Highlights from 2023 Pilot Predation Study Using Innovative Molecular Methods (eDNA qPCR and Metabarcoding)

Ralph Lampman

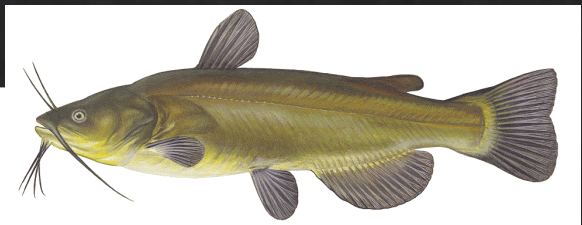
January 23, 2024

Anadromous Fish Evaluation Program Annual Meeting

Photo Credit: Freshwater Illustrated / USFWS

Collaborative Predation Studies

- **Funding from BPA, BOR, ACOE, BIA**
- Lab study initially -> now moving onto field studies using molecular techniques (eDNA qPCR & metabarcoding)



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ORIGINAL ARTICLE

Ecology of FRESHWATER FISH WILEY

An experimental study to evaluate predation threats on two native larval lampreys in the Columbia River Basin, USA

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ARTICLE

Whose Kids Did You Eat? Genetic Identification of Species and Parents of Larval Lampreys in Fish Predator Guts

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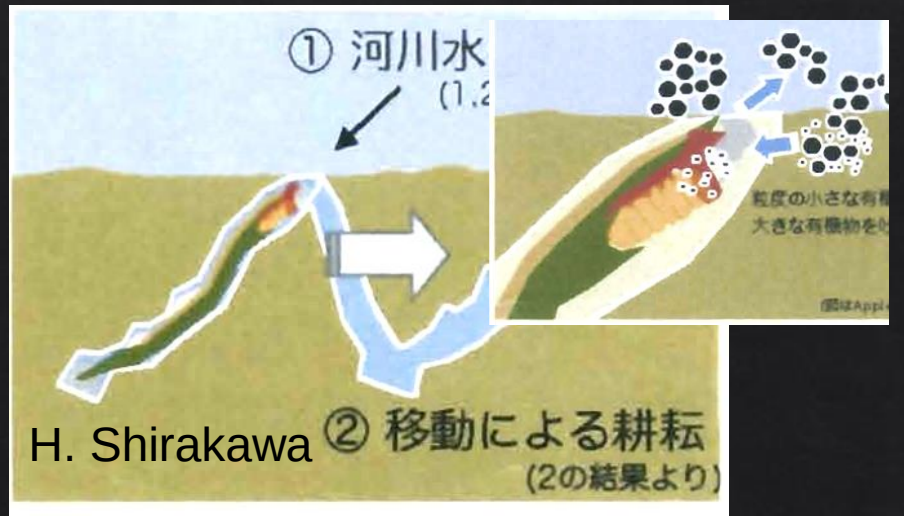
4 Key Lamprey Ecosystem Benefits

Tribal Culture & Food Source

Food for Numerous Species

Buffer for Salmon Predation

“Farmer of the Underwater World”




Fredrik Coster
Photography

Pacific Lamprey 3 Main Life Stages

10 – 200 mm

Ammocoete (Larva)

Freshwater

100 – 190 mm

Macrophthalmia (Juvenile)

To Ocean

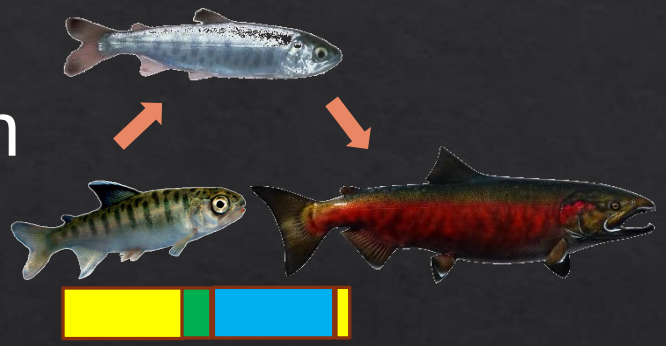
330 – 800 mm

Adult

Back to Freshwater (Spawn)

Life Cycle Timeline (*Updated)

Coho Salmon



= Freshwater
= Transition
= Ocean

Pacific Lamprey

Year

0 2 4 6 8 10 12 14

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FEATURE ARTICLE

Pacific Lamprey Translocations to the Snake River Boost Abundance of All Life Stages

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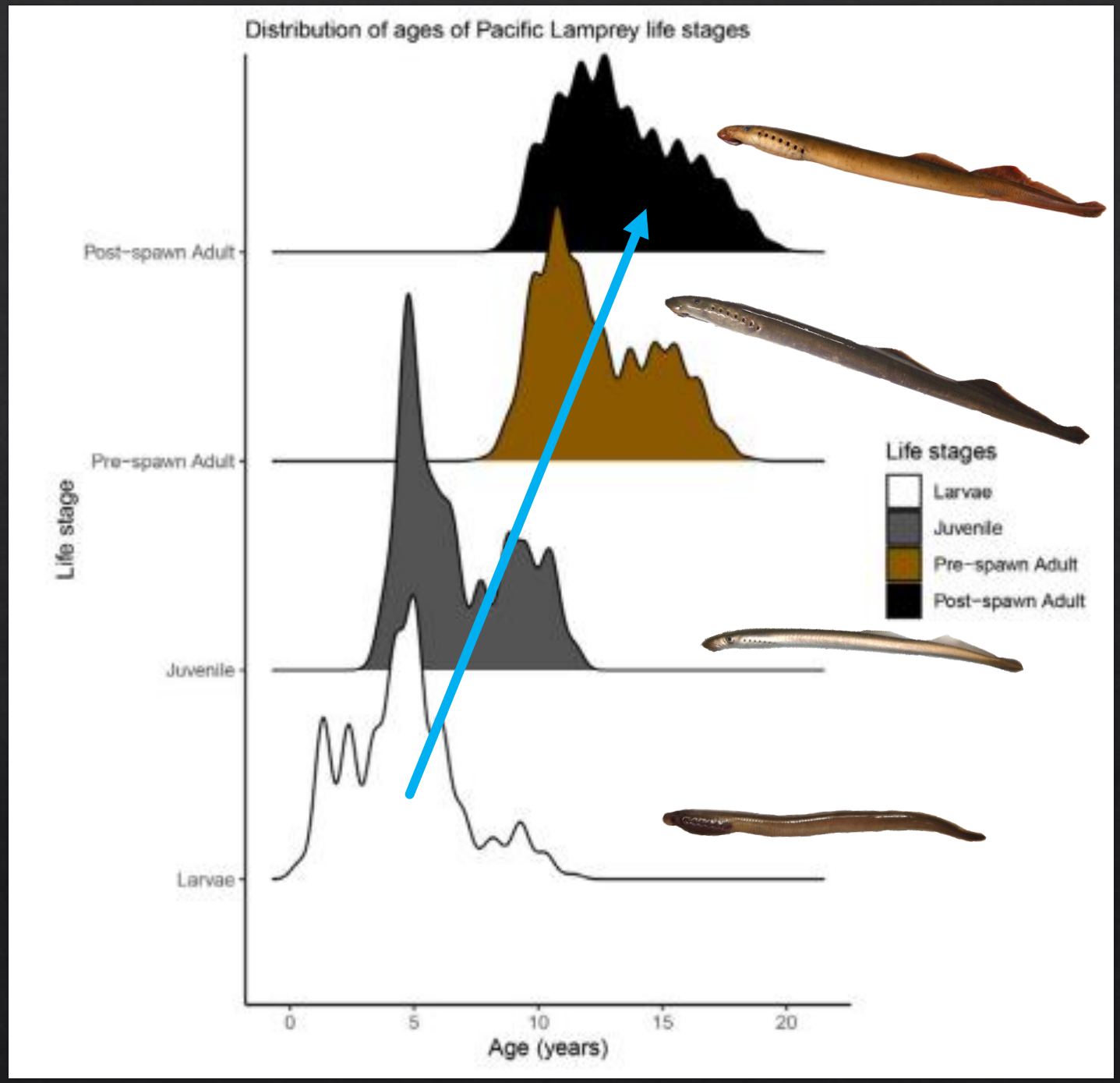
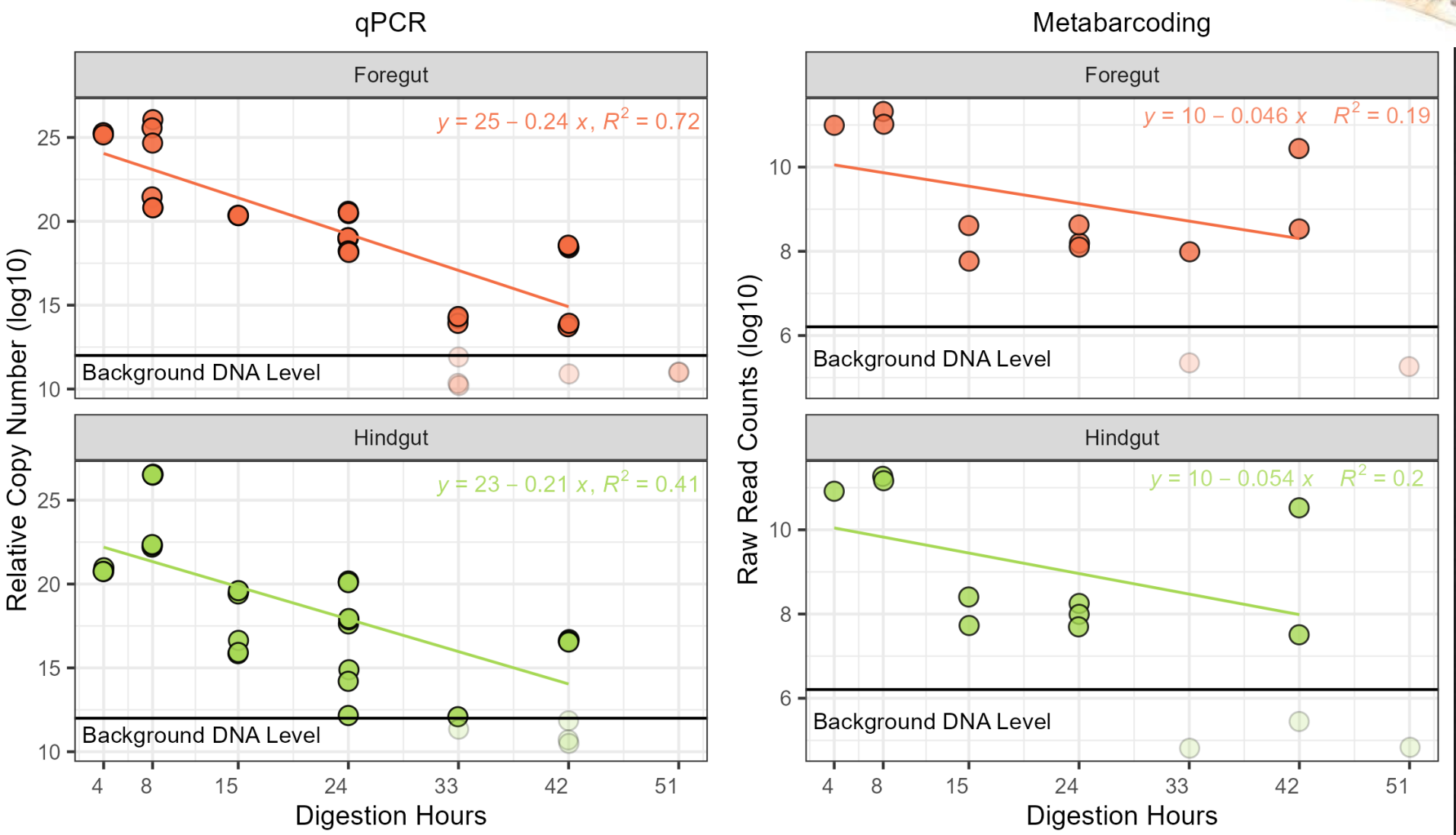


Northern Pikeminnow



Smallmouth Bass

qPCR

Foregut

$y = 27 - 0.15\,x$, $R^2 = 0.17$

Background DNA Level

Hindgut

$y = 20 - 0.041\,x$, $R^2 = 0.033$

Background DNA Level

Relative Copy Number (log10)

30
25
20
15

4 8 15 24 33 42 51 60 72

Digestion Hours

Metabarcoding

Foregut

$y = 11 + 0.006\,x$ $R^2 = 0.02$

Background DNA Level

Hindgut

$y = 11 - 0.022\,x$ $R^2 = 0.2$

Background DNA Level

Raw Read Counts (log10)

10
8
6

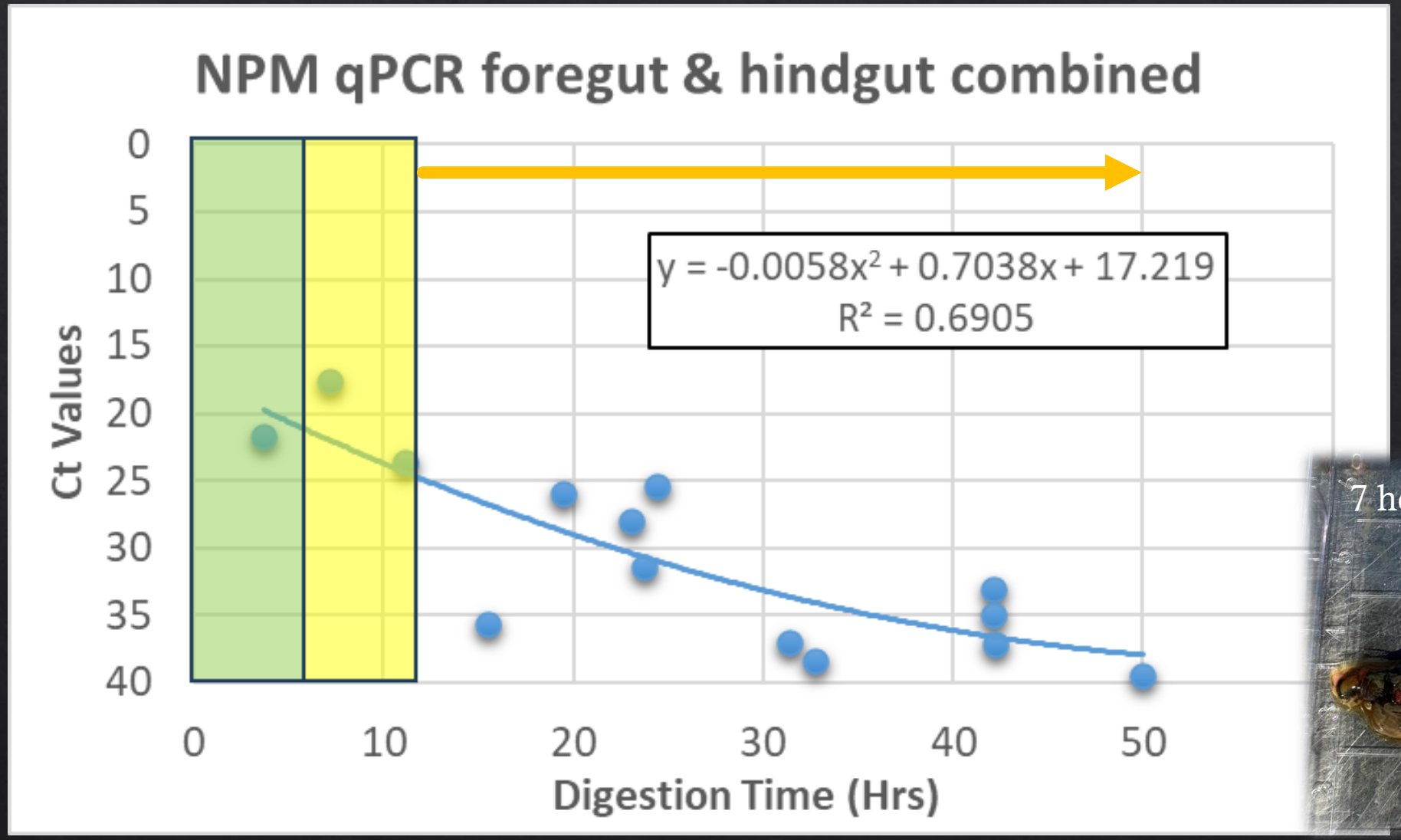
4 8 15 24 33 42 51 60 72

Digestion Hours

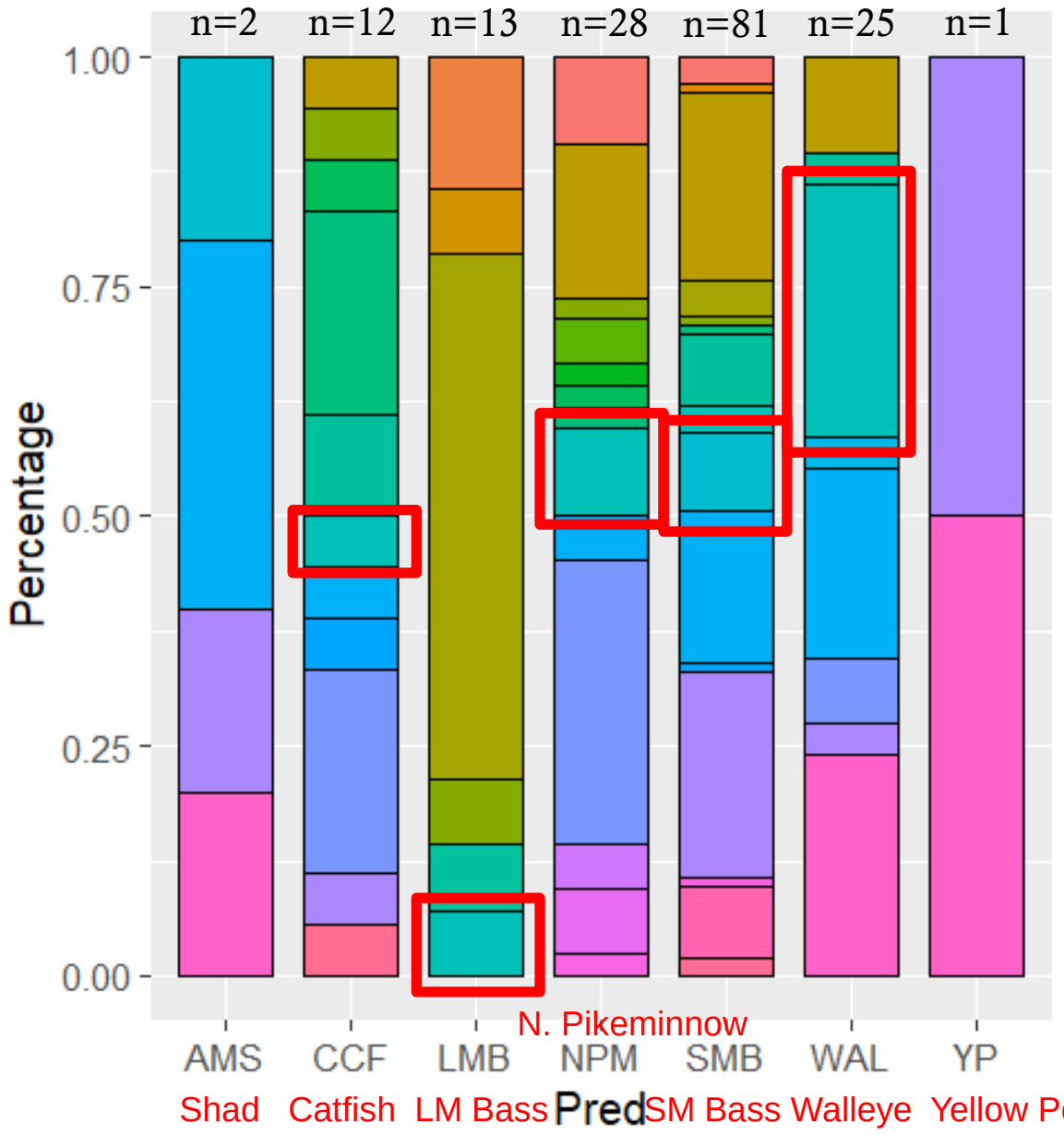
Gut Sample Location ● Foregut ● Hindgut

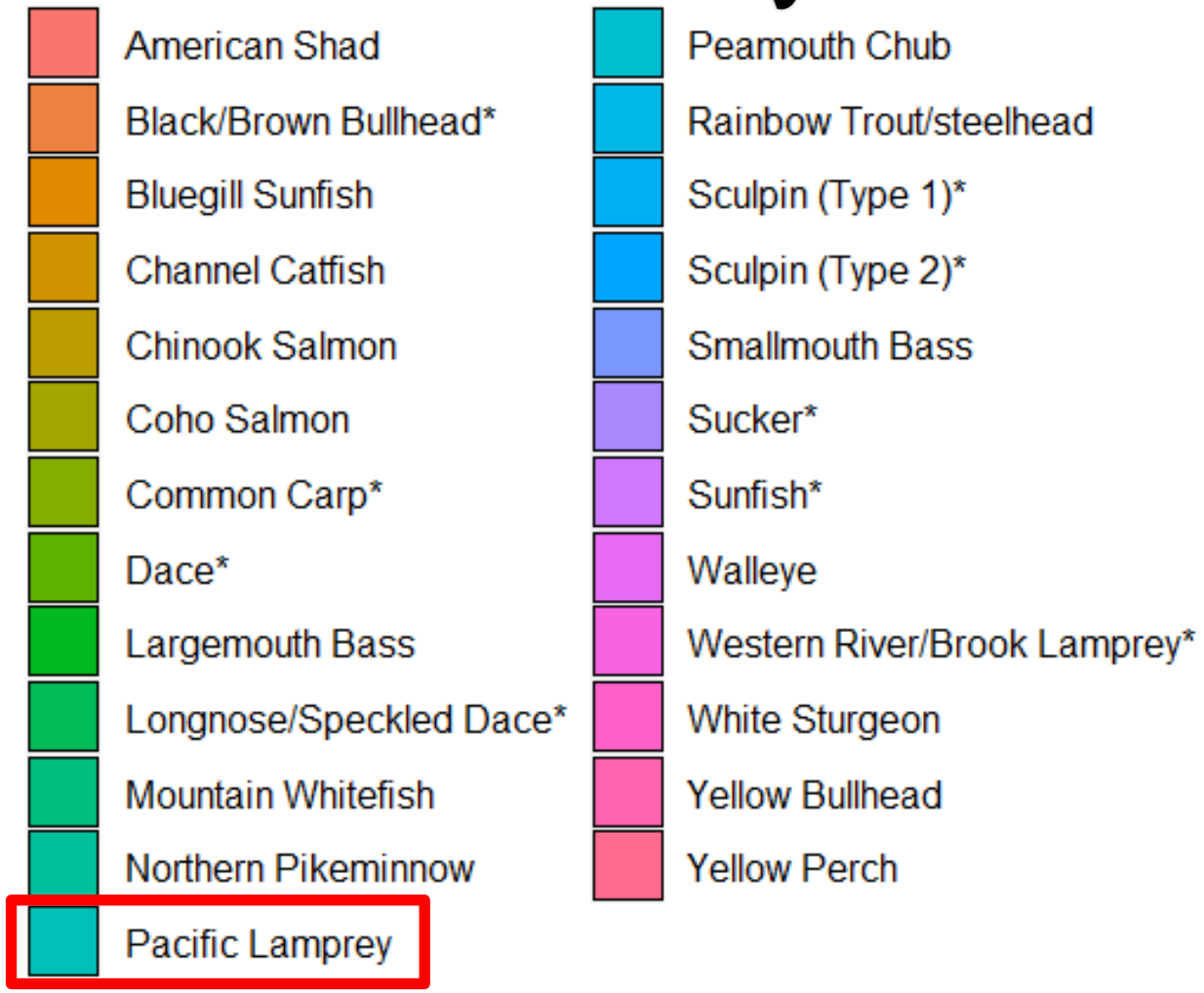
0-6 Hours = Lamprey visually identifiable

6-12 Hours = Lamprey may be visually identifiable (especially if paying close attention)



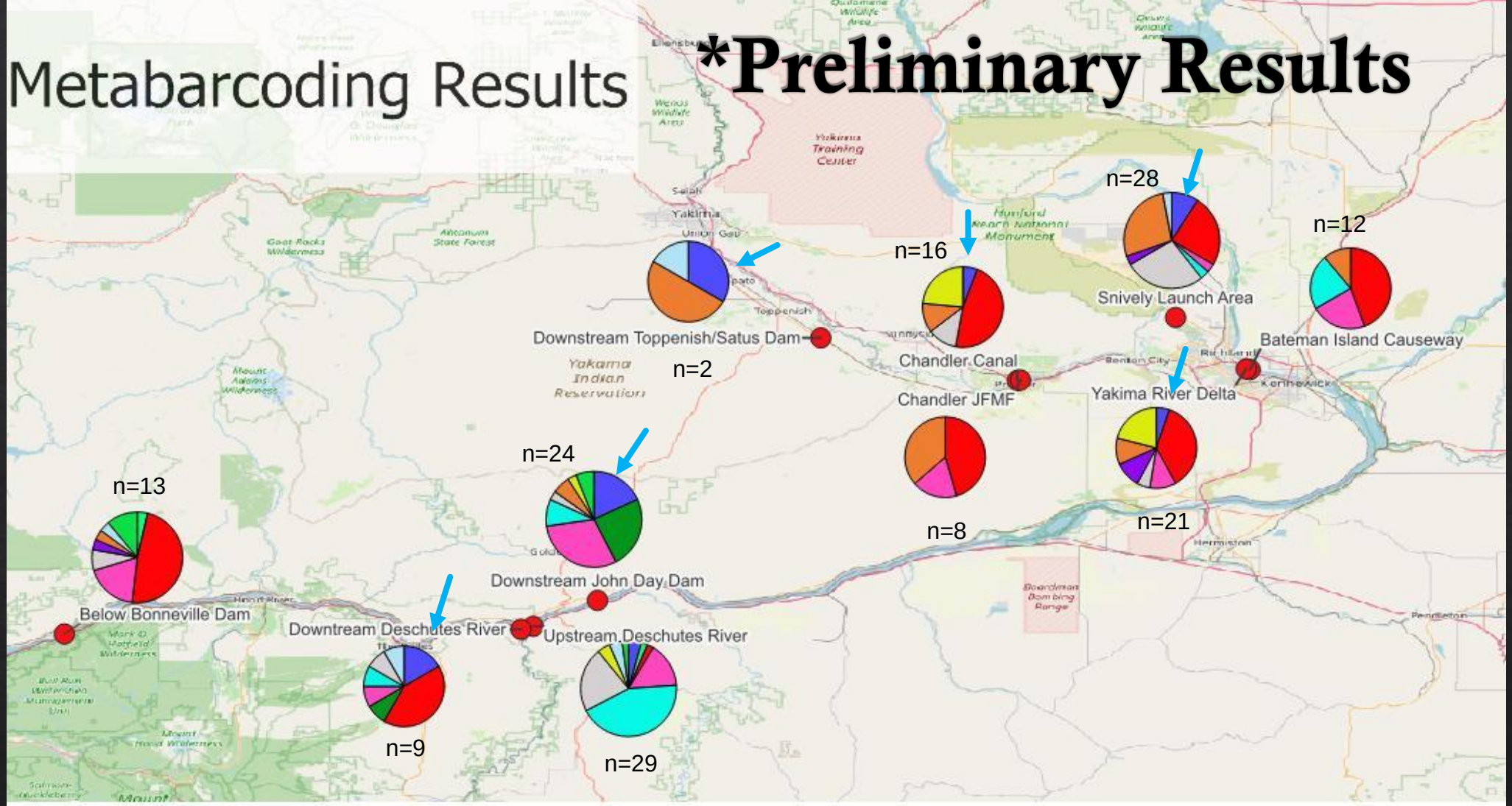
*Preliminary Results





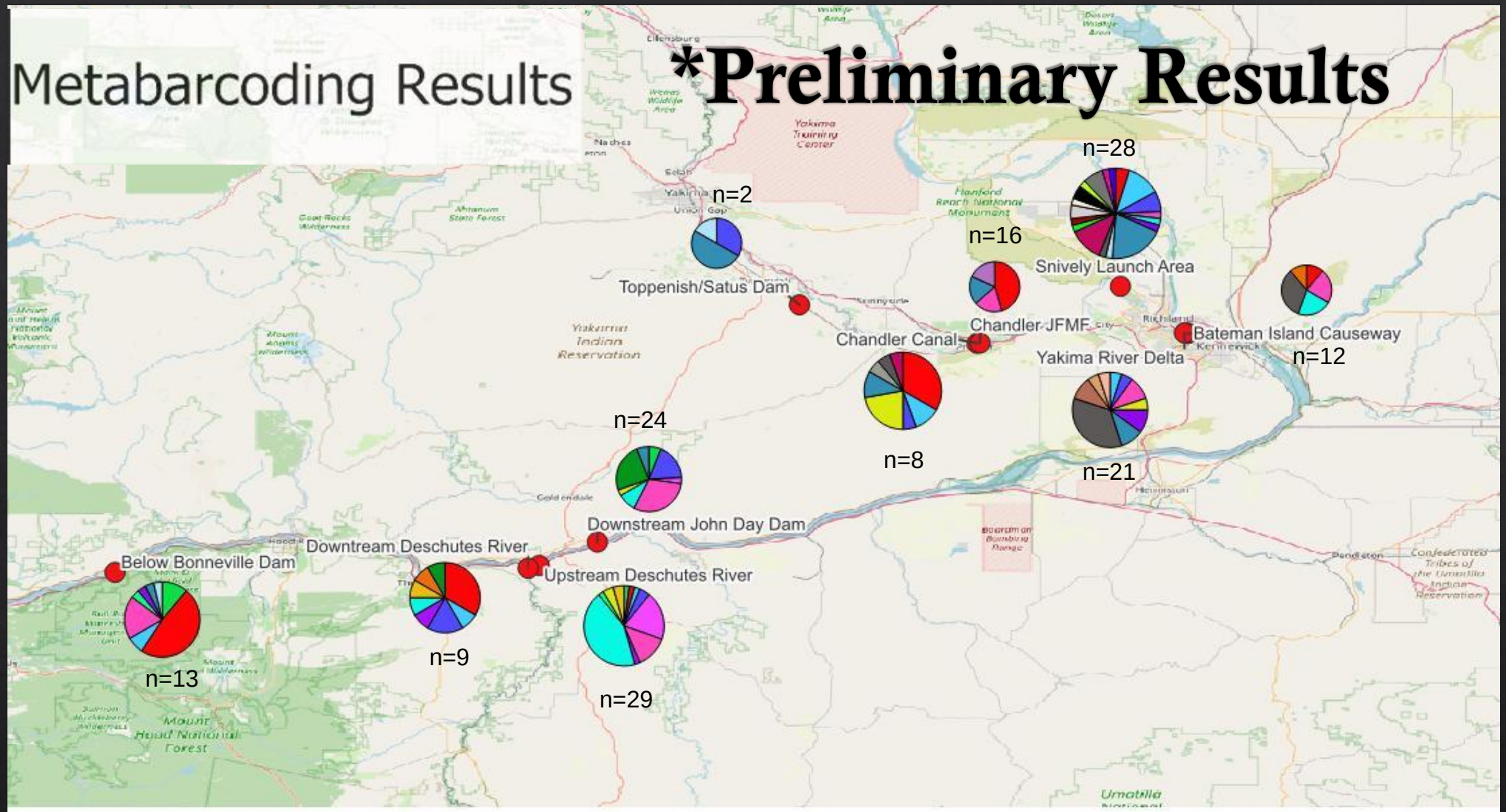
Metabarcoding Results

*Preliminary Results



Metabarcoding Results

*Preliminary Results



- Sampling Sites
- American Shad
- Chinook Salmon
- Northern Pikeminnow
- Pacific Lamprey
- Peamouth Chub
- Sculpin (Type 1)*
- Sculpin (Type 2)*
- Sucker*
- Western River/Brook Lamprey*
- Yellow Bullhead
- Yellow Perch
- Rainbow Trout/steelhead
- White Sturgeon
- Common Carp*
- Smallmouth Bass
- Walleye
- Barn Swallow
- Coho Salmon
- Mountain Whitefish
- Sunfish*
- Bluegill Sunfish
- American Beaver
- Common Starling
- Dace*
- Largemouth Bass
- Longnose/Speckled Dace*
- Mallard
- Perching Birds/Song Birds*
- Song Sparrow
- Striped Skunk
- Black/Brown Bullhead*
- Channel Catfish
- Wood Duck

SM Bass NPM Walleye Catfish LM Bass Shad Y. Perch

Common Name	Family	Scientific Name	Species Type	Species Category	Species Type Rank	# of Detection (ALL)	# of Detection (SMB)	# of Detection (NPM)	# of Detection (WAL)	# of Detection (CCF)	# of Detection (LMB)	# of Detection (AMS)	# of Detection (YP)
Chinook Salmon	Salmonidae	Oncorhynchus tshawytscha	Fish	Native	1	20%	26%	25%	12%	8%	-	-	-
Sculpin (Type 1)*	Cottoidea	Cottus spp. (Type 1)*	Fish	Native	2	17%	21%	4%	24%	8%	-	100%	-
Sucker*	Catostomidae	Catostomus spp.*	Fish	Native	3	13%	22%	-	4%	-	-	50%	100%
Coho Salmon	Salmonidae	Oncorhynchus kisutch	Fish	Native	5	7%	5%	-	-	-	62%	-	-
Pacific Lamprey	Petromyzontidae	Entosphenus tridentatus	Fish	Native	6	6%	2%	11%	20%	-	-	-	-
Northern Pikeminnow	Cyprinidae	Ptychocheilus oregonensis	Fish	Native	7	6%	9%	-	-	-	8%	-	-
White Sturgeon	Acipenseriformes	Acipenser transmontanus	Fish	Native	8	5%	-	-	28%	-	-	50%	-
Peamouth Chub	Cyprinidae	Mylocheilus caurinus	Fish	Native	10	4%	7%	-	-	-	-	-	-
Mountain Whitefish	Salmonidae	Prosopium williamsoni	Fish	Native	12	2%	1%	4%	-	17%	-	-	-
Dace*	Cyprinidae	Rhinichthys spp.*	Fish	Native	15	1%	-	7%	-	-	-	-	-
Longnose/Speckled Dace*	Cyprinidae	Rhinichthys cataractae/osculus*	Fish	Native	15	1%	-	4%	-	8%	-	-	-
Rainbow Trout/steelhead	Salmonidae	Oncorhynchus mykiss	Fish	Native	20	1%	-	-	4%	-	-	-	-
Sculpin (Type 2)*	Cottoidea	Cottus spp. (Type 2)*	Fish	Native	20	1%	-	-	-	8%	-	-	-
Western River/Brook Lamprey*	Petromyzontidae	Lampetra ayresii/richardsoni*	Fish	Native	20	1%	-	4%	-	-	-	-	-
Smallmouth Bass	Centrarchidae	Micropterus dolomieu	Fish	Non-Native	4	8%	-	32%	-	25%	-	-	-
Yellow Bullhead	Ictaluridae	Ameiurus natalis	Fish	Non-Native	8	5%	10%	-	-	-	-	-	-
American Shad	Clupeidae	Alosa sapidissima	Fish	Non-Native	11	3%	2%	11%	-	-	-	-	-
Common Carp*	Cyprinidae	Cyprinus spp.*	Fish	Non-Native	13	2%	1%	-	-	8%	8%	-	-
Walleye	Percidae	Sander vitreus	Fish	Non-Native	13	2%	-	7%	-	-	-	-	-
Black/Brown Bullhead*	Ictaluridae	Ameiurus melas/nebulosus*	Fish	Non-Native	15	1%	-	-	-	-	15%	-	-
Sunfish*	Centrarchidae	Lepomis*	Fish	Non-Native	15	1%	-	7%	-	-	-	-	-
Yellow Perch	Percidae	Perca flavescens	Fish	Non-Native	15	1%	2%	-	-	-	-	-	-
Bluegill Sunfish	Centrarchidae	Lepomis macrochirus	Fish	Non-Native	20	1%	1%	-	-	-	-	-	-
Channel Catfish	Ictaluridae	Ictalurus punctatus	Fish	Non-Native	20	1%	-	-	-	-	-	-	-
Common Starling	Sturnidae	Sturnus vulgaris	Bird	Non-Native	1	1%	-	-	-	8%	-	-	-
Perching Birds/Song Birds*	Passeriformes	Passeriformes*	Bird	-	1	1%	-	4%	-	-	-	-	-
Song Sparrow	Passerellidae	Melospiza melodia	Bird	Native	1	1%	-	-	-	8%	-	-	-
American Beaver	Castoridae	Castor canadensis	Mammal	Native	1	1%	-	4%	-	-	-	-	-
Fish	-	-	**Fish**	-	-	109%	111%	114%	92%	83%	92%	200%	100%
Bird	-	-	**Bird**	-	-	2%	0%	4%	0%	17%	0%	0%	0%
Mammal	-	-	**Mammal**	-	-	1%	0%	4%	0%	0%	0%	0%	0%
Native	-	-	**Fish**	**Native**	-	84%	94%	57%	92%	50%	69%	200%	100%
Non-Native	-	-	**Fish**	**Non-Native**	-	25%	17%	57%	0%	33%	23%	0%	0%
% Native			**Fish**	-	-	77%	84%	50%	100%	60%	75%	100%	100%
Total Detection	-	-	-	-	-	111%	111%	121%	92%	100%	92%	200%	100%
Predator Fish Sample Size	-	-	-	-	-	162	81	28	25	12	13	2	1

SM Bass NPM Walleye Catfish LM Bass Shad Y. Perch

Common Name	Family	Scientific Name	Species Type	Species Category	Species Type Rank	Cumulative Quantitative Count (ALL)	Cumulative Quantitative Count (SMB)	Cumulative Quantitative Count (NPM)	Cumulative Quantitative Count (WAL)	Cumulative Quantitative Count (CCF)	Cumulative Quantitative Count (LMB)	Cumulative Quantitative Count (AMS)	Cumulative Quantitative Count (YP)
Sculpin (Type 1)*	Cottoidea	Cottus spp. (Type 1)*	Fish	Native	1	841177	622683	573	174826	10360	0	32735	0
Chinook Salmon	Salmonidae	Oncorhynchus tshawytscha	Fish	Native	2	492230	199257	208925	80376	3672	0	0	0
Pacific Lamprey	Petromyzontidae	Entosphenus tridentatus	Fish	Native	3	371028	3588	22846	344594	0	0	0	0
Coho Salmon	Salmonidae	Oncorhynchus kisutch	Fish	Native	4	299533	83619	0	0	0	215914	0	0
Sucker*	Catostomidae	Catostomus spp.*	Fish	Native	6	161317	141566	0	2996	0	0	5673	11082
Mountain Whitefish	Salmonidae	Prosopium williamsoni	Fish	Native	7	150696	42085	35685	0	72926	0	0	0
White Sturgeon	Acipenseriformes	Acipenser transmontanus	Fish	Native	9	67740	0	0	66312	0	0	1428	0
Northern Pikeminnow	Cyprinidae	Ptychocheilus oregonensis	Fish	Native	12	36859	12293	0	0	0	2618	0	0
Dace*	Cyprinidae	Rhinichthys spp.*	Fish	Native	15	28753	0	28753	0	0	0	0	0
Peamouth Chub	Cyprinidae	Mylocheilus caurinus	Fish	Native	16	22922	22922	0	0	0	0	0	0
Rainbow Trout/steelhead	Salmonidae	Oncorhynchus mykiss	Fish	Native	19	14981	0	0	14981	0	0	0	0
Longnose/Speckled Dace*	Cyprinidae	Rhinichthys cataractae/osculus*	Fish	Native	20	12659	0	11972	0	687	0	0	0
Sculpin (Type 2)*	Cottoidea	Cottus spp. (Type 2)*	Fish	Native	22	2397	0	0	0	2397	0	0	0
Western River/Brook Lamprey*	Petromyzontidae	Lampetra ayresii/richardsoni*	Fish	Native	23	1363	0	1363	0	0	0	0	0
Yellow Bullhead	Ictaluridae	Ameiurus natalis	Fish	Non-Native	5	201404	201404	0	0	0	0	0	0
American Shad	Clupeidae	Alosa sapidissima	Fish	Non-Native	8	95471	64998	30473	0	0	0	0	0
Sunfish*	Centrarchidae	Lepomis*	Fish	Non-Native	10	63415	0	63415	0	0	0	0	0
Smallmouth Bass	Centrarchidae	Micropterus dolomieu	Fish	Non-Native	11	41894	0	22581	0	14086	0	0	0
Yellow Perch	Percidae	Perca flavescens	Fish	Non-Native	13	32637	32637	0	0	0	0	0	0
Black/Brown Bullhead*	Ictaluridae	Ameiurus melas/nebulosus*	Fish	Non-Native	14	29601	0	0	0	0	29601	0	0
Channel Catfish	Ictaluridae	Ictalurus punctatus	Fish	Non-Native	17	18069	0	0	0	0	0	0	0
Walleye	Percidae	Sander vitreus	Fish	Non-Native	18	16597	0	4456	0	0	0	0	0
Common Carp*	Cyprinidae	Cyprinus spp.*	Fish	Non-Native	21	5288	877	0	0	2634	1777	0	0
Bluegill Sunfish	Centrarchidae	Lepomis macrochirus	Fish	Non-Native	24	1159	1159	0	0	0	0	0	0
Song Sparrow	Passerellidae	Melospiza melodia	Bird	Native	1	7807	0	0	0	7807	0	0	0
Perching Birds/Song Birds*	Passeriformes	Passeriformes*	Bird	-	2	1113	0	1113	0	0	0	0	0
Common Starling	Sturnidae	Sturnus vulgaris	Bird	Non-Native	3	812	0	0	0	812	0	0	0
American Beaver	Castoridae	Castor canadensis	Mammal	Native	1	1681	0	1681	0	0	0	0	0
Fish	-	-	**Fish**	-	-	**3009190**	**1429088**	**431042**	**684085**	**106762**	**249910**	**39836**	**11082**
Bird	-	-	**Bird**	-	-	**9732**	**0**	**1113**	**0**	**8619**	**0**	**0**	**0**
Mammal	-	-	**Mammal**	-	-	**1681**	**0**	**1681**	**0**	**0**	**0**	**0**	**0**
Native	-	-	**Fish**	**Native**	-	**2503655**	**1128013**	**310117**	**684085**	**90042**	**218532**	**39836**	**11082**
Non-Native	-	-	**Fish**	**Non-Native**	-	**505535**	**301075**	**120925**	**0**	**16720**	**31378**	**0**	**0**
% Native			**Fish**	-	-	**83%**	**79%**	**72%**	**100%**	**84%**	**87%**	**100%**	**100%**
Total Count	-	-	-	-	-	**3020603**	**1429088**	**433836**	**684085**	**115381**	**249910**	**39836**	**11082**
Predator Fish Sample Size	-	-	-	-	-	**162**	**81**	**28**	**25**	**12**	**13**	**2**	**1**
Count per Sample			-	-	-	**18646**	**17643**	**15494**	**27363**	**9615**	**19224**	**19918**	**11082**

Metabarcoding vs. eDNA qPCR

NPM Catfish Shad

SM Bass Walleye LM Bass Y. Perch

All Sample

Prey Species	Total Metabarcoding	Samples Excluded (Value <500)	Metabarcoding Positives ALL	SMB	NPM	WALL	CCF	LMB	AMS	YP	Metabarcoding % Positives Mean	SMB	NPM	WAL	CCF	LMB	AMS	YP
Overall Sample #	**972**	**9**	**162**	**81**	**28**	**25**	**12**	**13**	**2**	**1**	-	-	-	-	-	-	-	-
Pacific Lamprey	162	7	10	2	3	5	0	0	0	0	6.2%	2.5%	10.7%	20.0%	0.0%	0.0%	0.0%	0.0%
RBT/steelhead	162	0	1	0	0	1	0	0	0	0	0.6%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%
Total Positives (PL/RBT)	-	-	**11**	**2**	**3**	**6**	**0**	**0**	**0**	**0**	**3.4%**	**1.2%**	**5.4%**	**12.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Prey Species	Total qPCR	-	qPCR Positives ALL	SMB	NPM	WALL	CCF	LMB	AMS	YP	qPCR % Positives Mean	SMB	NPM	WAL	CCF	LMB	AMS	YP
Overall Sample #	**324**	-	**162**	**81**	**28**	**25**	**12**	**13**	**2**	**1**	-	-	-	-	-	-	-	-
Pacific Lamprey	162	-	18	6	4	7	0	0	0	1	11.1%	7.4%	14.3%	28.0%	0.0%	0.0%	0.0%	100%
RBT/steelhead	162	-	25	13	7	2	2	0	1	0	15.4%	16.0%	25.0%	8.0%	16.7%	0.0%	50.0%	0.0%
Total Positives (PL/RBT)	-	-	**43**	**19**	**11**	**9**	**2**	**0**	**1**	**1**	**13.3%**	**11.7%**	**19.6%**	**18.0%**	**8.3%**	**0.0%**	**25.0%**	**50.0%**

	Detection Ratio of qPCR vs. metabarcoding							
Pacific Lamprey	180%	300%	133%	140%	-	-	-	-
RBT/steelhead	2500%	NA	NA	200%	-	-	-	-
Average (2 Species)	391%	950%	367%	150%	-	-	-	-

Metabarcoding vs. eDNA qPCR

NPM Catfish Shad
SM Bass Walleye LM Bass Y. Perch

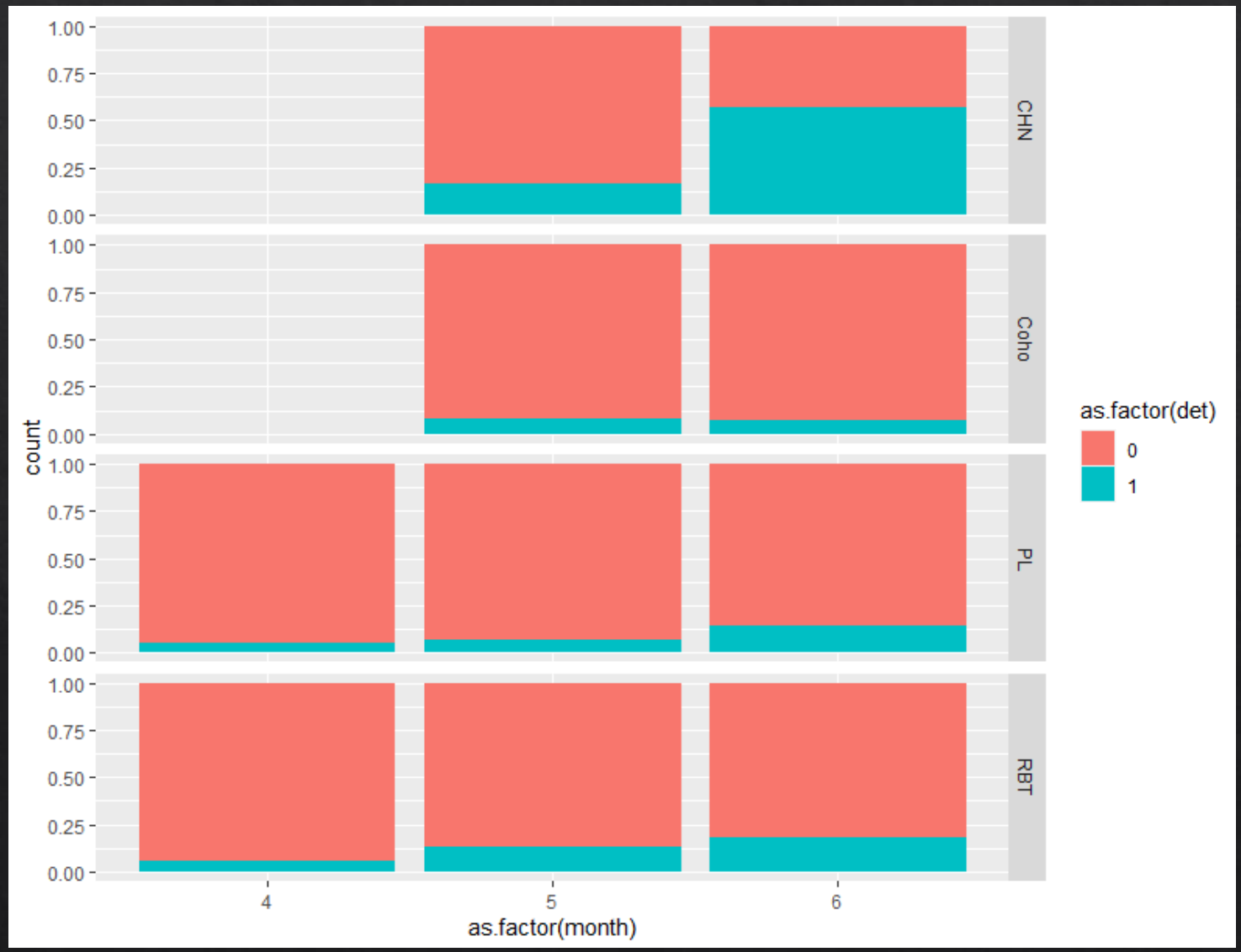
Subsample

Prey Species	Total Metabarcoding	Metabarcoding Positives ALL	SMB	NPM	WALL	CCF	LMB	AMS	YP	Metabarcoding % Positives Mean	SMB	NPM	WAL	CCF	LMB	AMS	YP
Overall Sample #	**104**	**26**	**6**	**7**	**6**	**7**	-	-	-	-	-	-	-	-	-	-	-
Pacific Lamprey	26	3	0	1	2	0	-	-	-	11.5%	0.0%	14.3%	33.3%	0.0%	-	-	-
RBT/steelhead	26	1	0	0	1	0	-	-	-	3.8%	0.0%	0.0%	16.7%	0.0%	-	-	-
Chinook	26	6	2	0	3	1	-	-	-	23.1%	33.3%	0.0%	50.0%	14.3%	-	-	-
Coho	26	1	1	0	0	0	-	-	-	3.8%	16.7%	0.0%	0.0%	0.0%	-	-	-
Total Positives (ALL)	-	**11**	**3**	**1**	**6**	**1**	-	-	-	**10.6%**	**12.5%**	**3.6%**	**25.0%**	**3.6%**	-	-	-

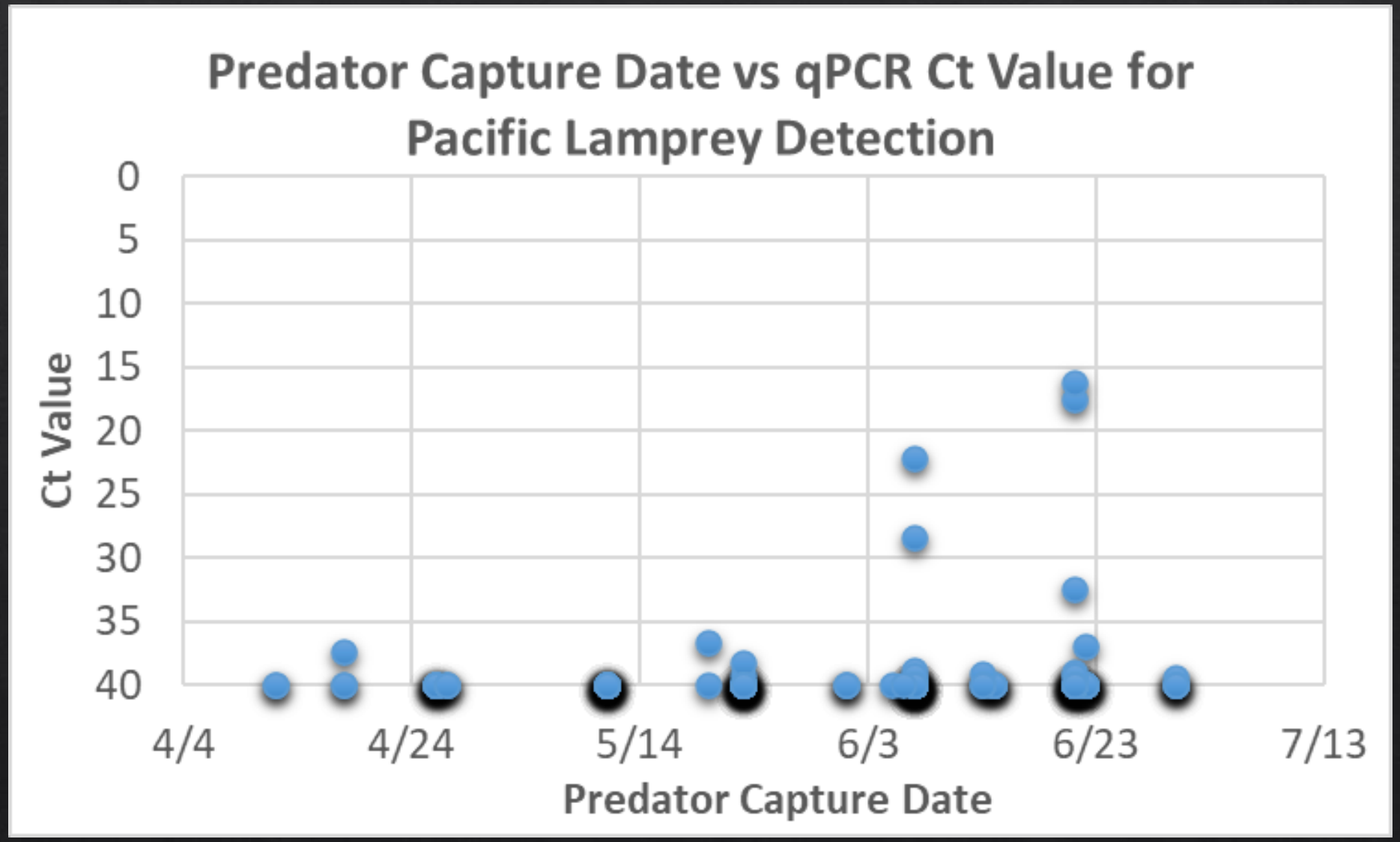
Prey Species	Total qPCR	qPCR Positives ALL	SMB	NPM	WALL	CCF	LMB	AMS	YP	qPCR % Positives Mean	SMB	NPM	WAL	CCF	LMB	AMS	YP
Overall Sample #	**104**	**26**	**6**	**7**	**6**	**7**	-	-	-	-	-	-	-	-	-	-	-
Pacific Lamprey	26	4	0	2	2	0	-	-	-	15.4%	0.0%	28.6%	33.3%	0.0%	-	-	-
RBT/steelhead	26	8	1	3	2	2	-	-	-	30.8%	16.7%	42.9%	33.3%	28.6%	-	-	-
Chinook	26	10	3	2	4	1	-	-	-	38.5%	50.0%	28.6%	66.7%	14.3%	-	-	-
Coho	26	2	1	1	0	0	-	-	-	7.7%	16.7%	14.3%	0.0%	0.0%	-	-	-
Total Positives (ALL)	-	**24**	**5**	**8**	**8**	**3**	-	-	-	**23.1%**	**20.8%**	**28.6%**	**33.3%**	**10.7%**	-	-	-

	Detection Ratio of qPCR vs.				
Pacific Lamprey	133%	-	200%	100%	-
RBT/steelhead	800%	-	-	200%	-
Chinook	167%	150%	-	133%	100%
Coho	200%	100%	-	-	-
Average (4 Species)	218%	167%	800%	133%	300%
Average (Salmonids)	250%	167%	-	150%	300%

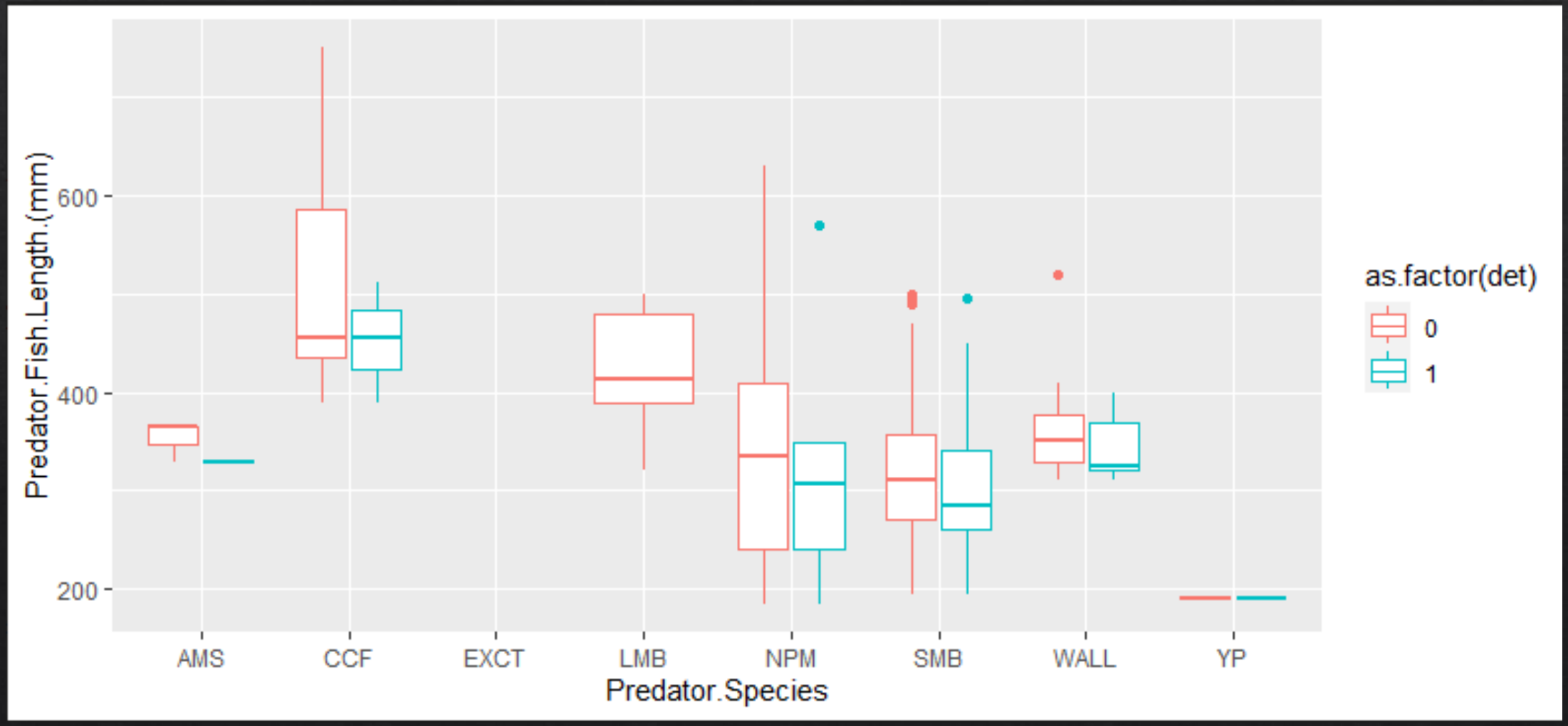
% Detection by Month (x-axis) & Prey Species (y-axis)



More Details on Timing/Season



Size of Predator Fishes with & without PL Detection



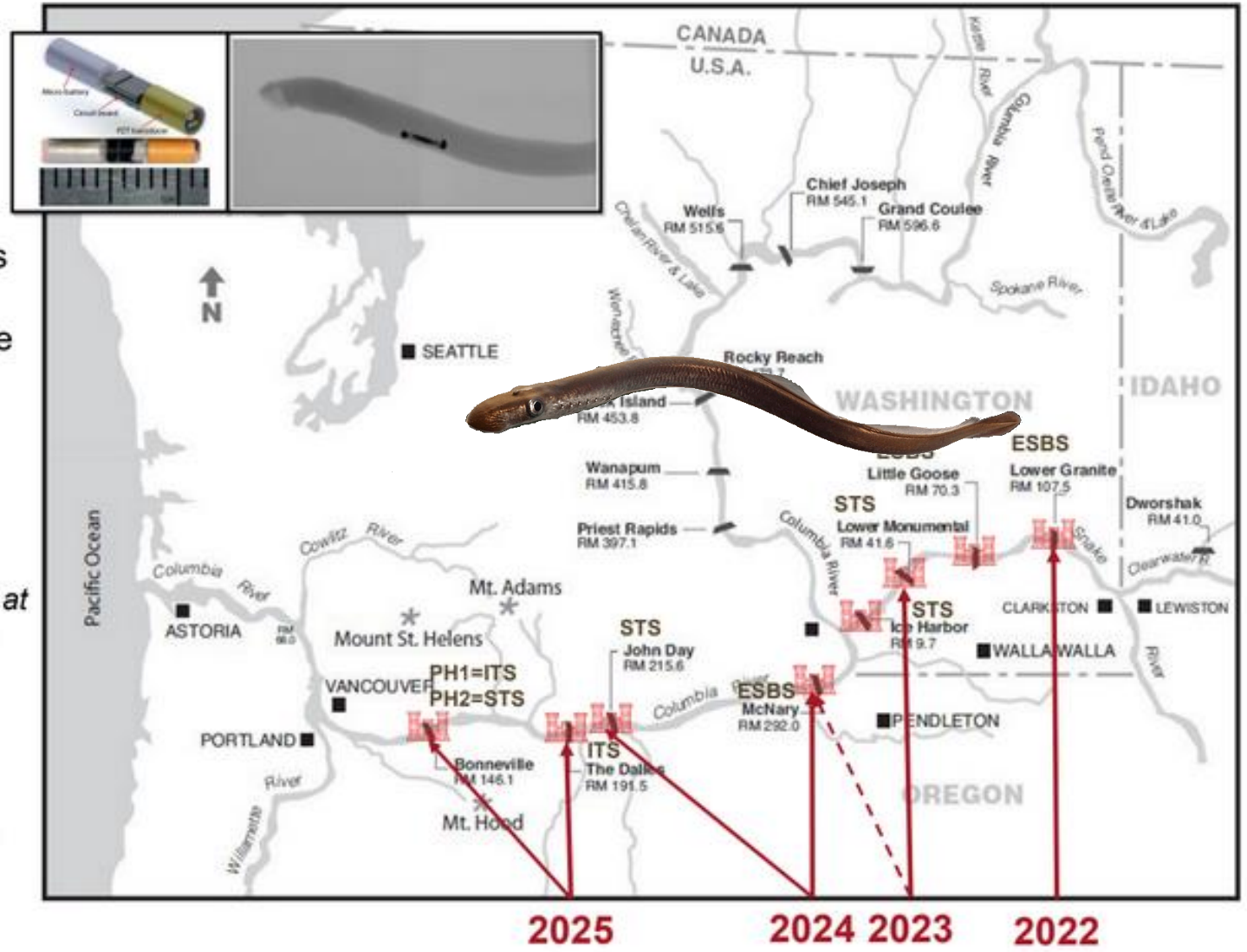
JUVENILE LAMPREY RM&E

Mainstem Passage

1. Juvenile Lamprey Acoustic Transmitter (JLAT) development
   - ✓ Developed 2014-2017 with USACE funding
   - ✓ 2 mm diameter x 12 mm length, weighs 0.08 g in air
   - ✓ lasts about 30 days at a 3-second pulse rate

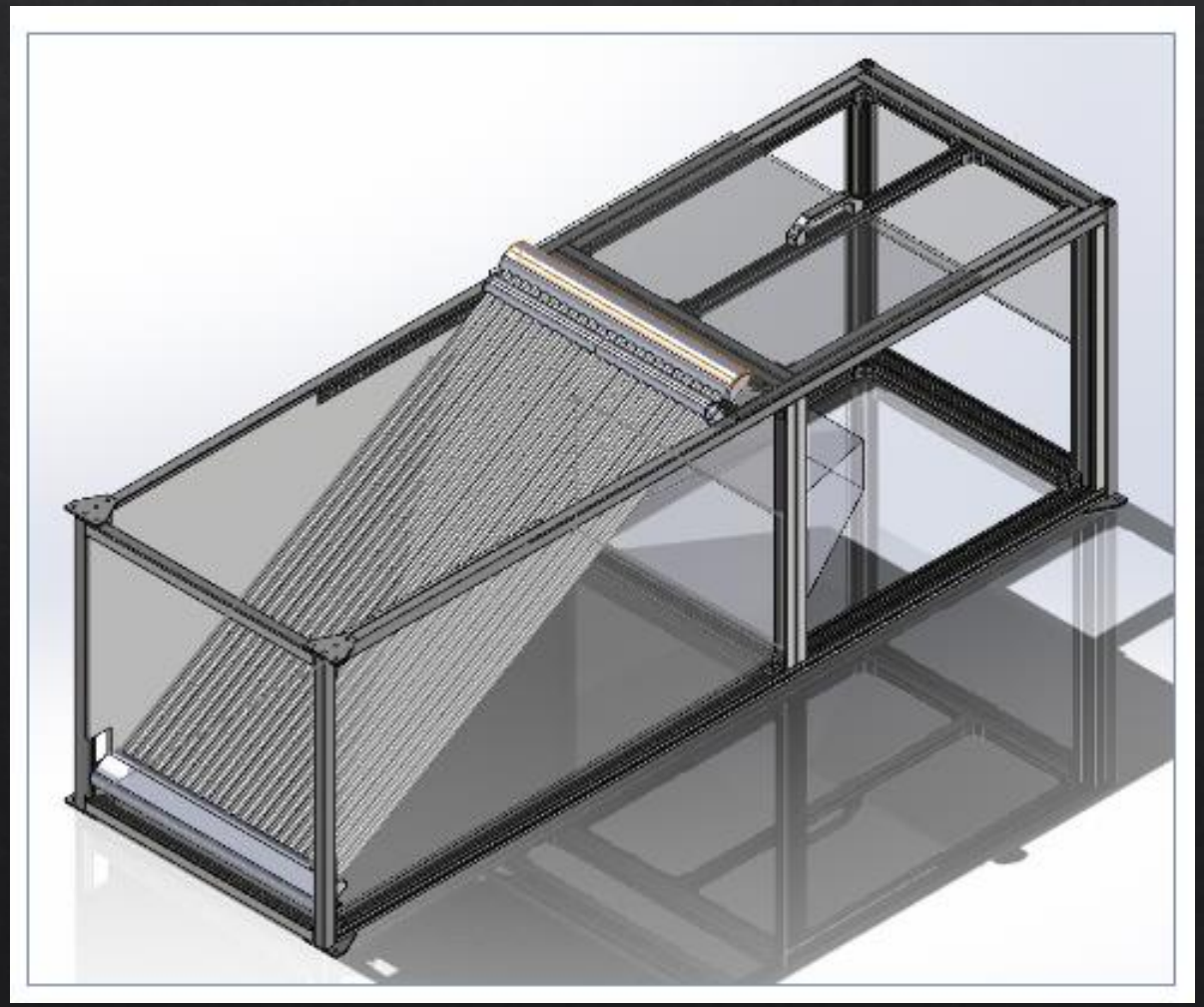
2. Juvenile Lamprey RM&E plan development and implementation
   - ❑ plan development in 2021

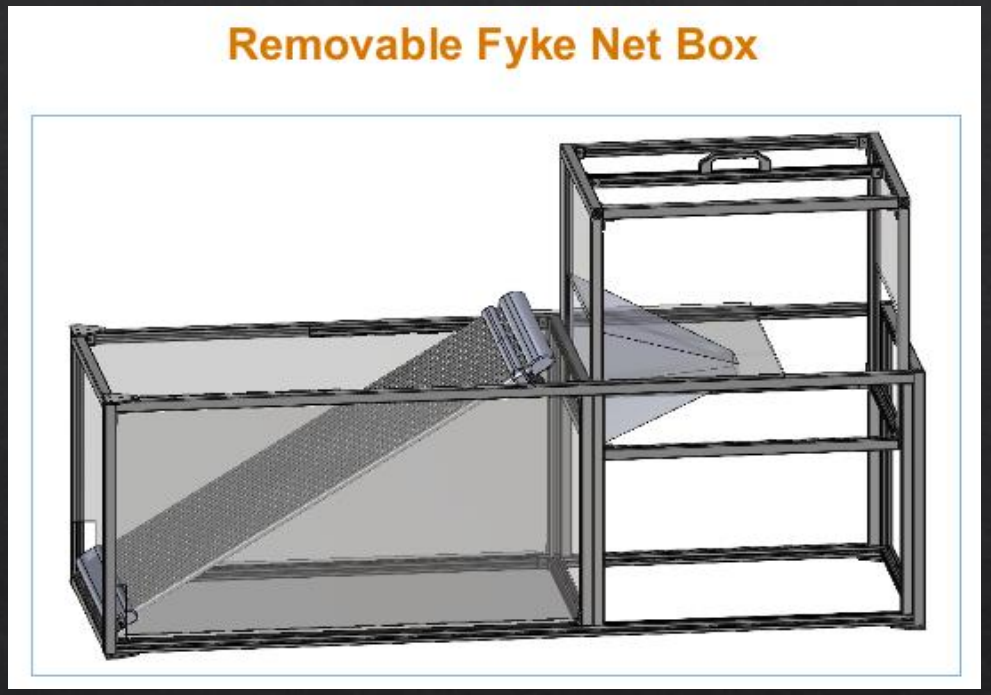
   focus on potential structural/operational changes at the FCRPS dams to improve passage conditions for juvenile lamprey
   - ❑ 4-year study 2022-2025
   - ❑ 1st year pilot study at LWG in 2022
   - ❑ 4th year study including BON in 2025 (coincident with post-construction adult lamprey passage evaluation)

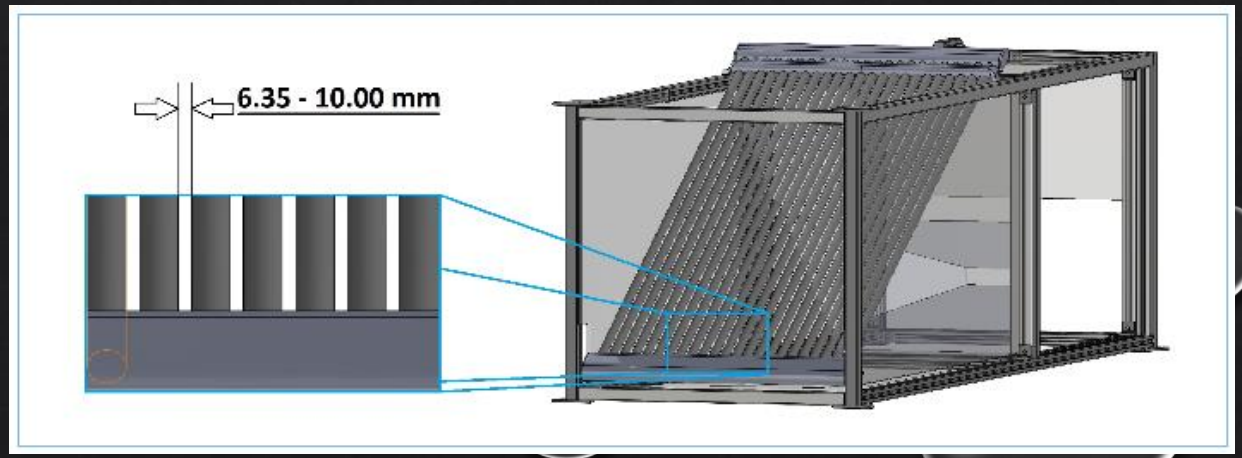


Credit: U.S. Army Corps of Engineers

Juvenile Trap Design (PNNL / CRITFC Tribes)







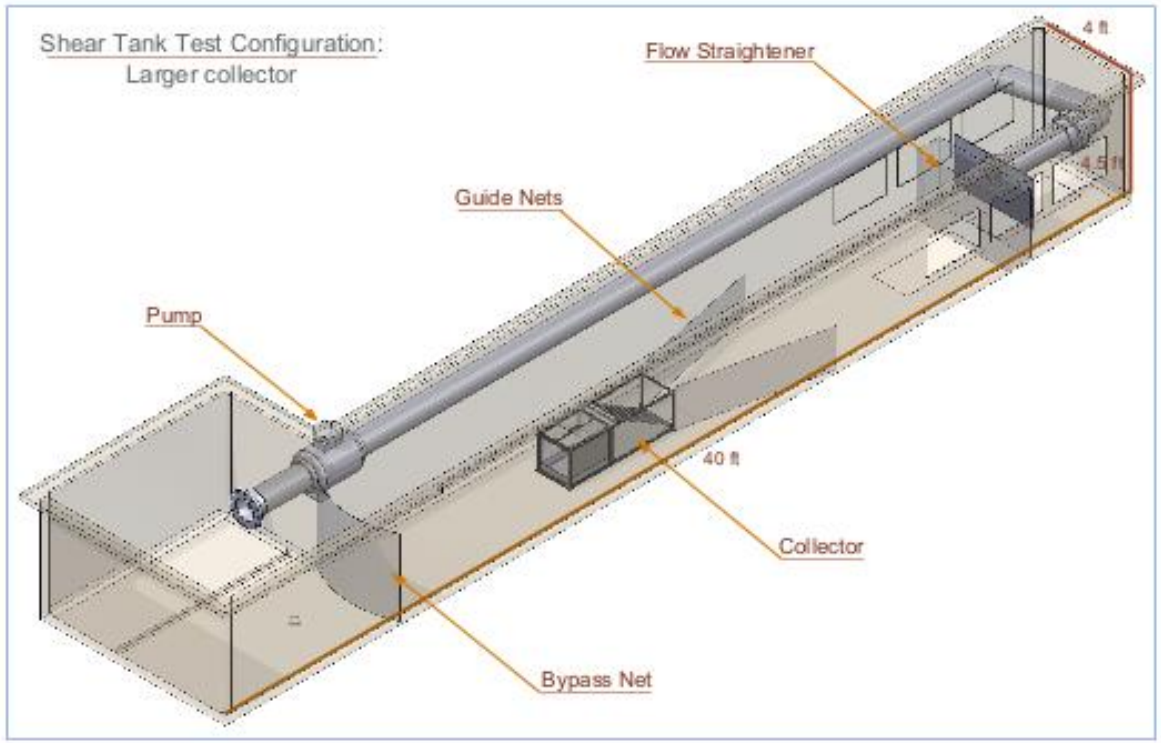
Testing with Salmonids (2024) & Potential Deployment Locations

Pacific Northwest NATIONAL LABORATORY

Shear Tank Configuration for Collector Testing - Larger Collector

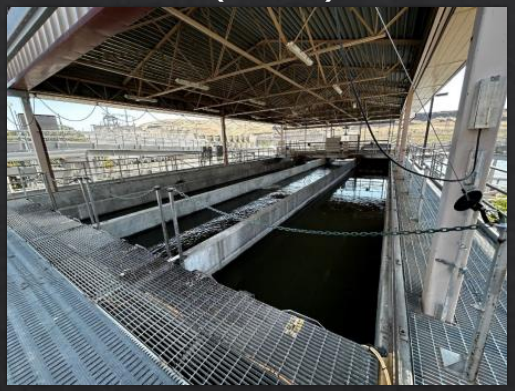
Features:

- Fiberglass shear tank
- Flow straightener
- Bypass net
- Digitally controlled pump for variable flow & velocity



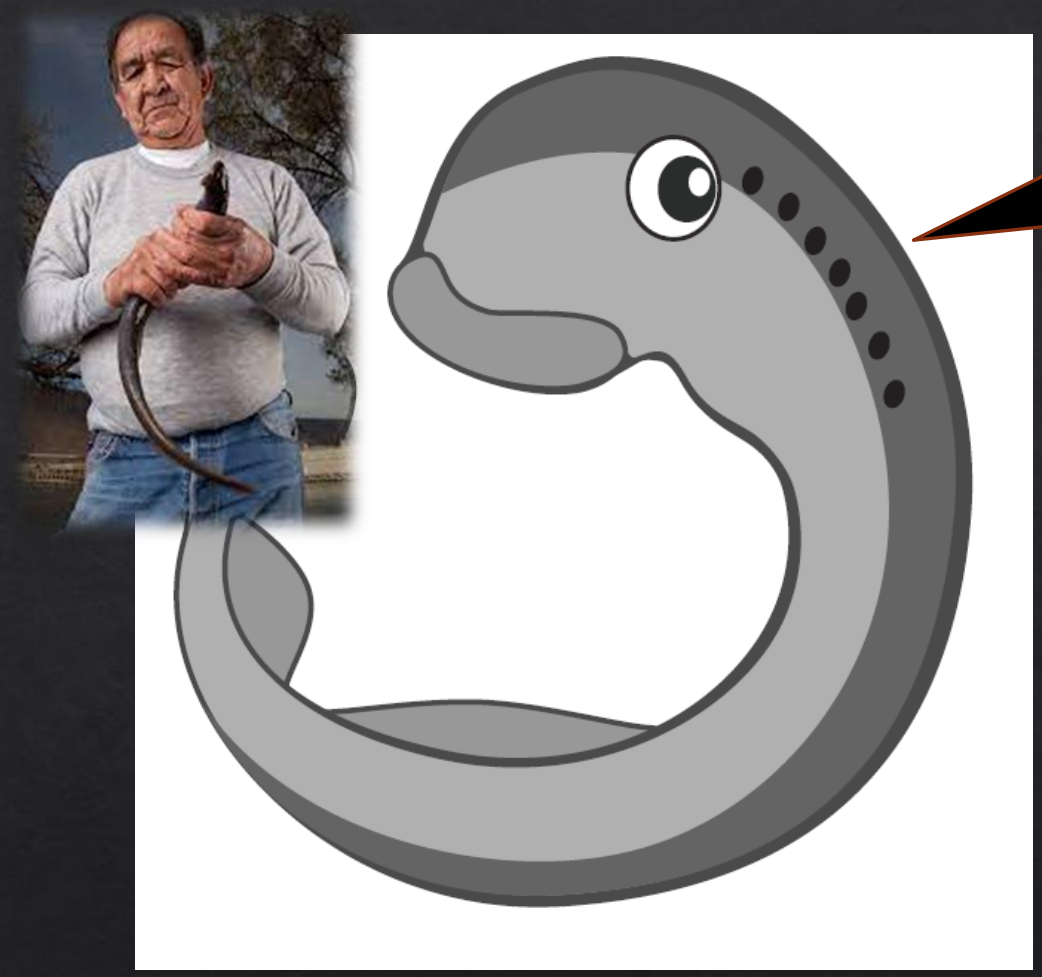
2ndary bypass flume (MCN)

Raceways (LMN)



Separator at juvenile bypass system (MCN)

"Spiritually he is one of us" (Elmer Crow)



Questions?

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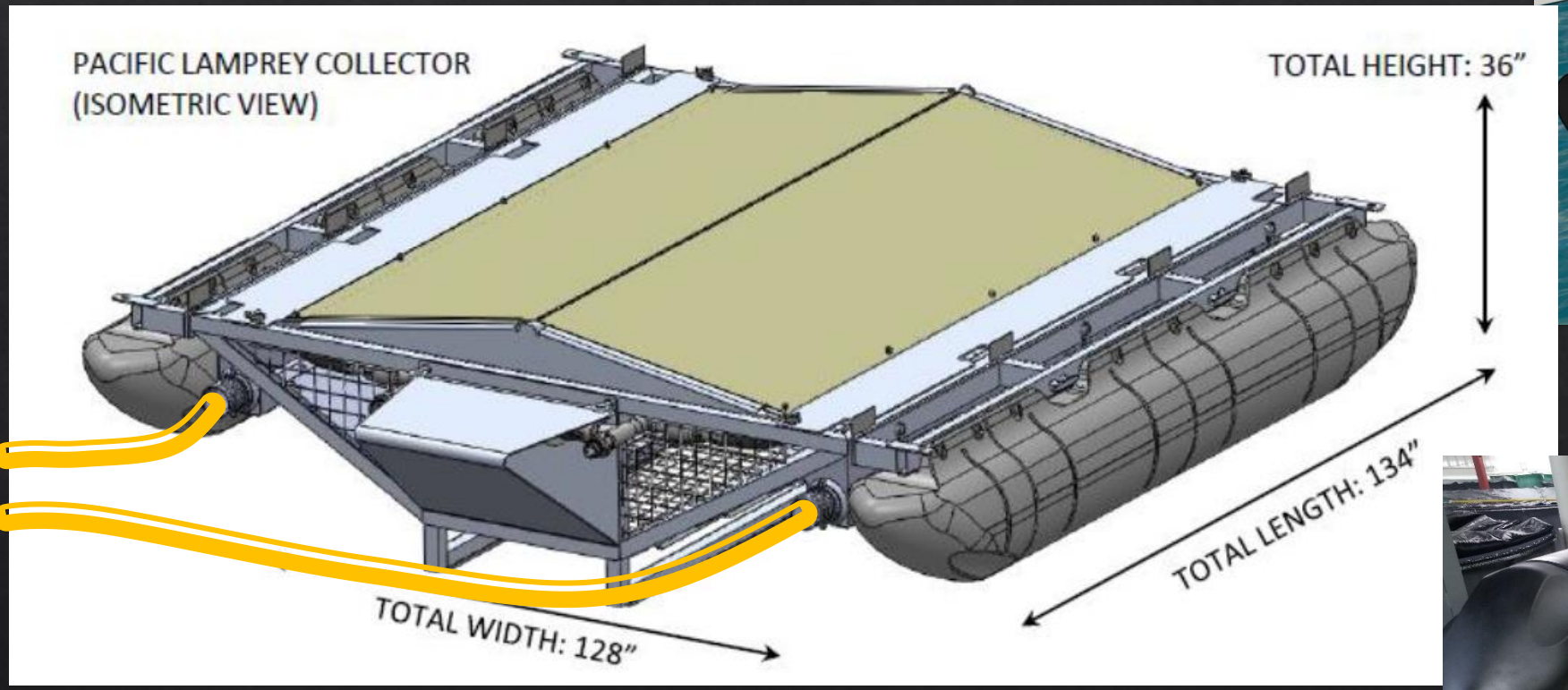
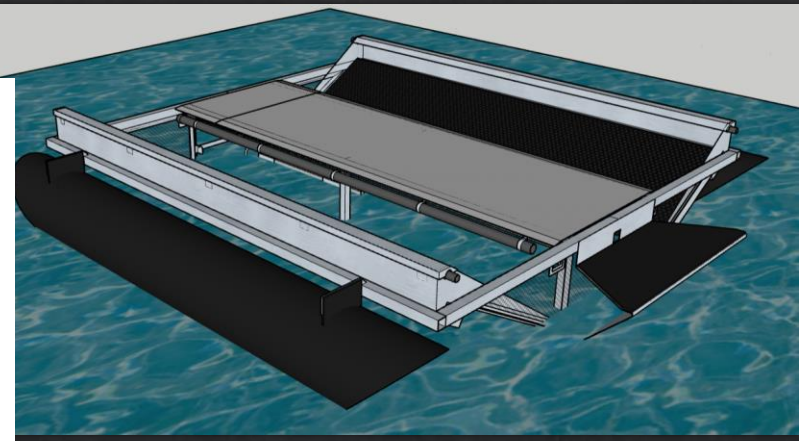
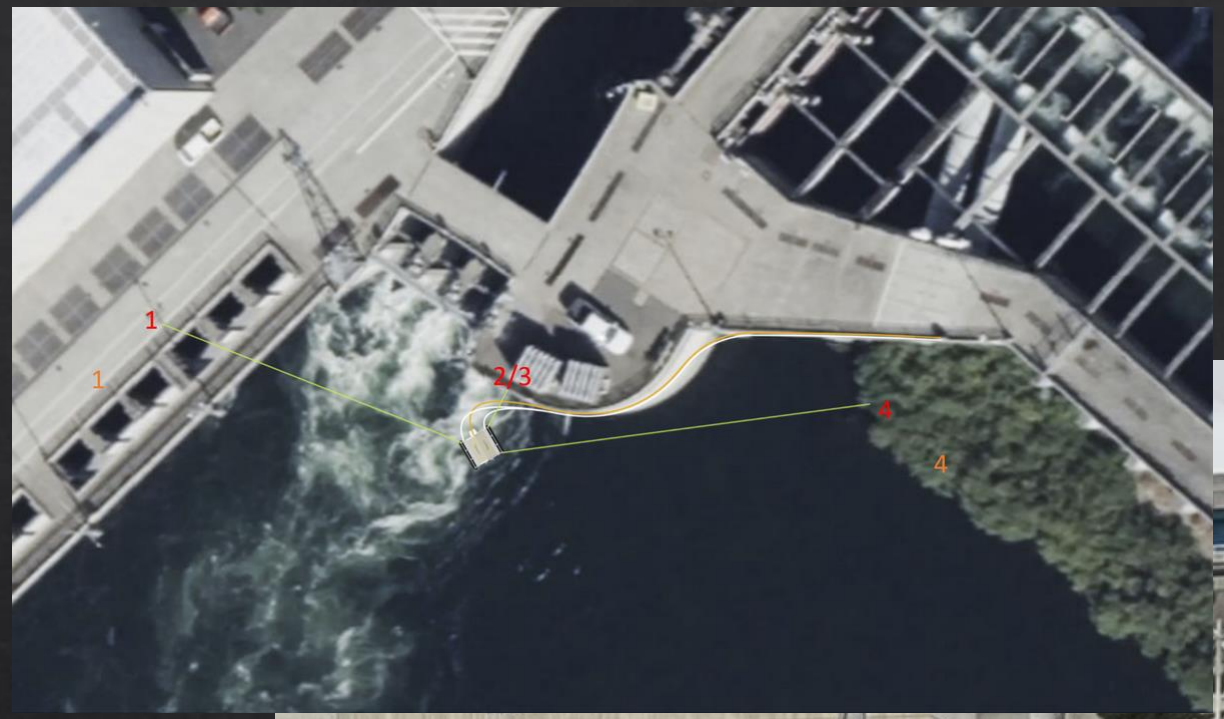
Portable Floating Surface Collector (PFSC) (PLCI Funding)

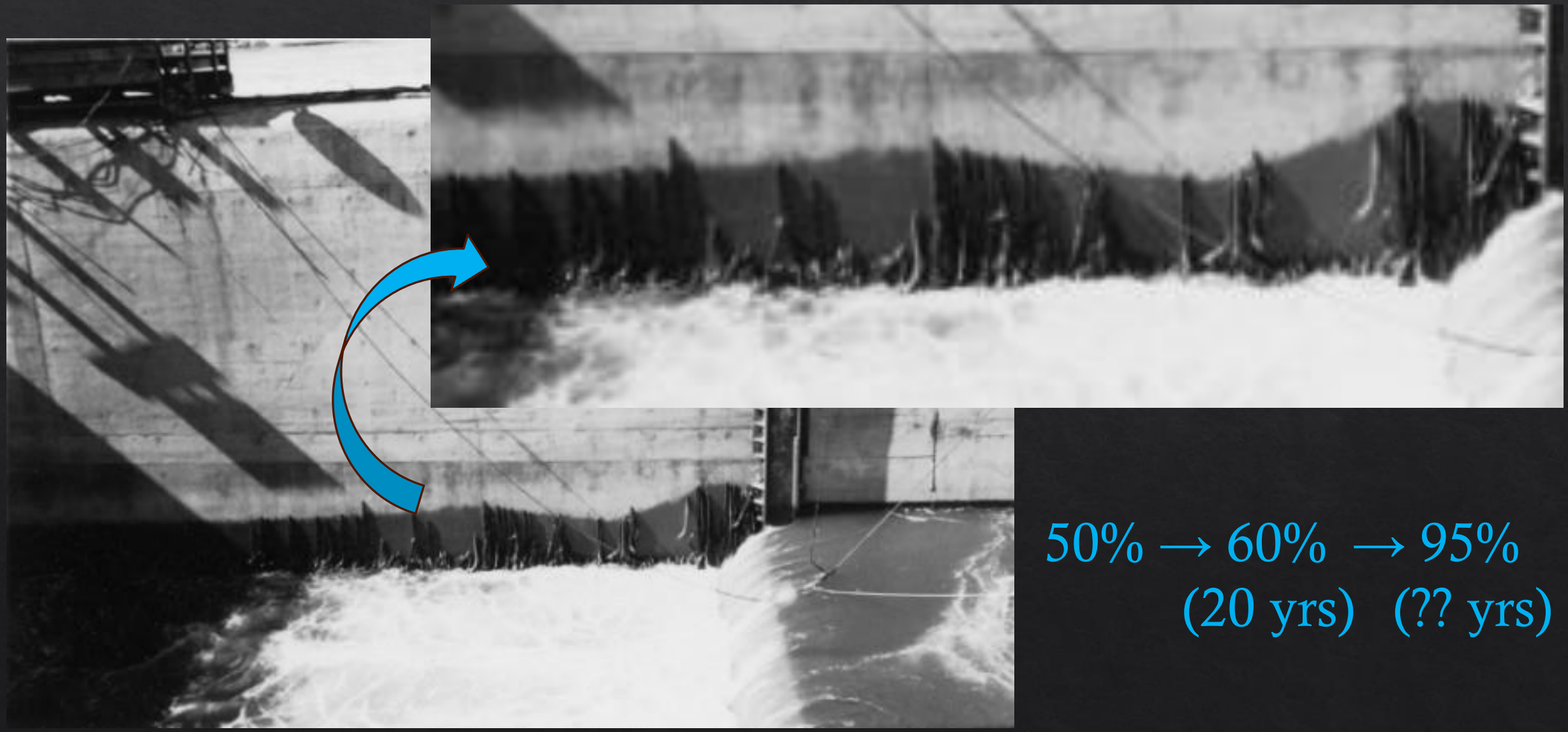




The Dalles Dam (East Entrance)



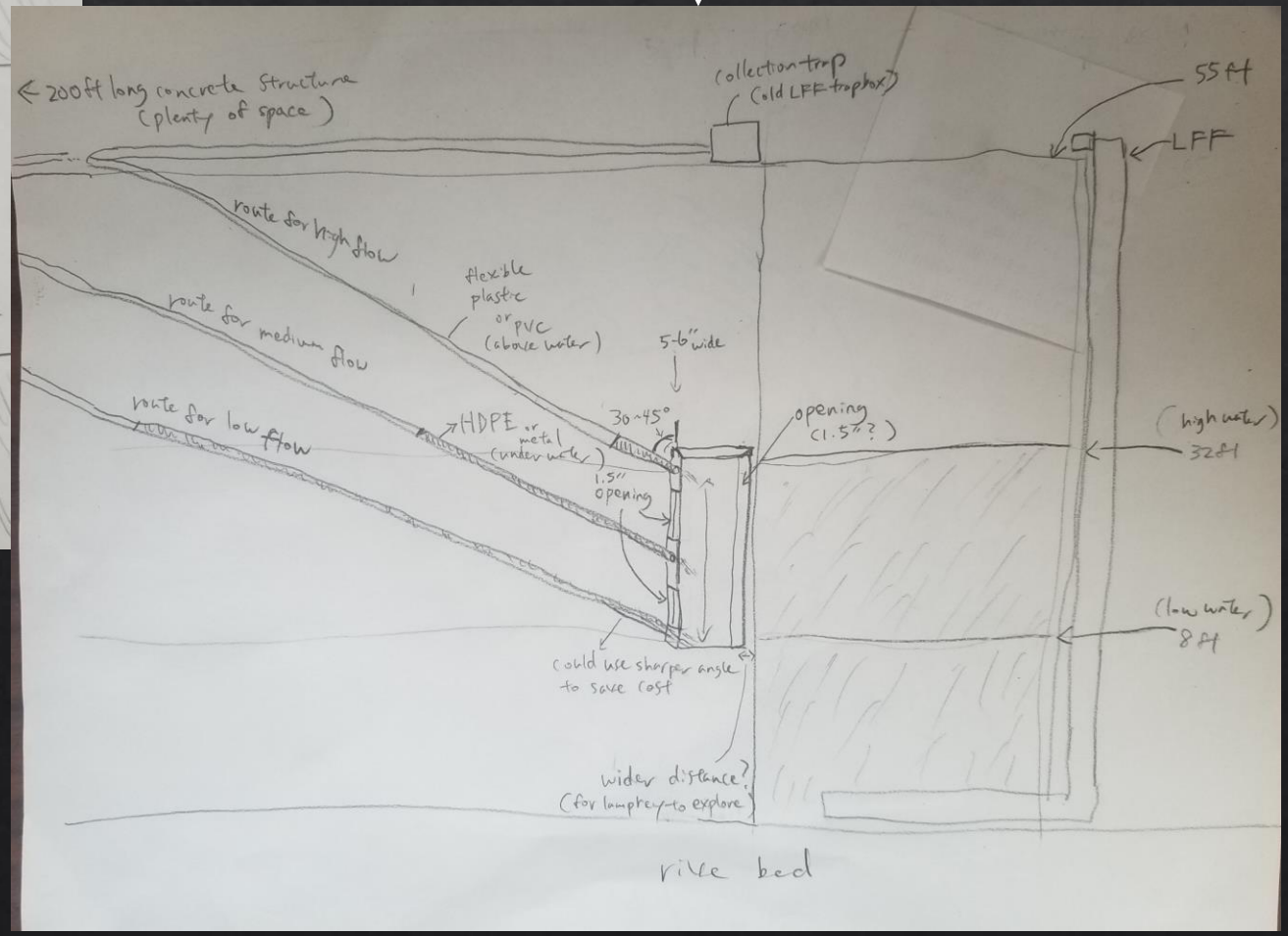
Bonneville Dam Temp. Fish Ladder (7/2/1937)



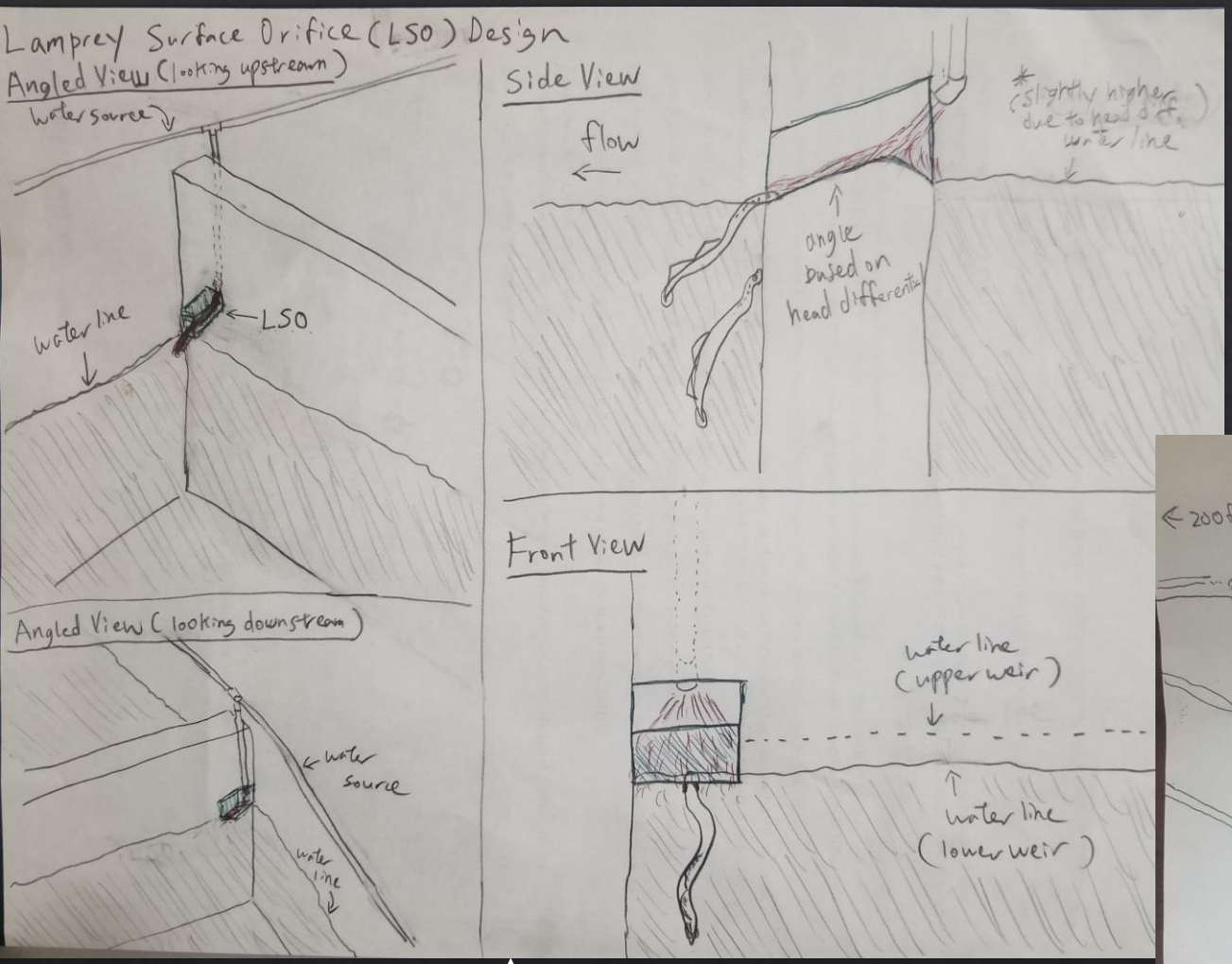
50% → 60% → 95%
(20 yrs) (?? yrs)

Mechanical Traps in Fish Ladder (need these in Lower Columbia dams!)

Lamprey Entrance Structure (LES) [Using 4” Tubes]



Lamprey Surface Orifice (LSO) in ladders



Hess et al. 2023 Paper

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SPECIAL SECTION

Native Lampreys: Research and Conservation of Ancient Fishes

The return of the adult Pacific Lamprey offspring from translocations to the Columbia River

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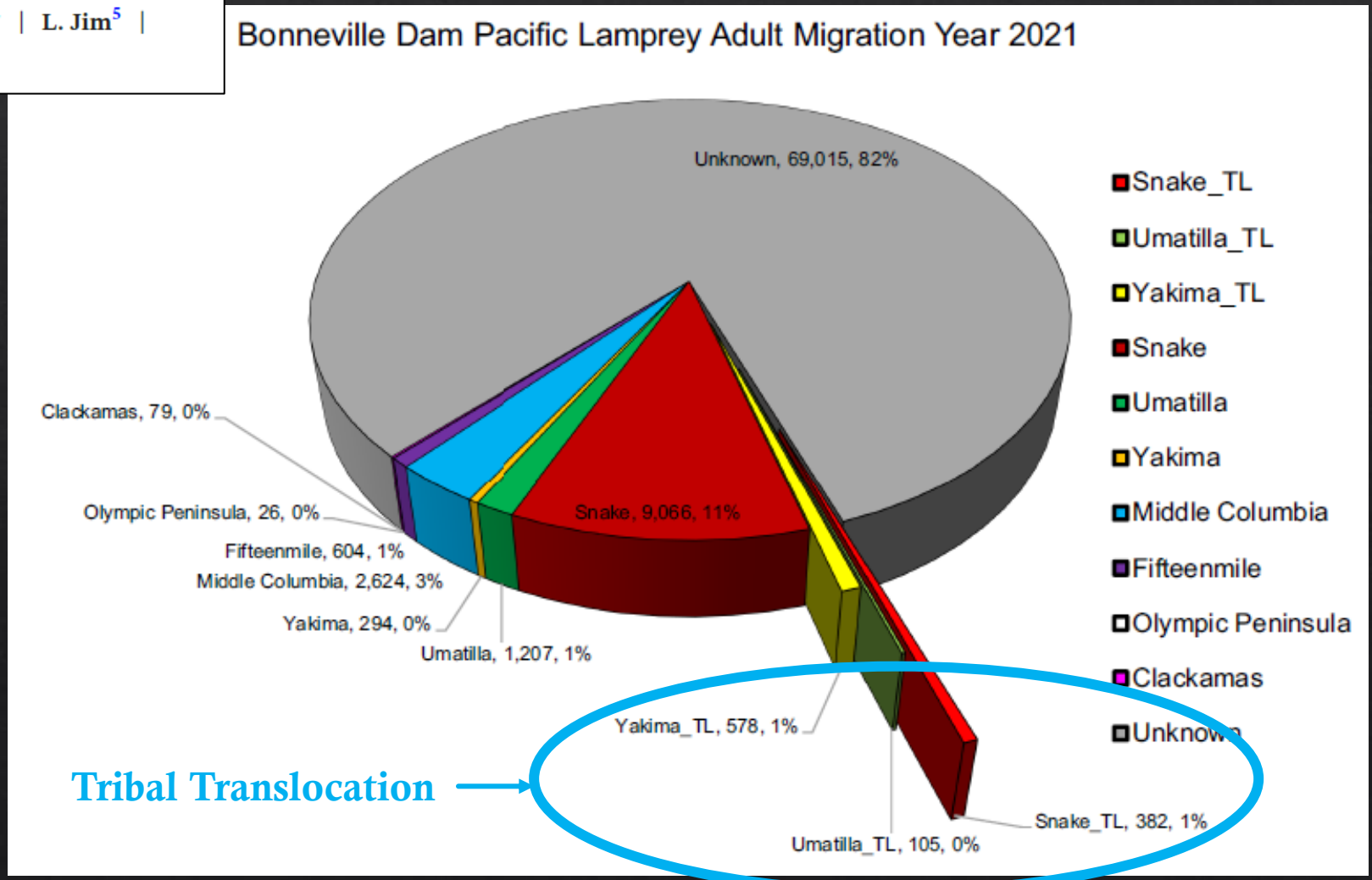
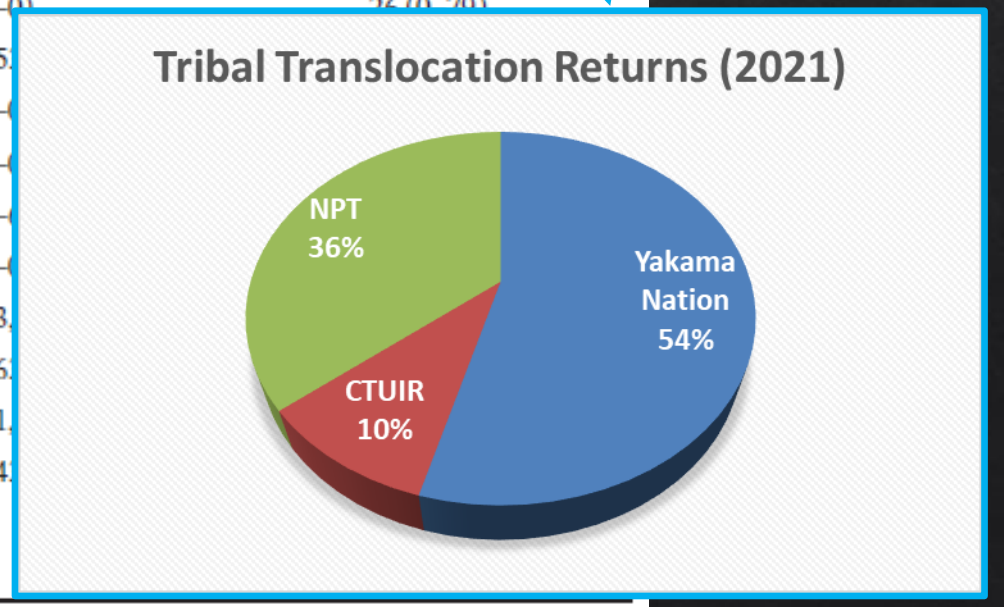


TABLE 1 Estimated stock composition of adult Pacific Lamprey at Bonneville Dam (2019–2021). Translocation programs within the three river basins (Snake, Umatilla, and Yakima rivers; indicated by "_TL") comprise the abundance of translocation adults at Bonneville Dam. The middle Columbia River is represented by juveniles from the John Day Dam juvenile bypass in the sibship baseline. Adults that were unassigned to the sibship baseline are listed based on the dam at which they were collected (i.e., Bonneville Dam, John Day Dam, mixed dams, and The Dalles Dam, respectively).

	2019 Estimate	2020 Estimate	2021 Estimate
Stock			
Snake River_TL	0 (0–0)	100 (0–328)	382 (159–665)
Umatilla River_TL	0 (0–0)	0 (0–0)	105 (0–237)
Yakima River_TL	0 (0–0)	23 (0–91)	578 (282–924)
Translocation subtotal	0	123	1065
Umatilla River	0 (0–0)	22 (0–67)	1207 (919–1522)
Middle Columbia River	174 (70–313)	135 (45–224)	2624 (2204–3044)
Fifteenmile Creek	0 (0–0)	22 (0–67)	604 (394–814)
Olympic Peninsula	0 (0–0)	0 (0–	26 (0–79)
Snake River	5634 (4973–6330)	1854 (15	
Clackamas River	0 (0–0)	0 (0–	
Yakima River	0 (0–0)	0 (0–	
Klickitat River	35 (0–104)	22 (0–	
Pacific Ocean	35 (0–104)	0 (0–	
Bonneville Dam	51,854 (50,704–52,897)	14,252 (13	
John Day Dam	3826 (3269–4417)	988 (76	
Mixed dams	313 (139–487)	22,690 (21	
The Dalles Dam	9007 (8138–9877)	1796 (14	
Volitional subtotal	70,878	41,781	
Grand total	70,878	41,904	



Adult Translocation (Reality Check)