Predicting Fish Behavior Near Pile Dikes and Navigation Markers

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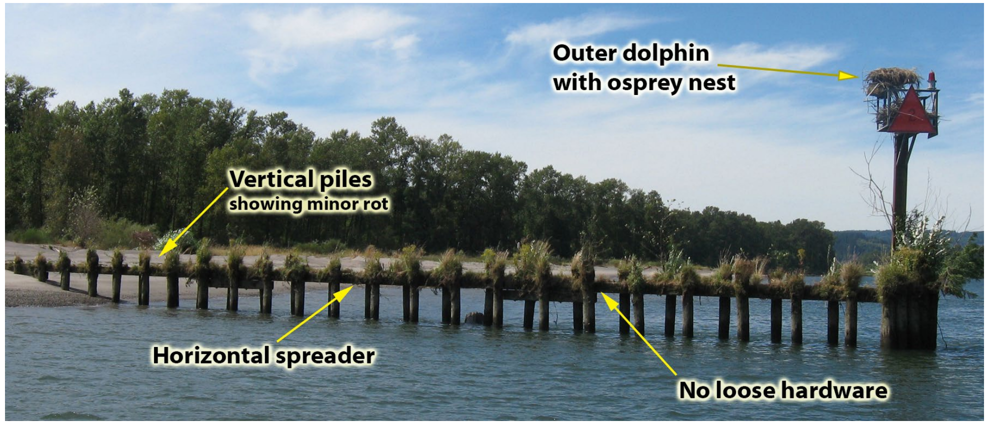

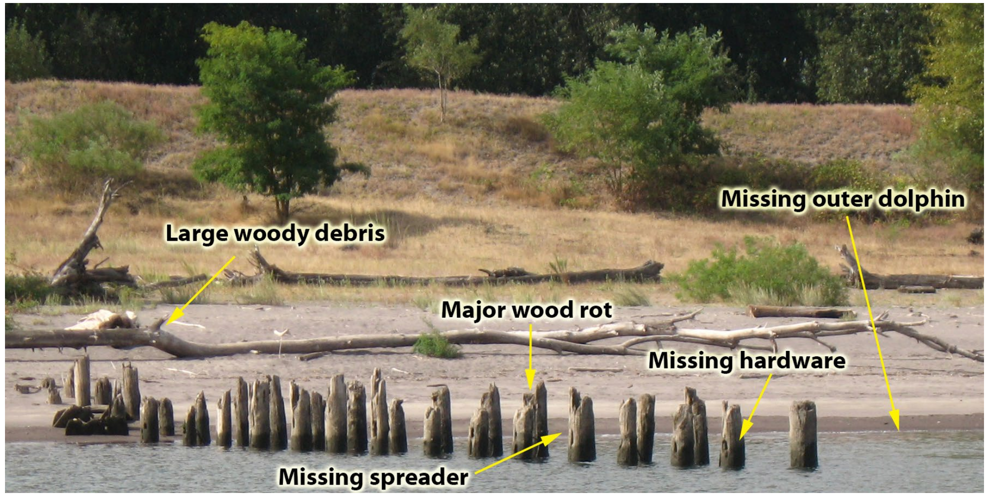

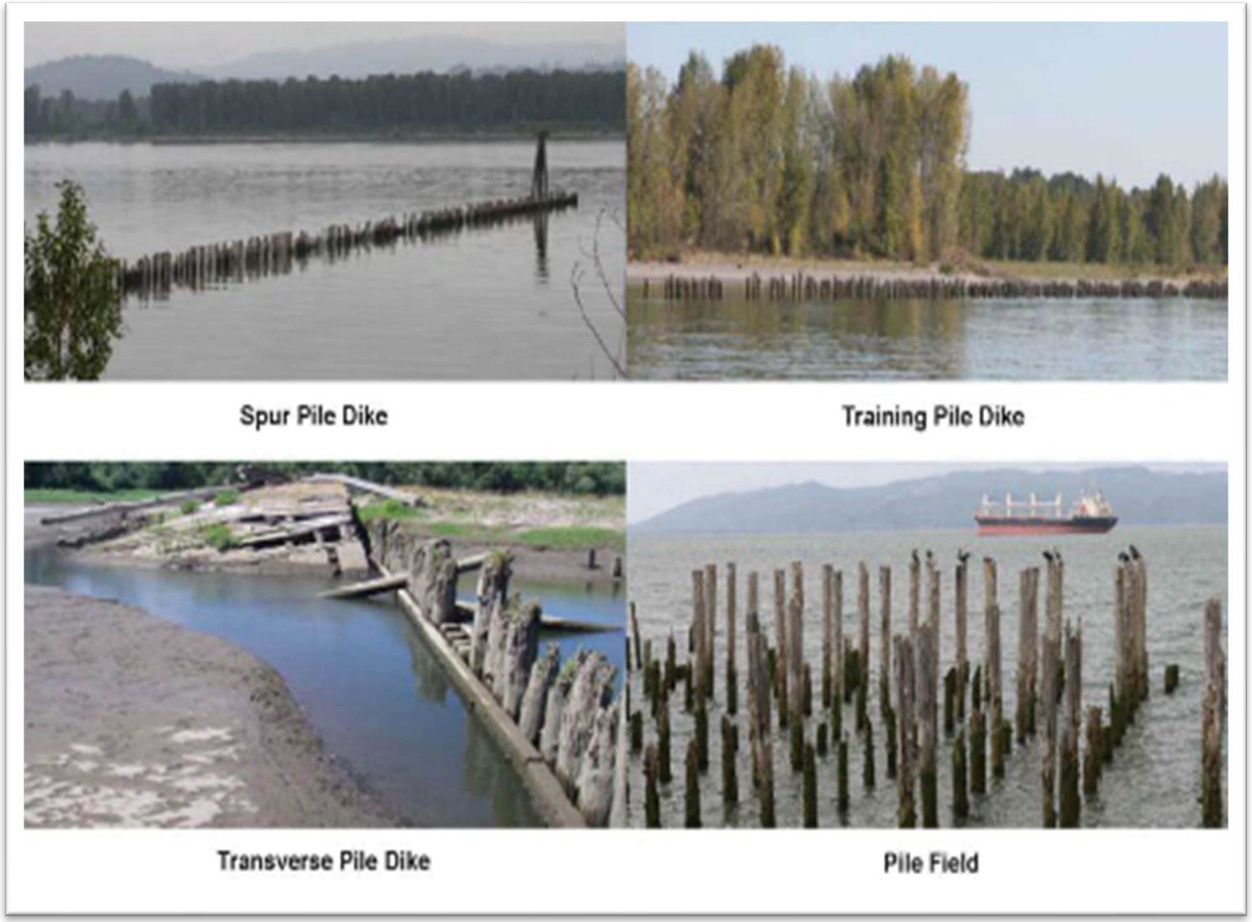

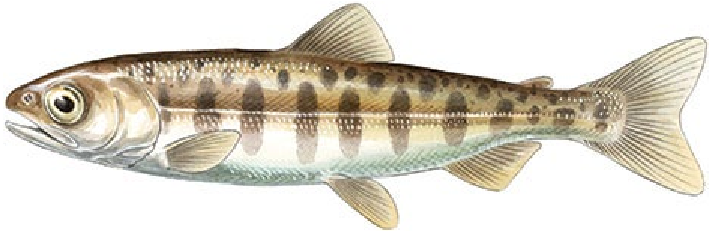

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Fish Response

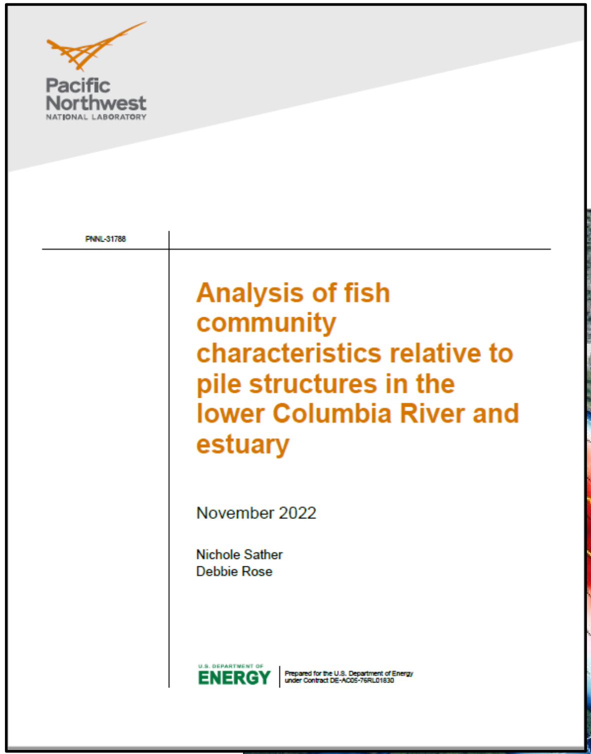
Environmental Considerations

Fish impacts need to be addressed for every USACE Navigation/O&M project…

What if we could:

…simultaneously review design conditions and assess potential fish impacts?

…Predict transit time, survival, path, and migratory route of fish based on design documents?



Pacific Northwest
NATIONAL LABORATORY

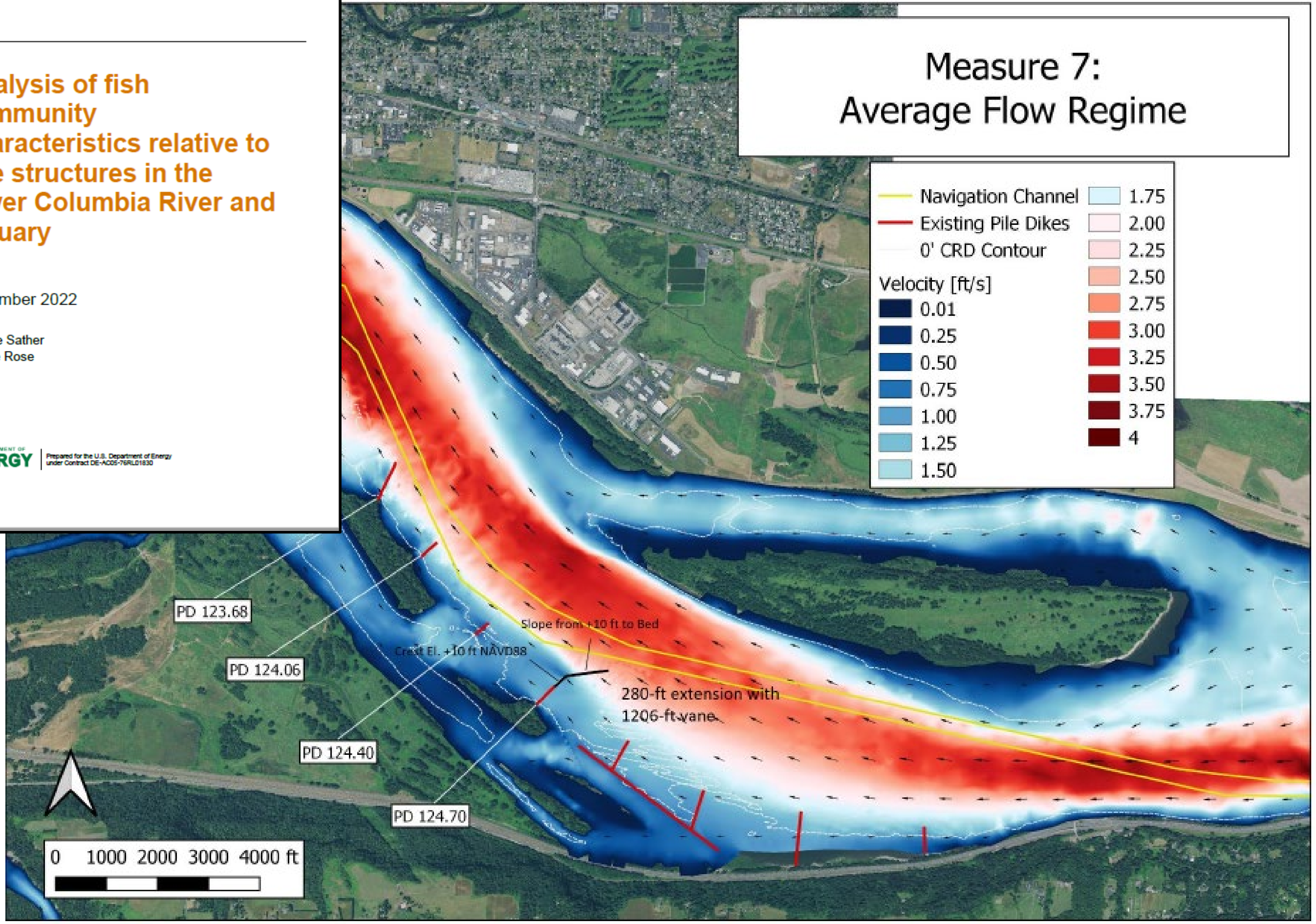
PNNL-31788

Analysis of fish community characteristics relative to pile structures in the lower Columbia River and estuary

November 2022

Nichole Sather
Debbie Rose

U.S. DEPARTMENT OF ENERGY | Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830



Ex: Fish Response to Pile Dikes ≈ *f* [(Pile dike structure)+(Flow)+(Location)+(Salmon life history)]

Model fish parameters to predict behavior?

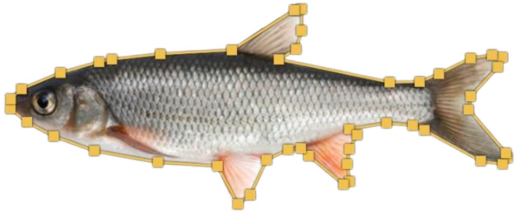
Ex: Fish Response to Pile Dikes ≈ *f* [(Pile dike structure)+(Flow)+(Location)+(Salmon life history)]

Modeling fish Behavior

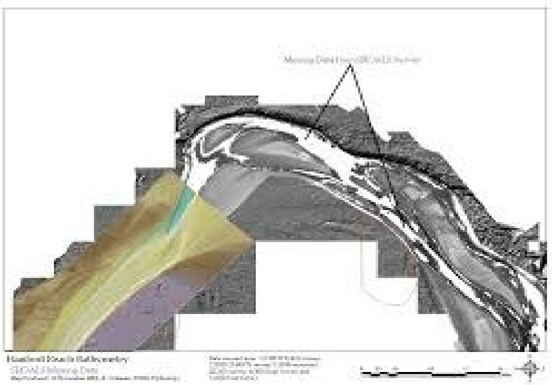
General Approach

Real Fish Data

->



Simulated Fish Data



Real River Data

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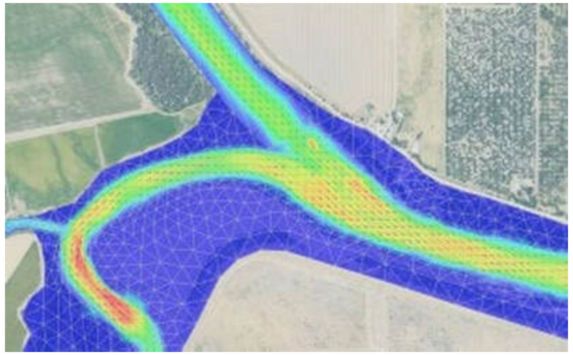
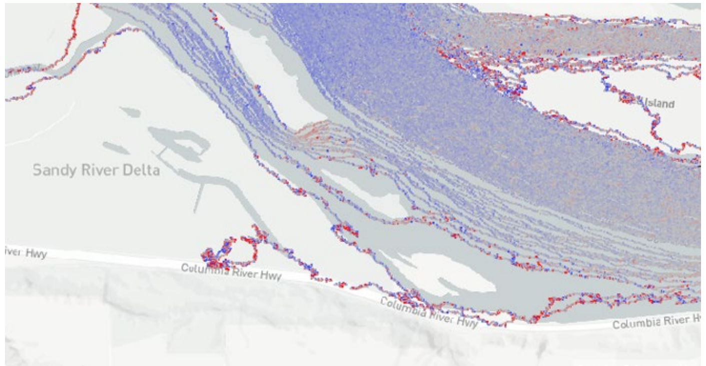


Simulated River Data

=>



Replicable model that allows prediction of fish behavior:

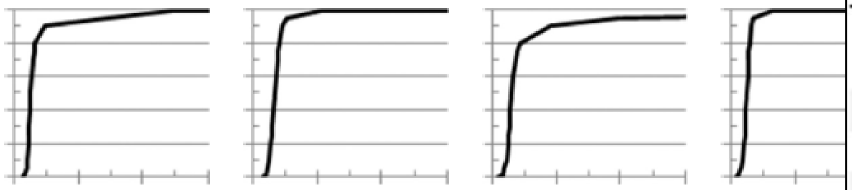
- Transit time
- Points of concentration
- Survival
- Migration route

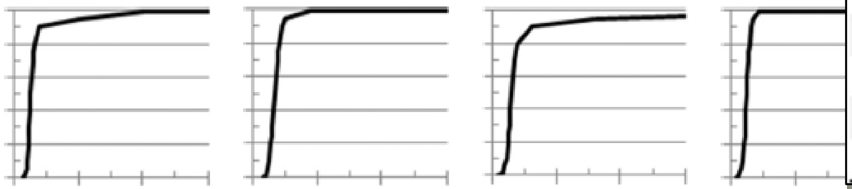
Real Fish Data

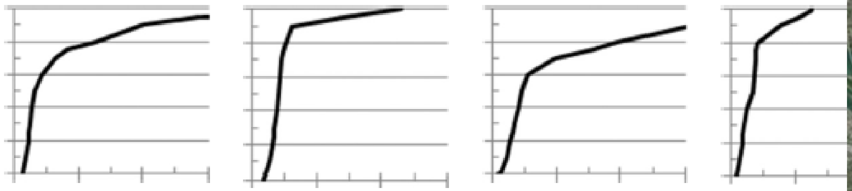
JSAT data Courtesy of PNNL, NWP, and NWW

Table 3. Residence times (h) of acoustic-tagged fish in the vicinity of the Sandy River delta during spring and summer 2007 and 2008.

Migration pathway	Statistic	2007 CH1	2007 CH0	2008 CH1	2008 STH	2008 CH0
All combined	Mean (SE)	4.0 (0.1)	3.8 (0.1)	6.6 (0.3)	2.7 (0.1)	3.3 (0.0)
	Median	2.6	3.4	3.0	2.5	
	Range	1.3–255.7	1.6–565.0	0.8–373.2	0.8–211.0	
	n	3567	5222	3748	1525	
	Cum. %					
Main only	Mean (SE)	3.6 (0.1)	3.7 (0.1)	5.5 (0.3)	2.7 (0.1)	
	Median	2.6	3.4	3.0	2.5	
	Range	1.4–255.7	1.8–565.0	0.8–373.2	0.8–211.0	
	n	3231	5028	3347	1468	
	Cum. %					
Off-channel	Mean (SE)	8.4 (0.7)	4.8 (0.3)	15.2 (1.6)	3.7 (0.3)	
	Median	3.2	4.0	4.5	3.4	
	Range	1.3–107.0	1.7–23.2	0.9–278.1	0.9–12.6	
	n	336	194	401	57	
	Cum. %					







Note: The *x*-axis scale is from 0 to 30 h, which includes 90%–100% of observed residence times. The *y*-axis scale is cumulative

Statistic	Yearling Chinook	Steelhead	Fall Chinook
From the Spillway to the Primary Array (31.4 km)			
1st Percentile Travel Time (hours)	5.78	4.9	6.26
Median and Standard Deviation in Travel Time (hours)	8.35 ± 3.05	6.85 ± 9.17	8.87 ± 3.59
99th Percentile Travel Time (hours)	20.80	19.16	23.1
Median Travel Rate (m/s)	1.04	1.27	0.98
Projected Egress Time (Spillway to the Tailrace End = 2.2 km)	0.59	0.48	0.62
From B2 to the Primary Array (31.8 km)			
1st Percentile Travel Time (hours)	6.23	4.90	6.46
Median and Standard Deviation in Travel Time (hours)	9.37 ± 6.14	7.60 ± 3.37	9.36 ± 5.37
99th Percentile Travel Time (hours)	34.88	22.43	31.36
Median Travel Rate (m/s)	0.94	1.16	0.94
Projected Egress Time from B2 to the Tailrace End (2.6 km)	0.77	0.62	0.77

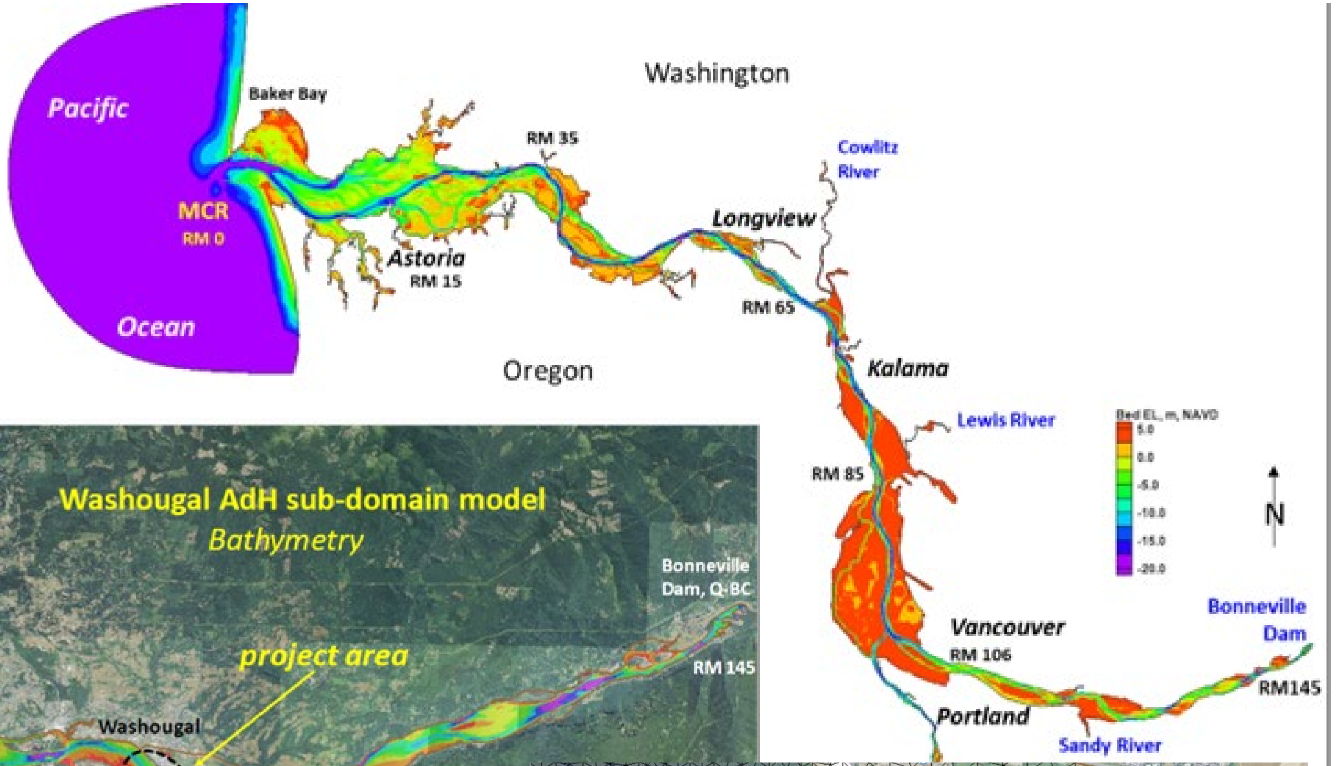
AdH Model

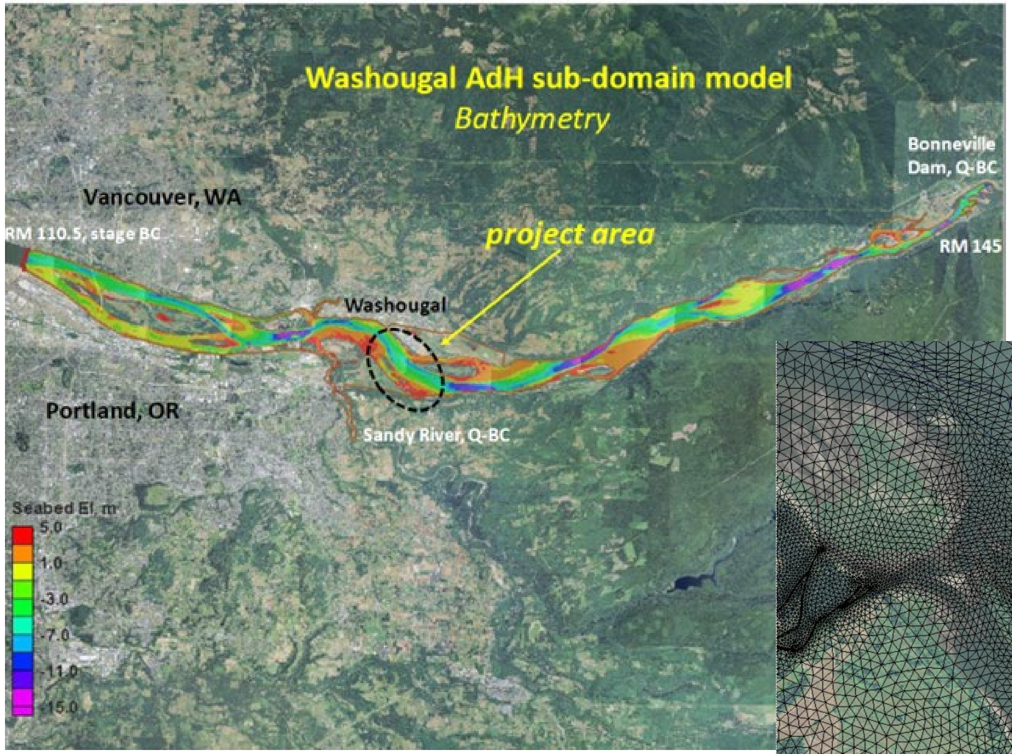
Courtesy of Rod Moritz (NWP) & David S. Smith (CHL)

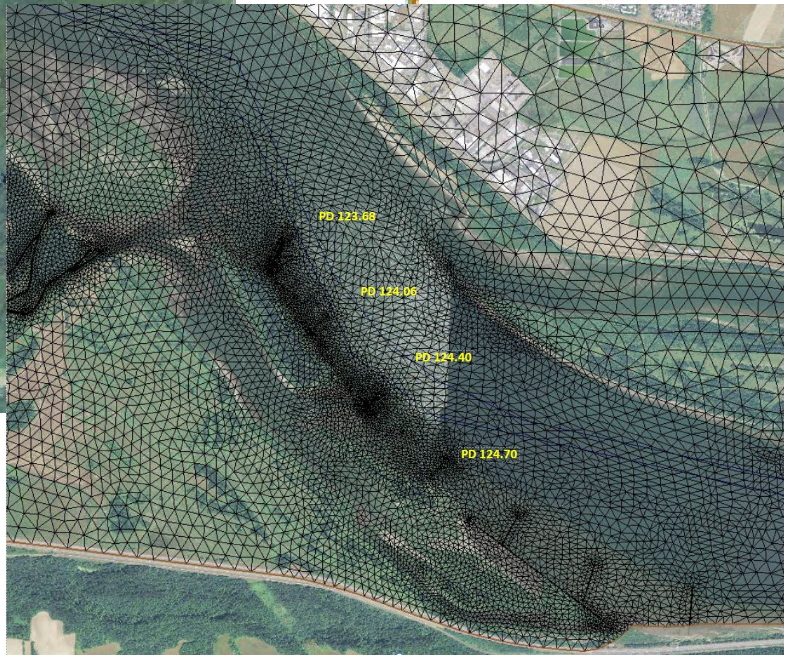
2D MCR AdH Model– depth averaged mesh with refinement near project location. Washougal sub-domain.

Flow based on JSAT fish conditions:

2007 = 225 kCFS Mean Flow
2008 = 300 kCFS Mean Flow







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Model Fish

Courtesy of Dr. Andy Goodwin (EL) & Dr. David L. Smith (EL)

Eulerian-Langrangian-Agent-Method (ELAM)

n = 500 “fish” particles released from B2 & Spillway per JSAT studies.

1 hr. run with 20 sec. output interval.

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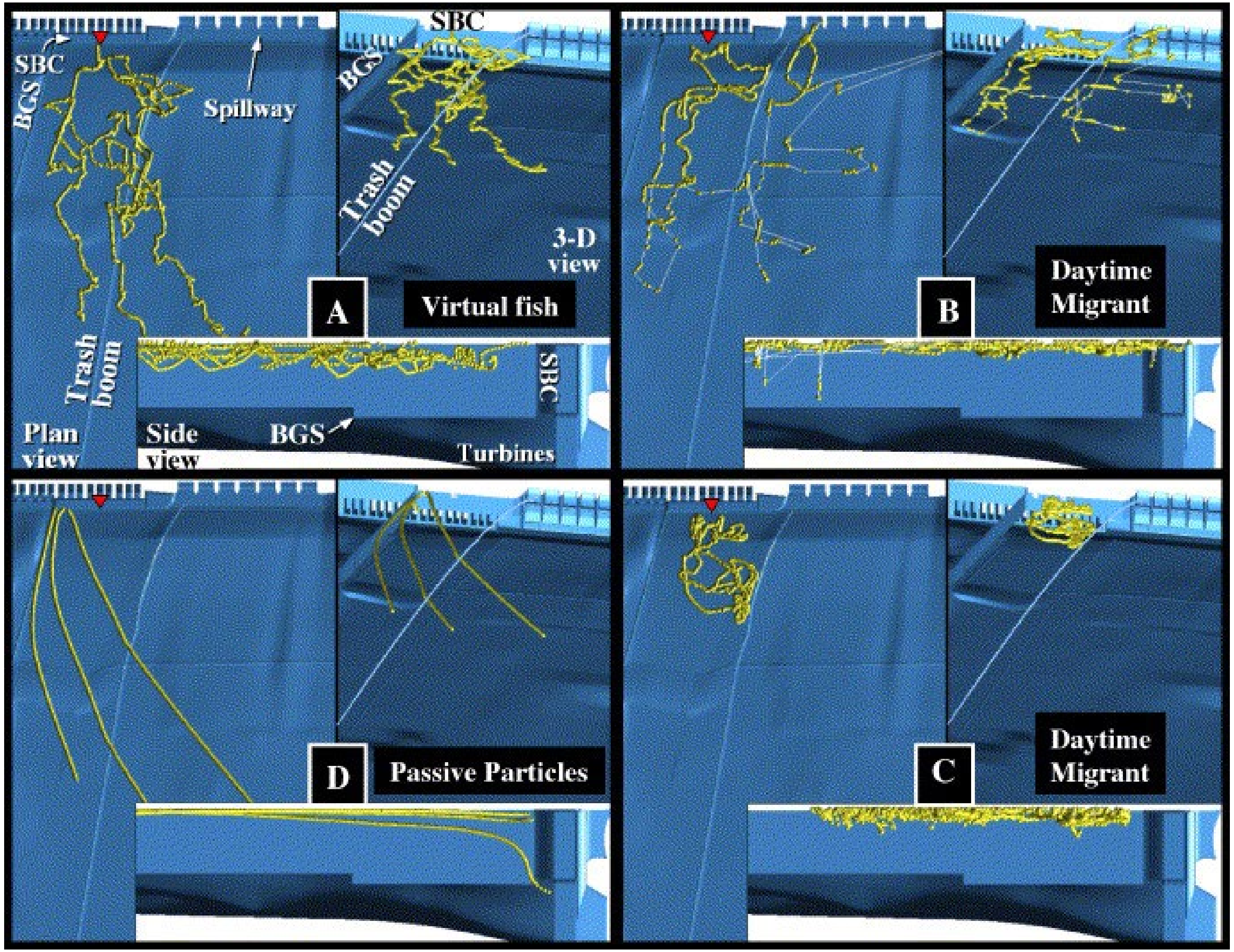
Predicting near-term, out-of-sample fish passage, guidance, and movement across diverse river environments by cognitively relating momentary behavioral decisions to multiscale memories of past hydrodynamic experiences

R. Andrew Goodwin[1]*, Yong G. Lai[2], David E. Taflin[3], David L. Smith[4], Jacob McQuirk[5], Robert Trang[5] and Rvan Reeves[5]



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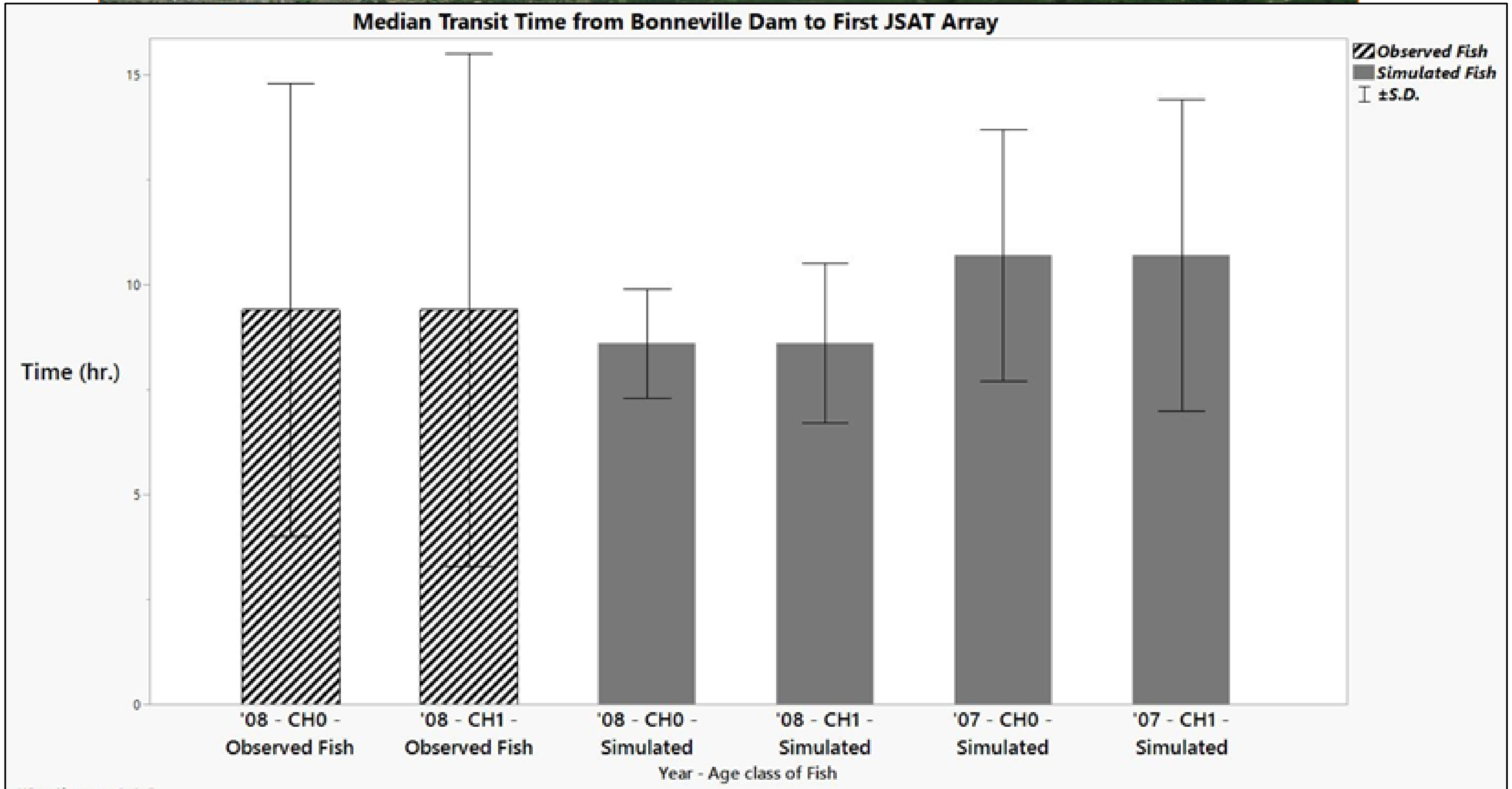
Calibration

Travel Time – Tune model

Equivalent travel times and survival from BON – first array.

JSAT Fish ≈ Modeled Fish

Assume model calibration a success and validate against JSAT fish in more dynamic environment.

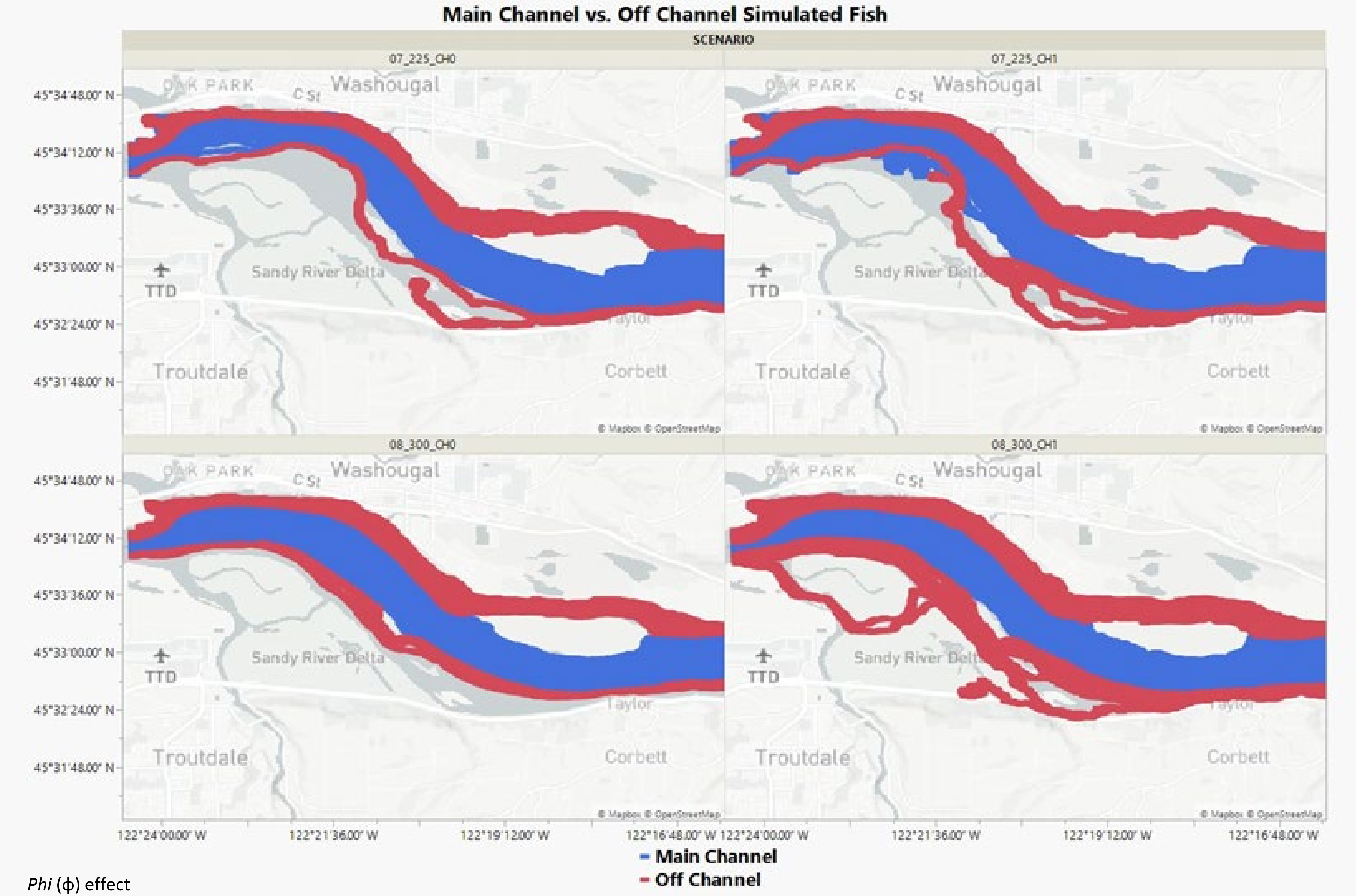


Validation

Model vs JSAT – Route of Travel

Main Channel Use:
JSAT fish ≥ 91%
Modeled fish ≥ 86%

Travel Route:
JSAT Fish ≈ Modeled Fish



Chi Square Goodness of Fit
Off-channel vs. Main Channel

Year - Cohort	X^2 Statistic	*P*	Degree Freedom	*Phi* (ϕ) effect
07 – CH0	6.513	<0.01072	1	0.255
07 – CH1	0.543	<0.46152	1	0.074
08 – CH0	0	0	1	0
08 – CH1	3.051	<0.08061	1	0.17

Validation

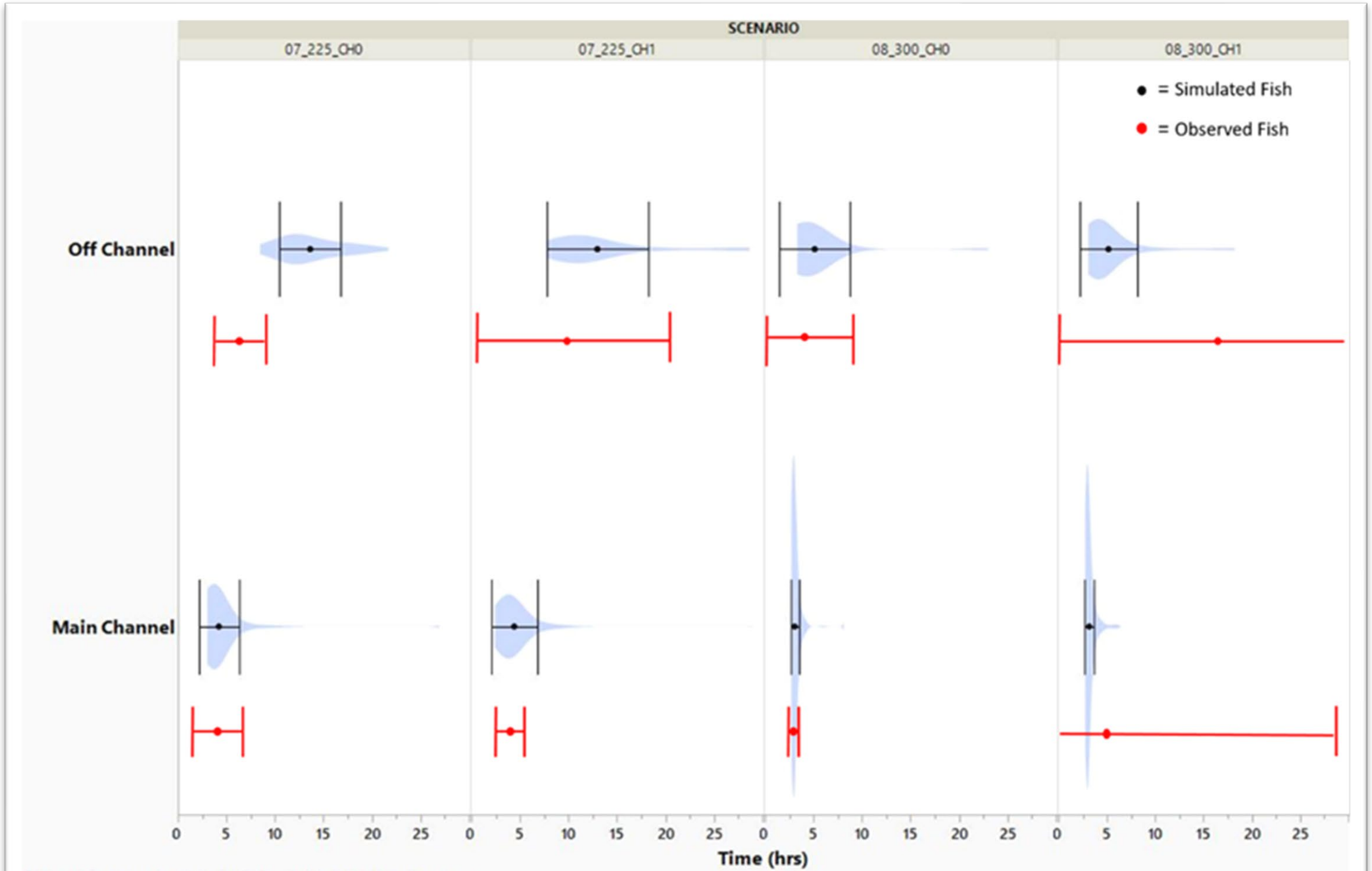
Model vs JSAT – Travel Time

- Almost complete overlap of Travel Time distributions.

- Simulated fish have less variance than JSAT fish.

Fish - Year - Cohort	*n*	% of sample	Mean	(SE)	Median	(SD)	CV	Range
	Off-Channel Fish Transit Time (hrs.)							
Simulated - 07-CH0	42	0.09	13.6	0.5	12.8	3.2	23.5	8.7 - 21.6
Observed - 07-CH0	209	0.04	4.8	0.3	4.0	4.3	90.4	1.7 - 23.2
Simulated - 07-CH1	49	0.10	13.0	0.8	11.5	5.3	40.4	8.0 - 28.5
Observed - 07-CH1	406	0.08	8.4	0.7	3.2	14.1	167.9	1.3 - 107.0
Simulated - 08 -CH0	28	0.06	5.1	0.7	4.2	3.6	70.6	3.6 - 22.8
Observed - 08-CH0	364	0.06	4.4	0.3	3.0	5.7	130.1	1.3 - 55.6
Simulated - 08-CH1	69	0.14	5.1	0.4	4.1	3.0	58.6	3.3 - 18.1
Observed - 08-CH1	658	0.09	15.2	1.6	4.5	41.0	270.0	1.7 - 23.2

Fish - Year - Cohort	*n*	% of sample	Mean	(SE)	Median	(SD)	CV	Range
	Main-Channel Fish Transit Time (hrs.)							
Simulated - 07-CH0	449	0.91	3.6	0.1	4.2	2.0	55.6	3.2 - 26.7
Observed - 07-CH0	5558	0.96	3.7	0.1	3.4	7.5	201.5	1.8 – 565.0
Simulated - 07-CH1	444	0.90	4.4	0.1	3.7	2.4	54.5	2.6 - 28.6
Observed - 07-CH1	4626	0.92	3.6	0.1	2.6	6.8	188.9	1.4 - 255.7
Simulated - 08 -CH0	471	0.94	3.1	0.0	2.9	0.4	12.9	2.7 - 8.1
Observed - 08-CH0	5576	0.94	3.2	0.0	3.0	0.0	0.0	1.6 - 26.5
Simulated - 08-CH1	431	0.86	3.2	0.0	3.0	0.5	15.9	2.8 - 6.3
Observed - 08-CH1	6437	0.91	5.5	0.3	3.0	24.1	437.6	0.8 - 373.2



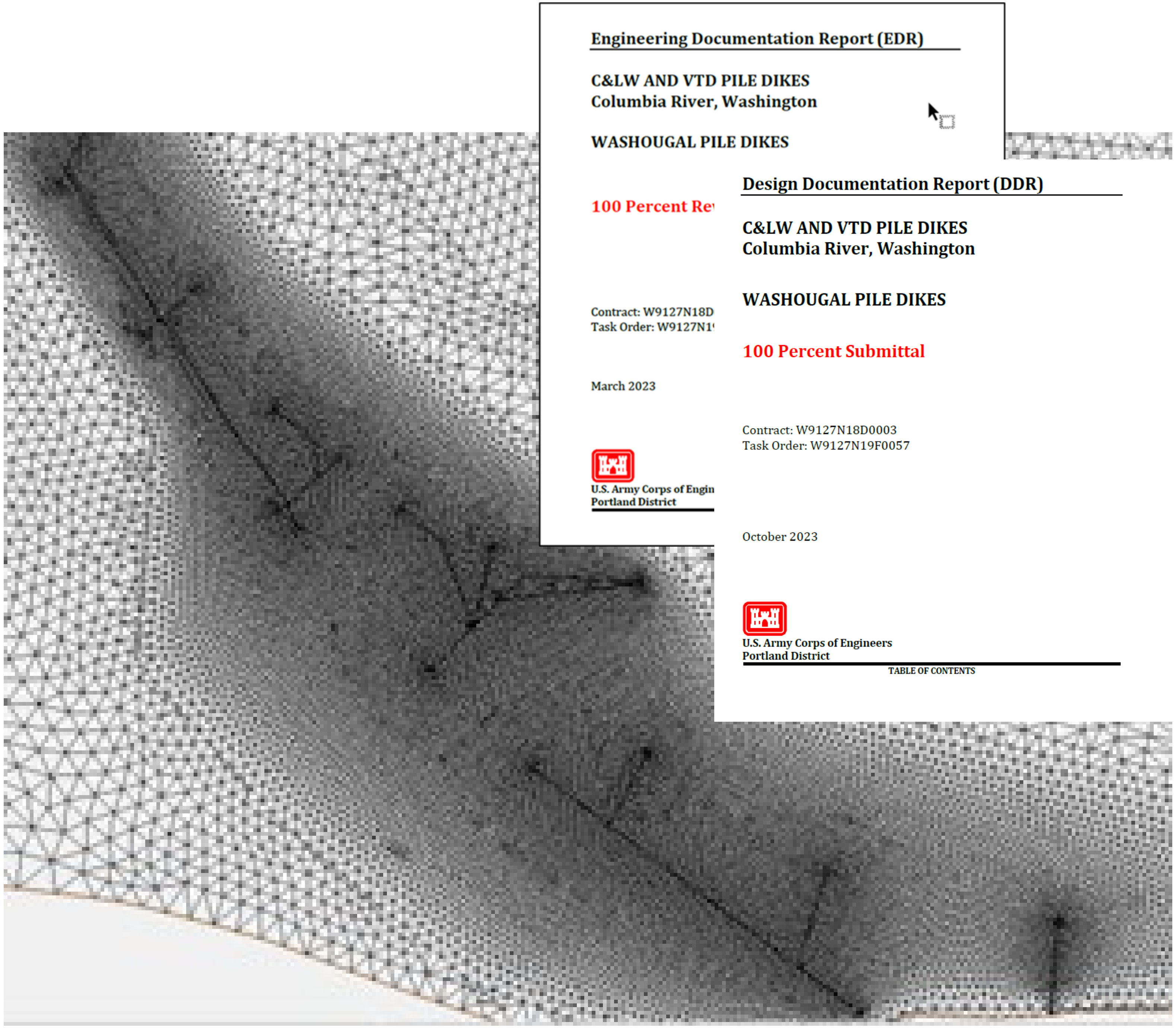
Each error bar is constructed using 1 standard deviation from the mean.

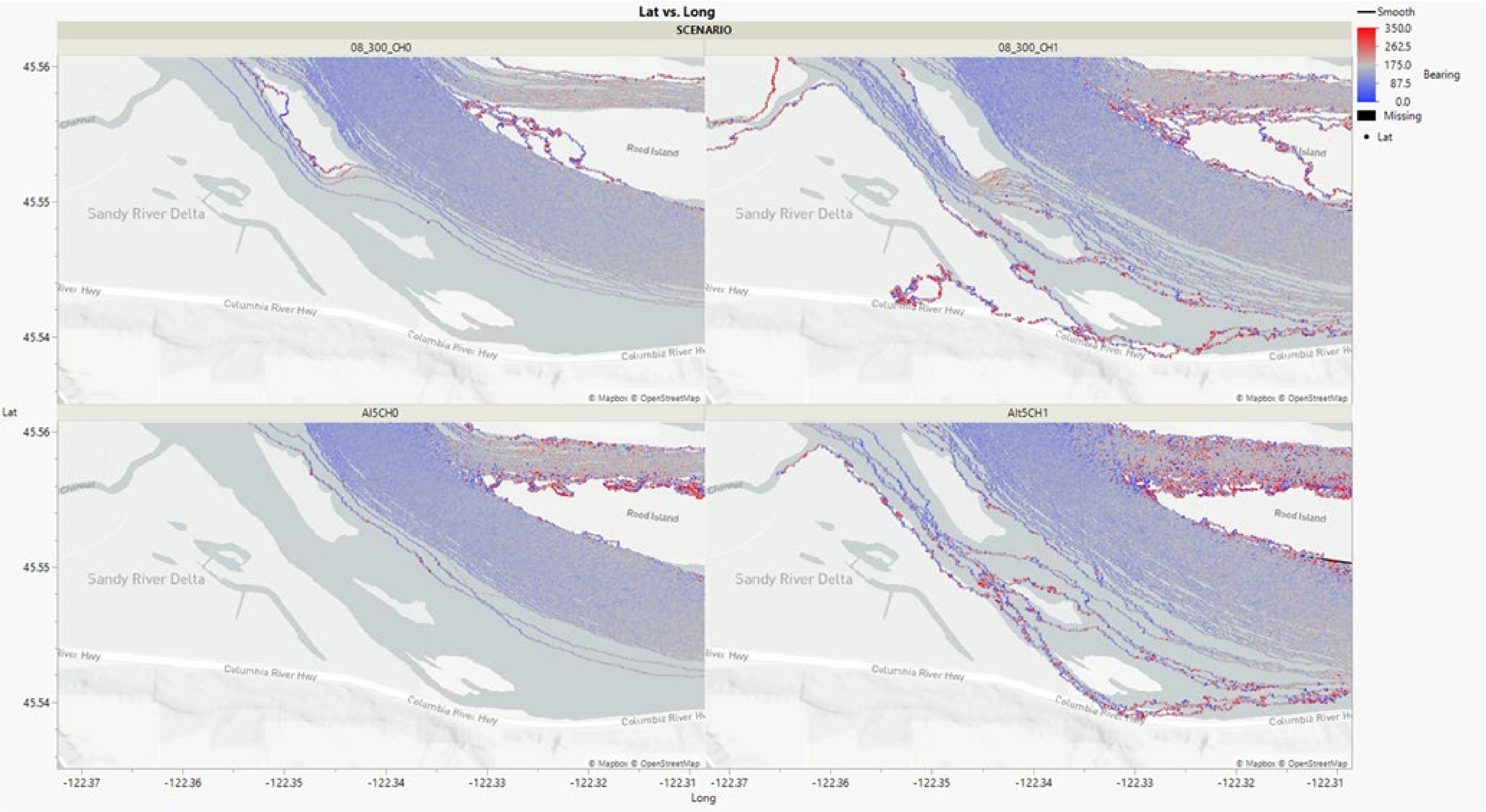
Application

Model Fish in Proposed Design

Contractor provided AdH models with Alternative Analysis of proposed pile dikes.

Ran the validated fish model with the proposed Pile Dike structures.



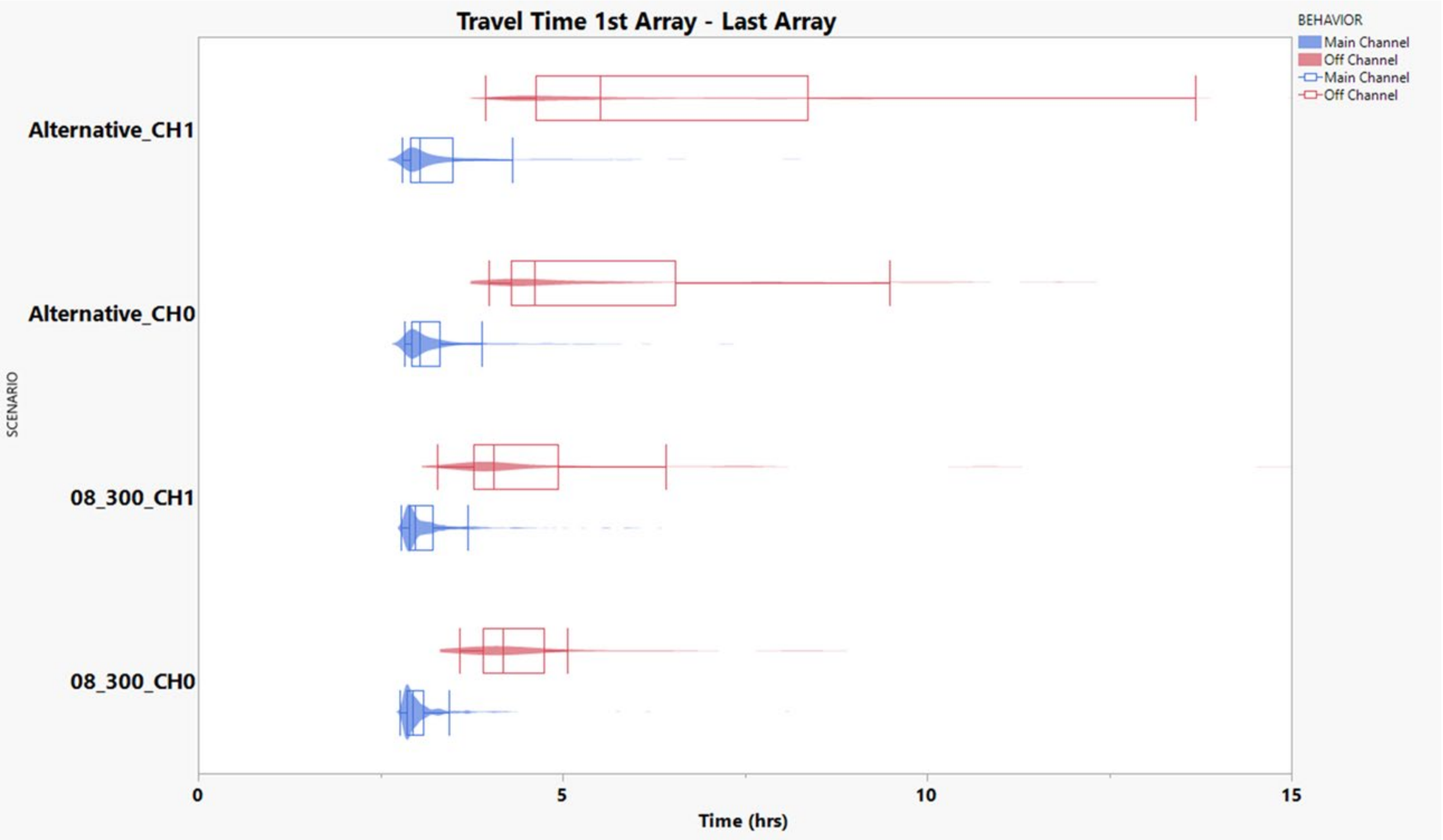


Lat vs. Long
SCENARIO
08_300_CH0
08_300_CH1
Alt5CH0
Alt5CH1
Smooth
350.0
262.5
175.0
87.5
0.0
Bearing
Missing
Lat
Long
45.56
45.55
45.54
-122.37
-122.36
-122.35
-122.34
-122.33
-122.32
-122.31
Sandy River Delta
Reed Island
Columbia River Hwy
© Mapbox © OpenStreetMap

Application

Model Fish in Proposed Design

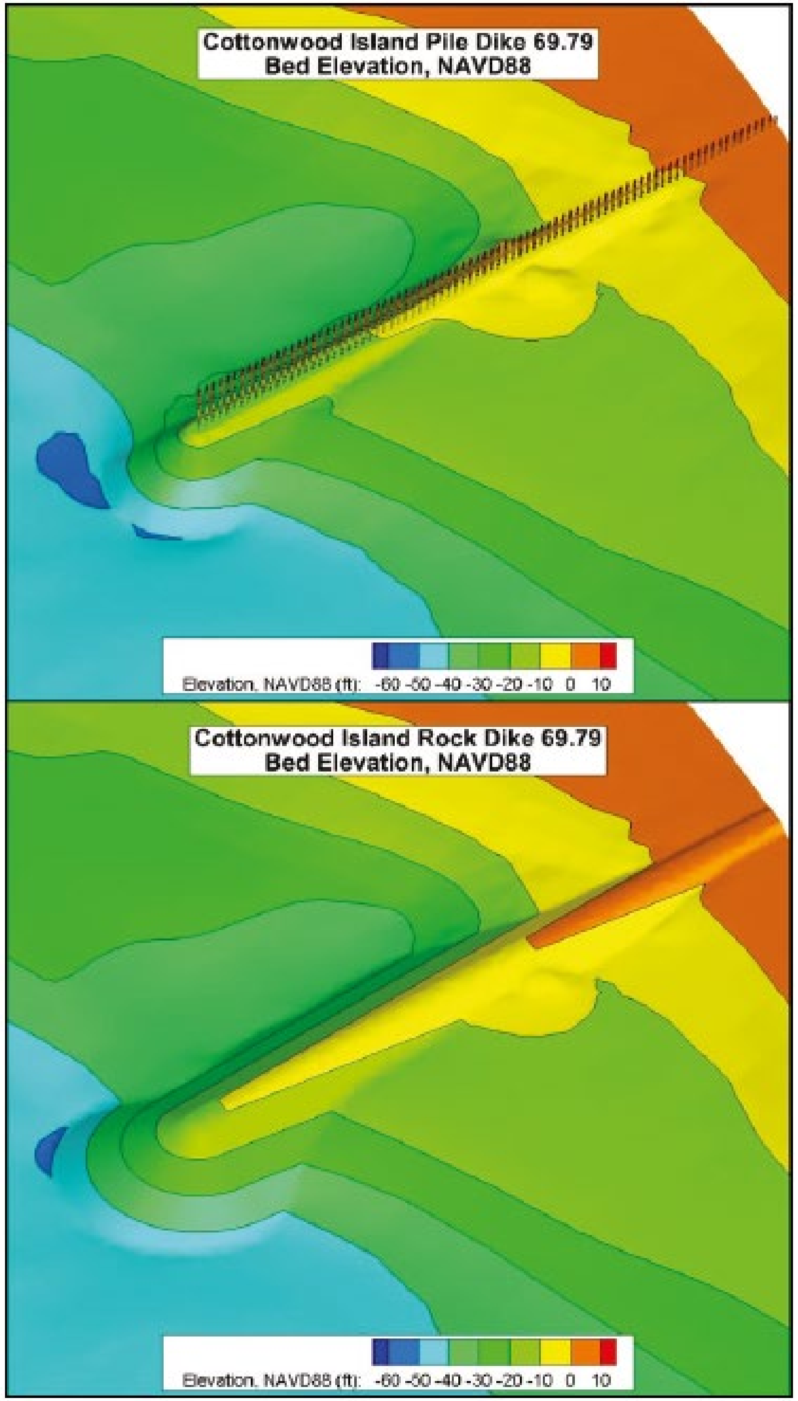
- No change in off-channel vs. main channel migration routes.
- Travel Time was statistically longer for the Alternative (~0.5 hrs). Biologically relevant?



Behavior	Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value
Main Channel	Alternative CH1	08_300_CH1	169.6672	35.34578	4.800211	<.0001*
Main Channel	Alternative CH0	08_300_CH1	147.5620	34.39970	4.289631	0.0001*
Off Channel	Alternative CH1	08_300_CH1	70.4343	10.24795	6.87301	<.0001*
Off channel	Alternative CH0	08_300_CH1	46.8805	12.85236	3.64762	0.0016*

So, what did we learn and where might this approach be applied to other projects?

- Expand application to ongoing lower river pile dike projects.
- Inform habitat development projects (i.e. DMMP).
- Identify concentration points (predation/rearing).
- NMFS Pile Dike PIT Antenna (i.e. Survival Studies)
- Inform ongoing juvenile lamprey telemetry studies.



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