\frac{\text{collected}}{\text{released}} = P_{RES} * P_{ENC} * P_{ENT} * P_{RET}$$

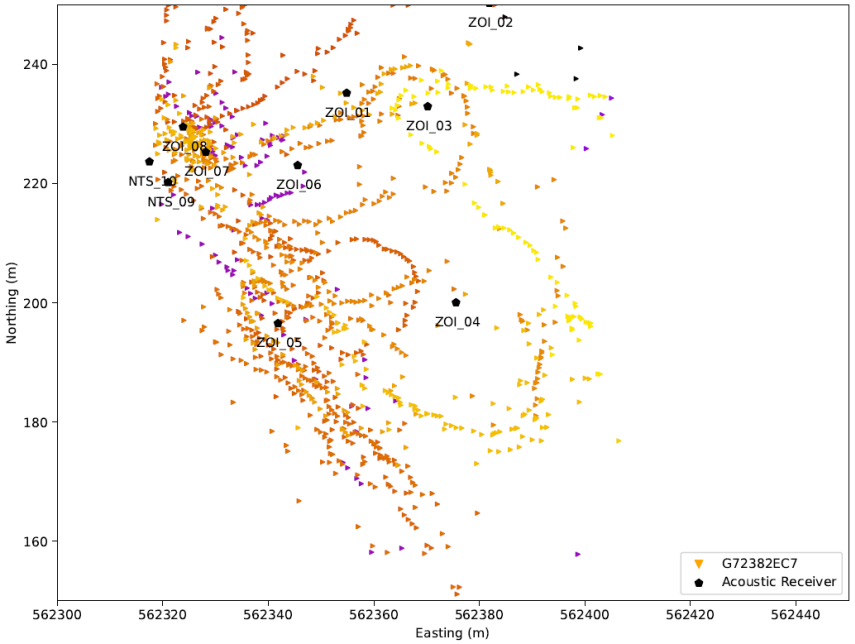
Passage Metrics (continued)

Species	N_{rel}	N_{fb}	N_{fb} (corrected)	N_{ZOI}	N_{NTS}	N_{NTS} (corrected)	N_{col}	N_{col} (activated)
Chinook Salmon	155	88	97	75	57	59	42	38
Coho Salmon	300	175	258	167	161	164	156	106
Steelhead	70	40	44	37	36	36	11	10
All	525	303	399	279	254	259	209	154

Milling Behavior Approach

Use fish tracks to identify areas in the ZOI where fish hold or delay migration





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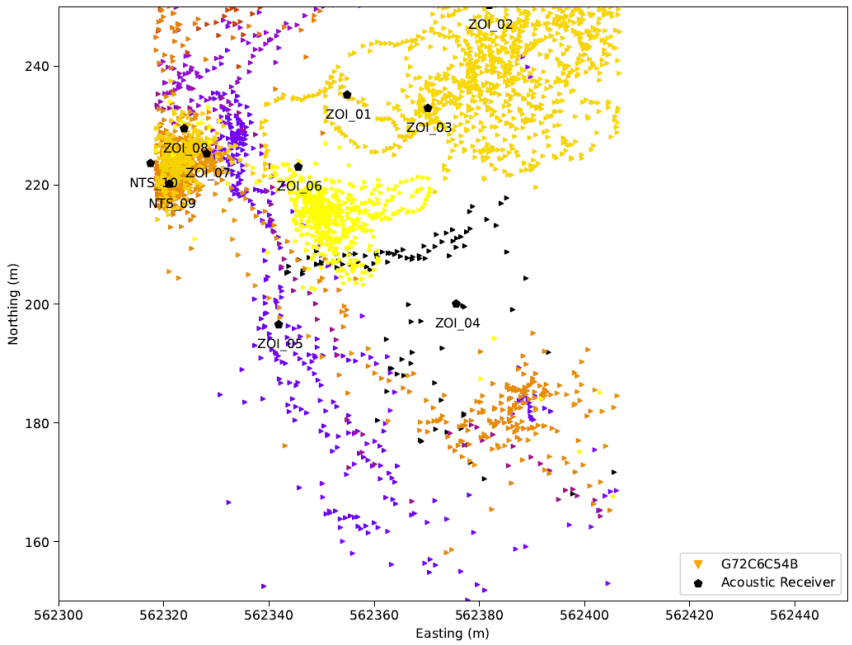
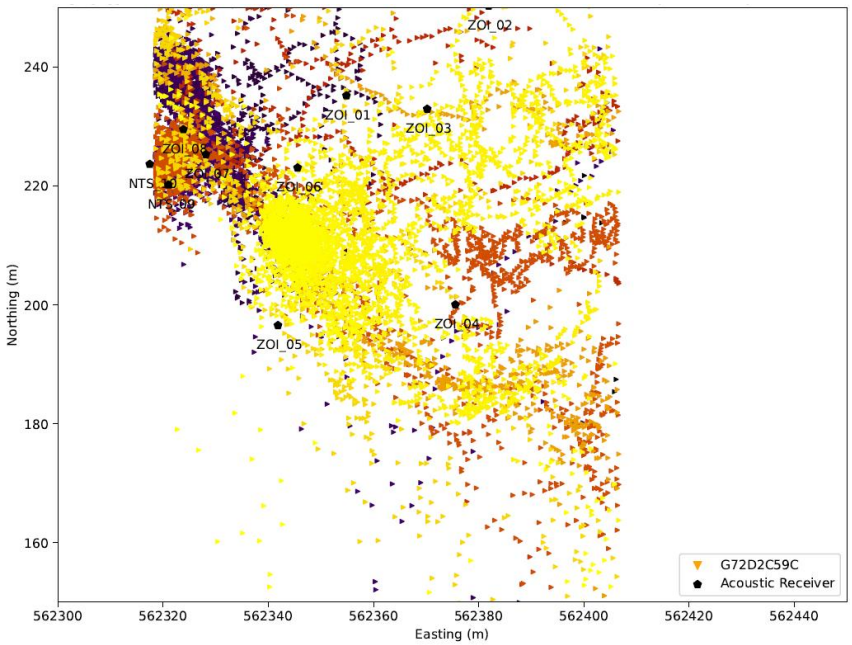
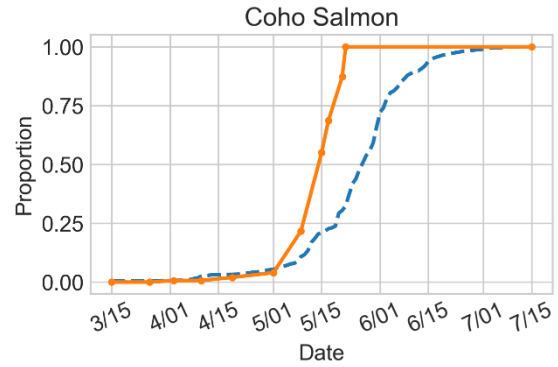
Milling Behavior Approach (continued)

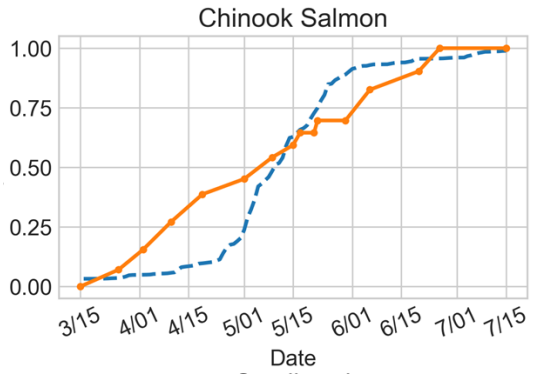


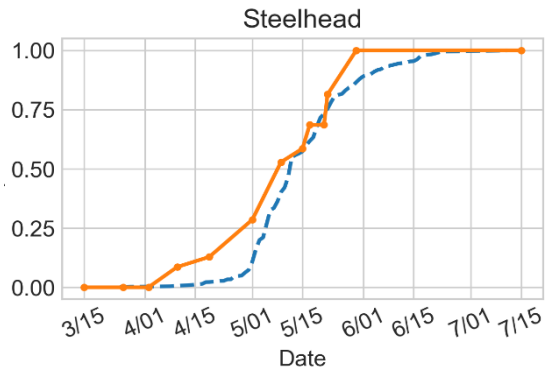


Fish Releases

- 525 study fish released between March 26 and June 26
  - 300 Coho salmon
  - 155 Chinook salmon
  - 70 steelhead







	Chinook Salmon			Coho Salmon			Steelhead		
Release Date	Tagged	Detected	Known Inactive	Tagged	Detected	Known Inactive	Tagged	Detected	Known Inactive
3/26/2019	11	8							
4/2/2019	13	9		2	2				
4/10/2019	18	8					6	1	
4/19/2019	18	8		4	4		3	1	
5/1/2019	10	10		6	5		11	5	
5/9/2019	14	12	1	53	50	3	17	16	
5/15/2019	8	6		100	57	9	4	3	
5/17/2019	8	3		41	24	13	7	3	
5/21/2019				56	15	18			
5/22/2019	8	1		38	18	7	9	2	1
5/30/2019							13	9	
6/6/2019	20	5	3						
6/20/2019	12	7							
6/26/2019	15	11							
Total	155	88	4	300	175	50	70	40	1

Note: “Known Inactive" are fish that were PIT detected at the collector but never detected on the acoustic receivers.