Evaluating Spring Chinook Salmon Releases Above Foster Dam, On The South Santiam River, Using Genetic Parentage Analysis

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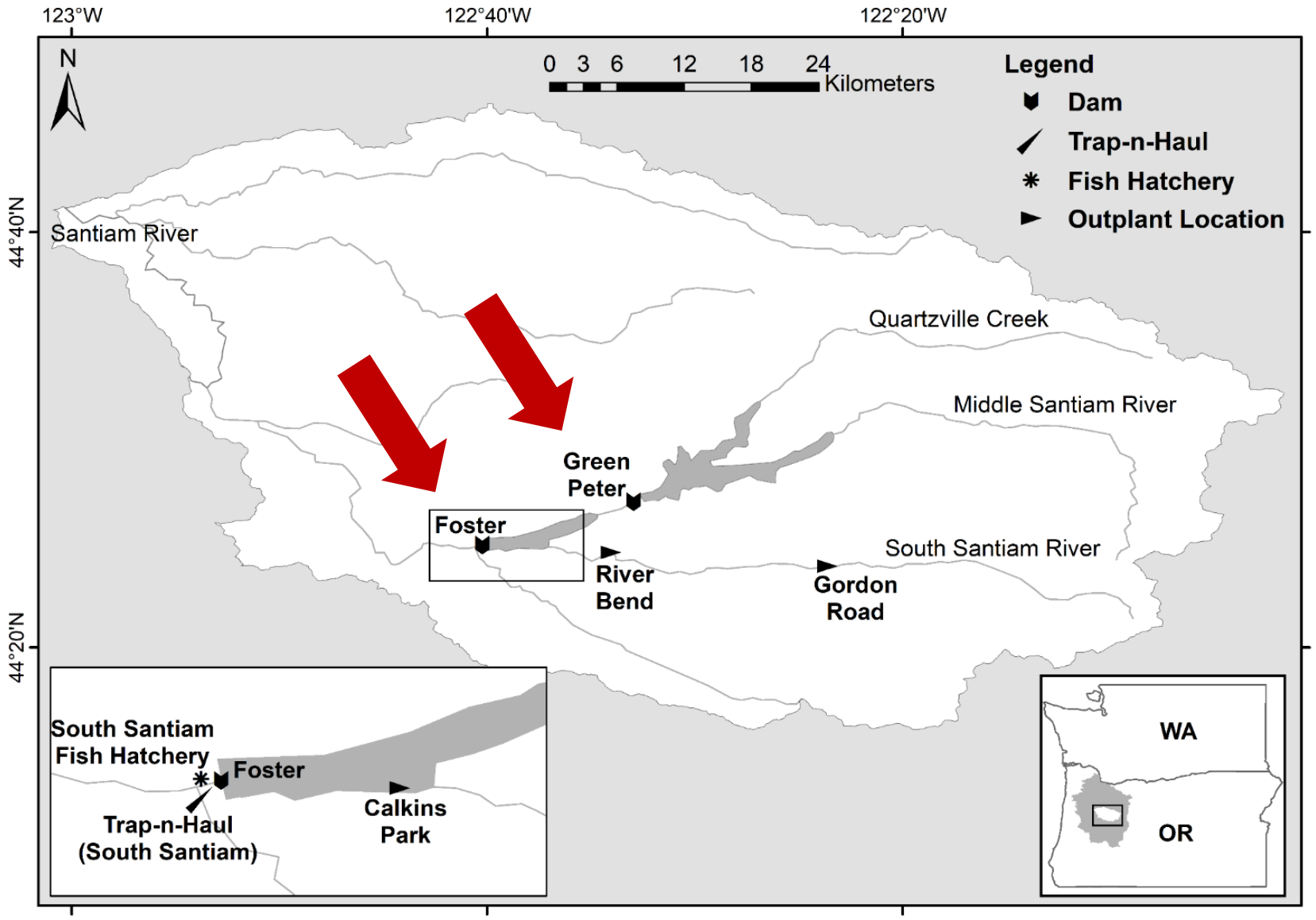
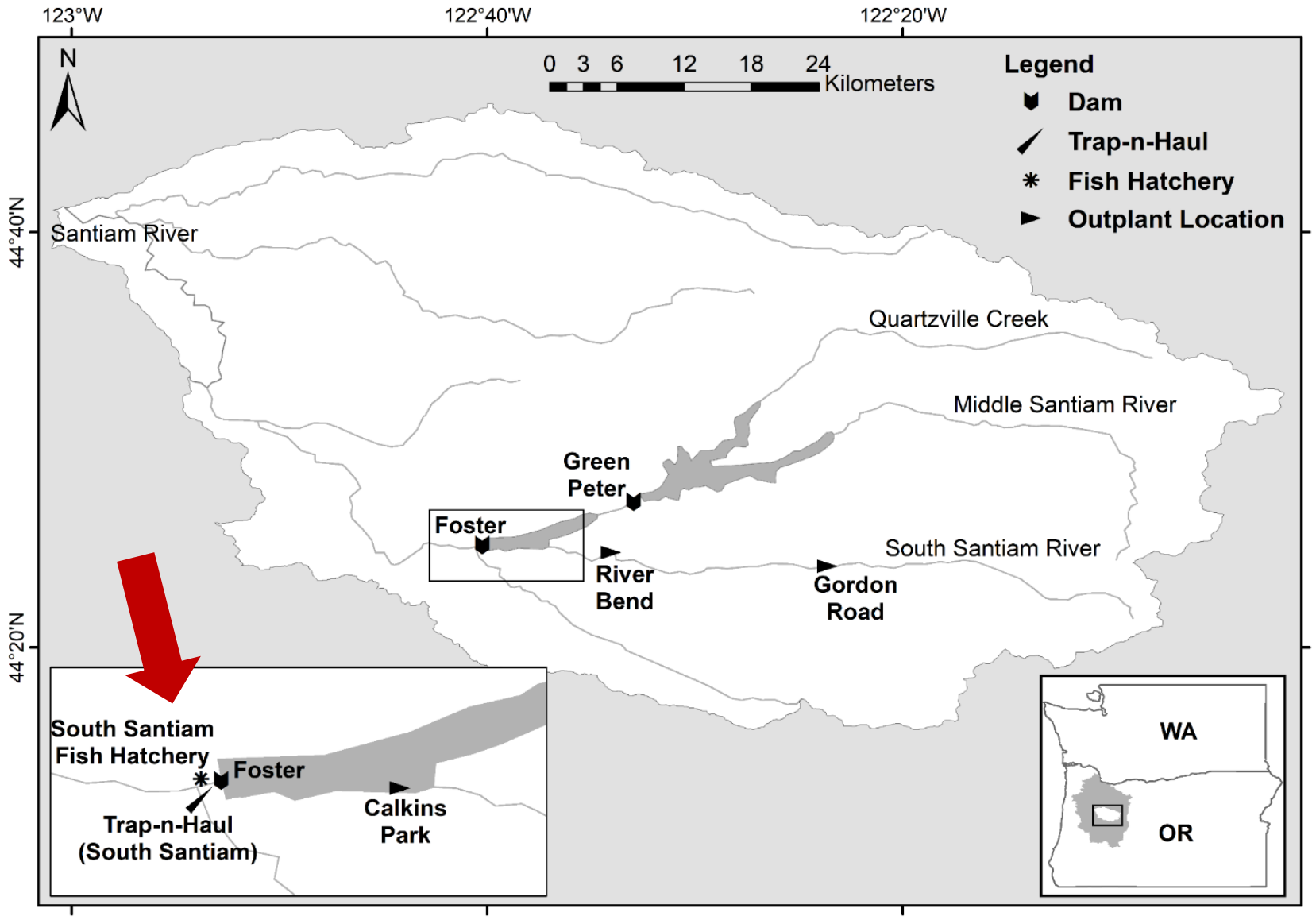
South Santiam River spring Chinook salmon



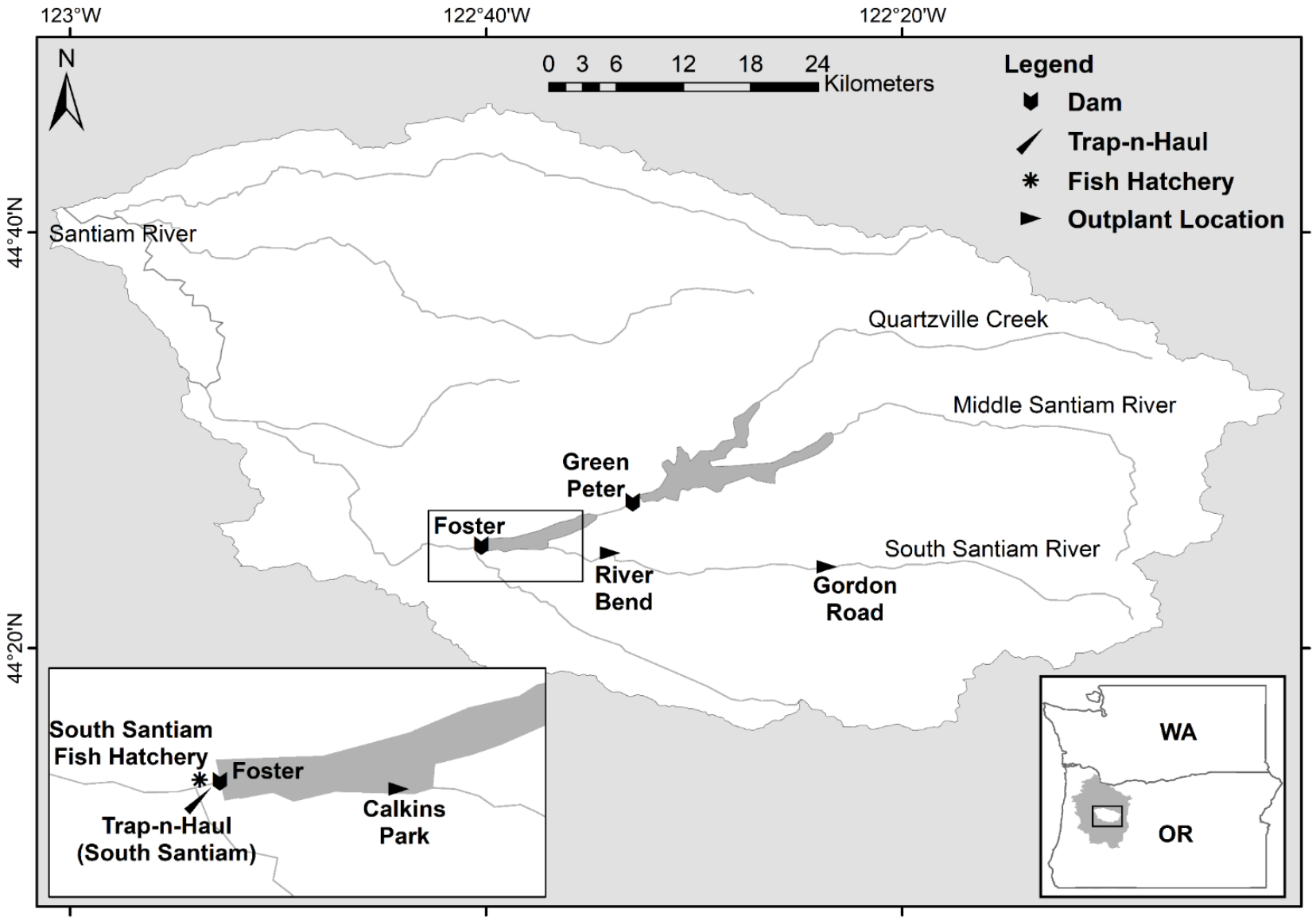
South Santiam River spring Chinook salmon

- Hatchery-origin (HOR) released above Foster Dam beginning in 1996
  - Estimated >99% HORs adipose fin removed otolith thermal mark



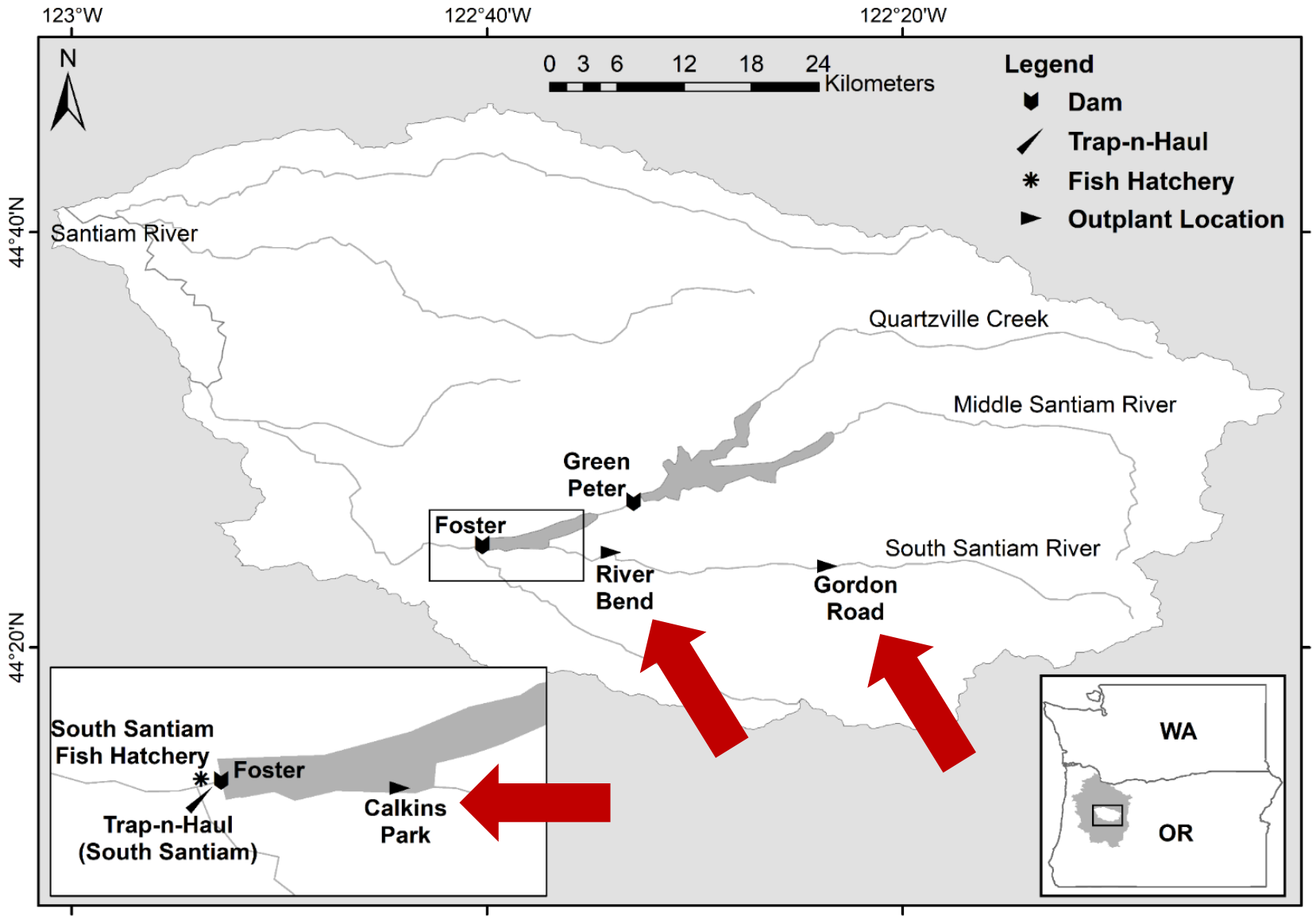
South Santiam River spring Chinook salmon

- Hatchery-origin (HOR) released above Foster Dam beginning in 1996
  - Estimated >99% HORs adipose fin removed otolith thermal mark
- Presumed natural-origin (NOR) reintroduced above Foster since 2009
  - Adipose fin intact



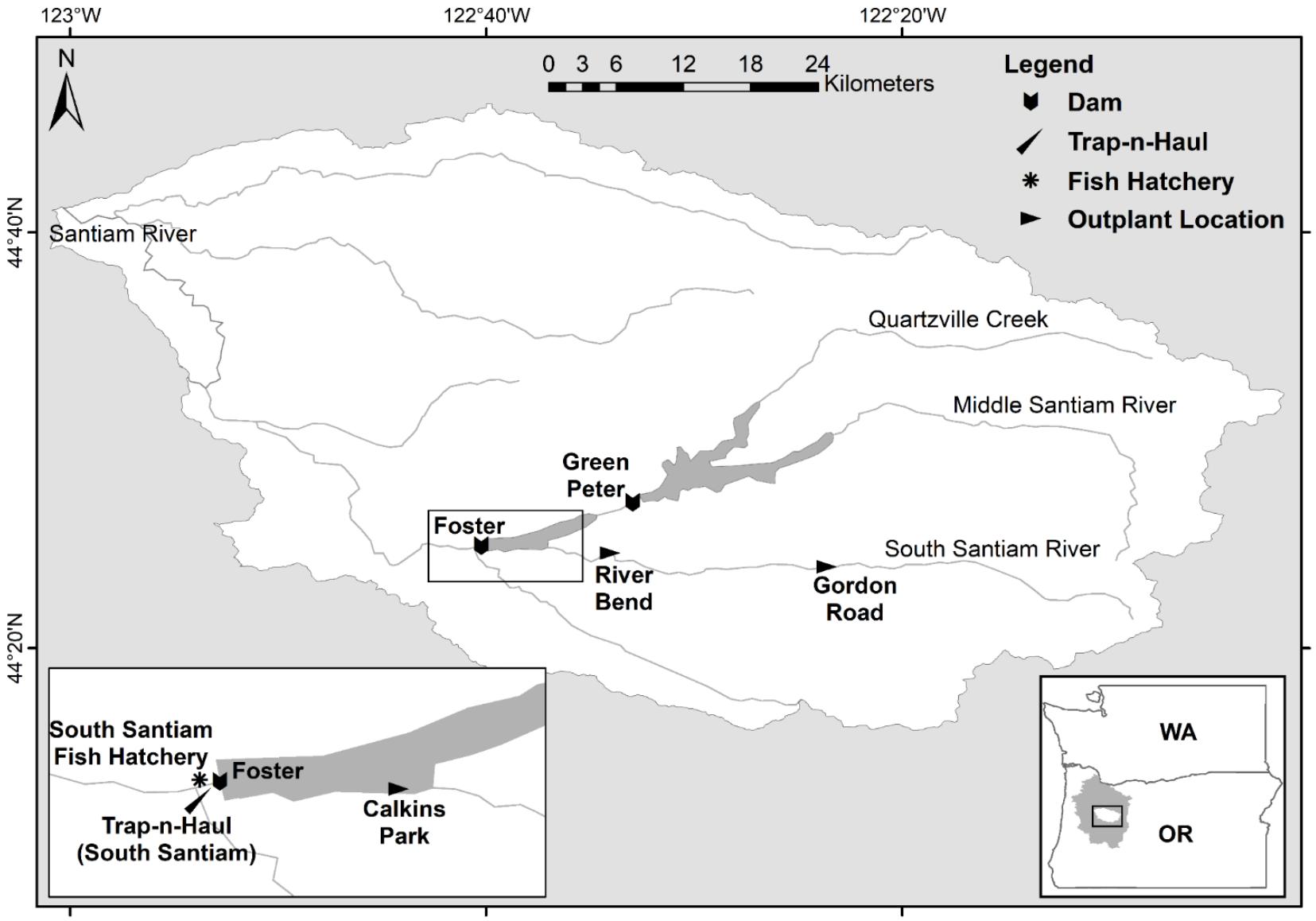
South Santiam River spring Chinook salmon

- Three release sites



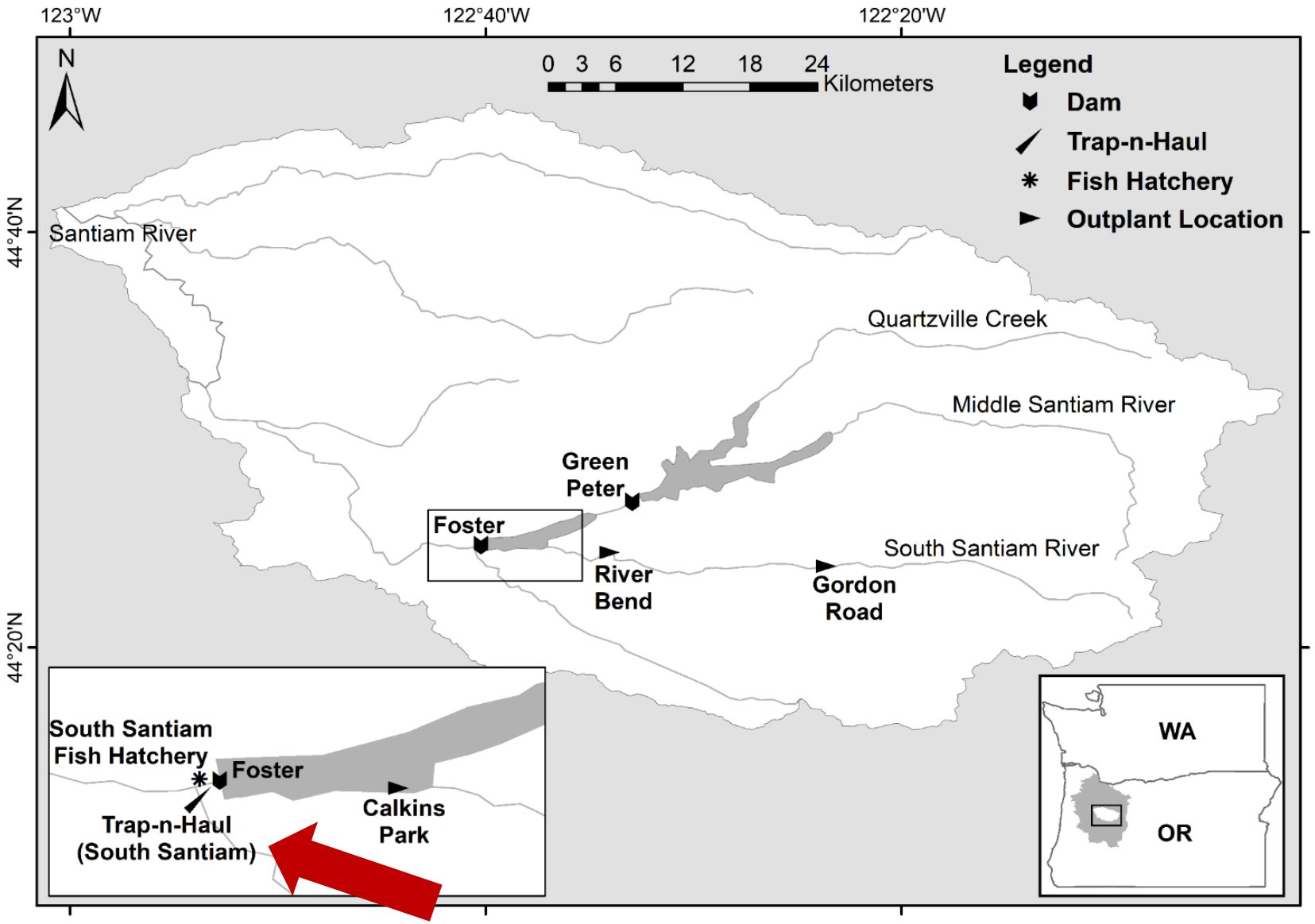
South Santiam River spring Chinook salmon

- Three release sites
- Annual releases above Foster may include HOR salmon
  - Adipose fin intact
  - Otolith thermal mark



South Santiam River spring Chinook salmon

- Three release sites
- Annual releases above Foster may include HOR salmon
  - Adipose fin intact
  - Otolith thermal mark
- Foster Fish Collection Facility operational in 2014

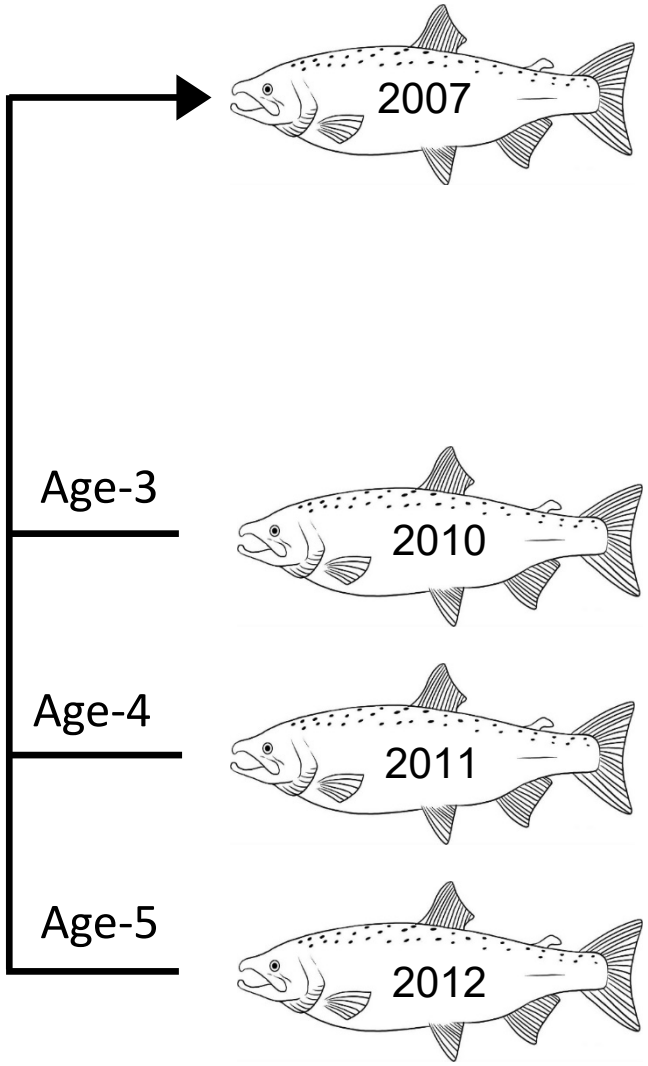


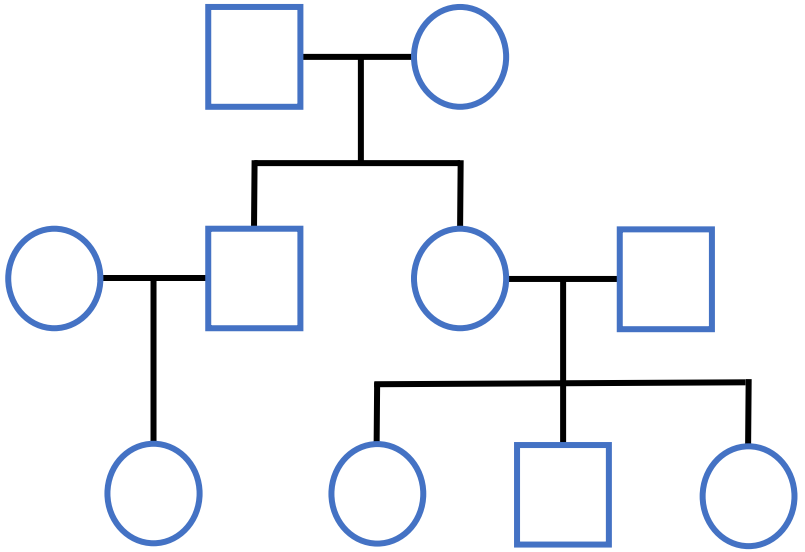
What is the contribution of the reintroduction program above Foster Dam to adult recruitment in the South Santiam River?

Tissue samples for genetic parentage analysis:

- Chinook salmon released above Foster Dam since 2007
- Carcasses below Foster Dam since 2011
- Carcasses above Foster Dam since 2014
- South Santiam Hatchery broodstock since 2015

Genetic parentage analysis





South Santiam genetic parentage analysis studies

	Adult offspring return years	Parent years
O'Malley *et al.* (2014)	2010 – 2013	2007 – 2010
O'Malley *et al.* (2015)	2014	2009 – 2011
O'Malley *et al.* (2017)	2015	2010 – 2012
O'Malley *et al.* (2024)	2016 – 2020	2011 – 2015

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Adult Chinook salmon returns in 2016 – 2020

Objectives:

1. Determine the number of unmarked, presumed NOR adult salmon that assign to
   - Salmon above Foster Dam or
   - Carcasses below Foster Dam

2. Determine the number of unmarked HOR salmon (adipose fin intact) that assign to
   - South Santiam Hatchery broodstock

3. Estimate the age structure of returning adult salmon

Objective 1 and 2 Results:
Assignments of adult returns in 2016 – 2020

Return year	# Adult returns
2016	309
2017	162
2018	138
2019	161
2020	349

Objective 1 and 2 Results: Assignments of adult returns in 2016 – 2020

Return year	# Adult returns	# Adult returns assigned to salmon			
		Above Foster	Below Foster	Hatchery Broodstock	All
2016	309	144	4	-	148 (48%)
2017	162	116	2	-	118 (73%)
2018	138	46	6	7	59 (43%)
2019	161	66	5	32	103 (64%)
2020	349	156	7	74	237 (68%)

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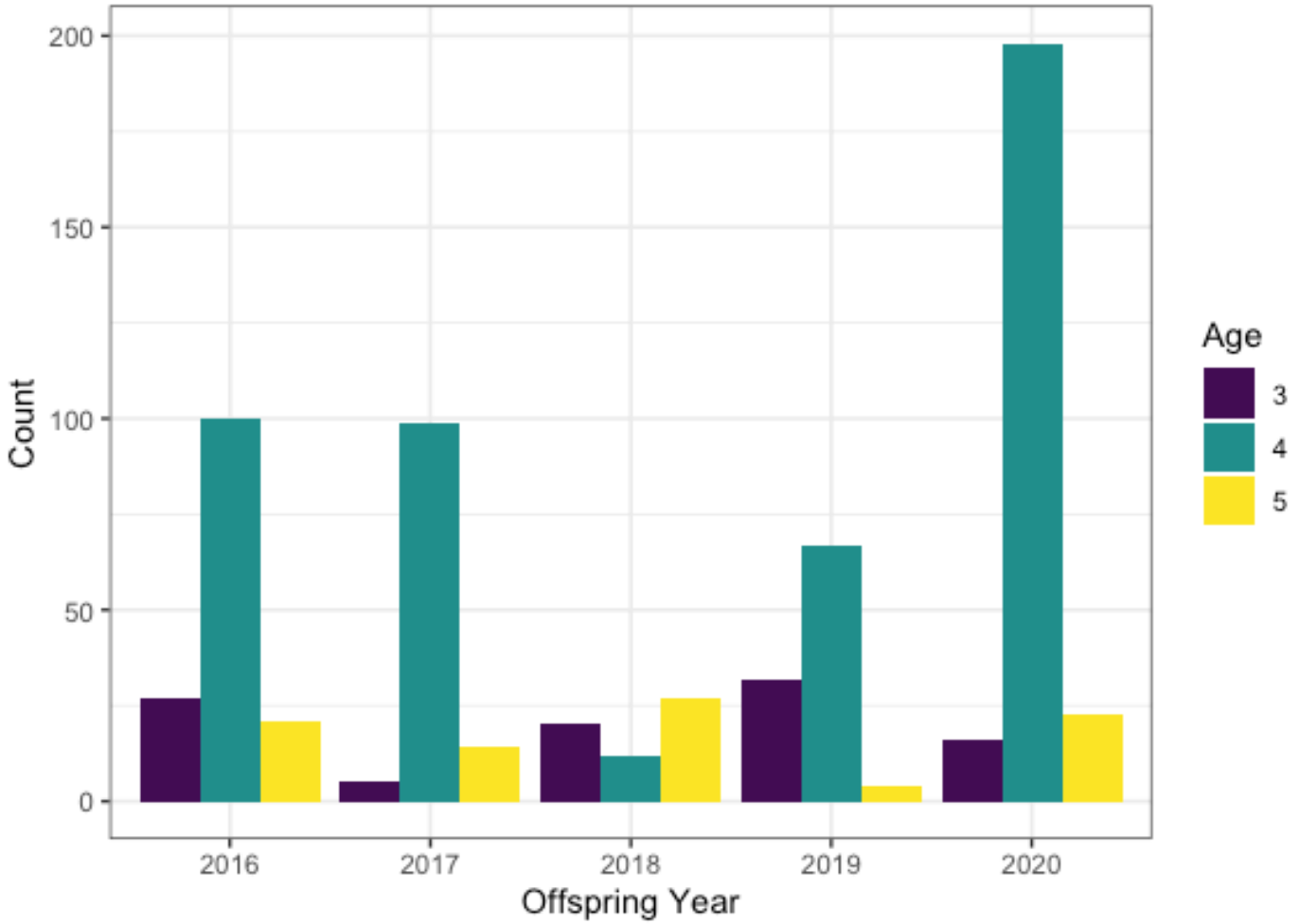
Objective 3 Results:
Age structure of adult returns in 2016 – 2020



Productivity of salmon above Foster Dam in 2011 – 2015

Objectives:

4. Estimate the Total Lifetime Fitness (TLF)

5. Evaluate potential predictors of TLF

6. Estimate Cohort Replacement Rate (CRR)

7. Estimate the effective number of breeders (N_b)

Objective 4 Results:
Total Lifetime Fitness (TLF) of NOR salmon above Foster Dam

TLF = age-3, age-4, age-5 adult offspring

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Release year	# Released	% Produced ≥1 adult offspring	Range # of offspring
2011	1175	9%	0 – 13
2012	992	10%	0 – 16
2013	918	11%	0 – 15
2014	409	4%	0 – 6
2015	570	10%	0 – 7

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Objective 5 Results:
Predictors of TLF for salmon above Foster Dam

Generalized Linear Mixed Model
4 release years (2012 – 2015)

Response Variable
Total Lifetime Fitness (TLF):

n = 2,842 individuals
included in the model

Fixed Effects

- Sex
- Release day
- Release location
- Release group density
- Release group sex ratio
- Total # of fish released annually
- Annual sex ratio
- Sex*release day
- Sex*release group density
- Sex*release group sex ratio
- Sex*annual sex ratio

Random Effects

- Year
- Release group

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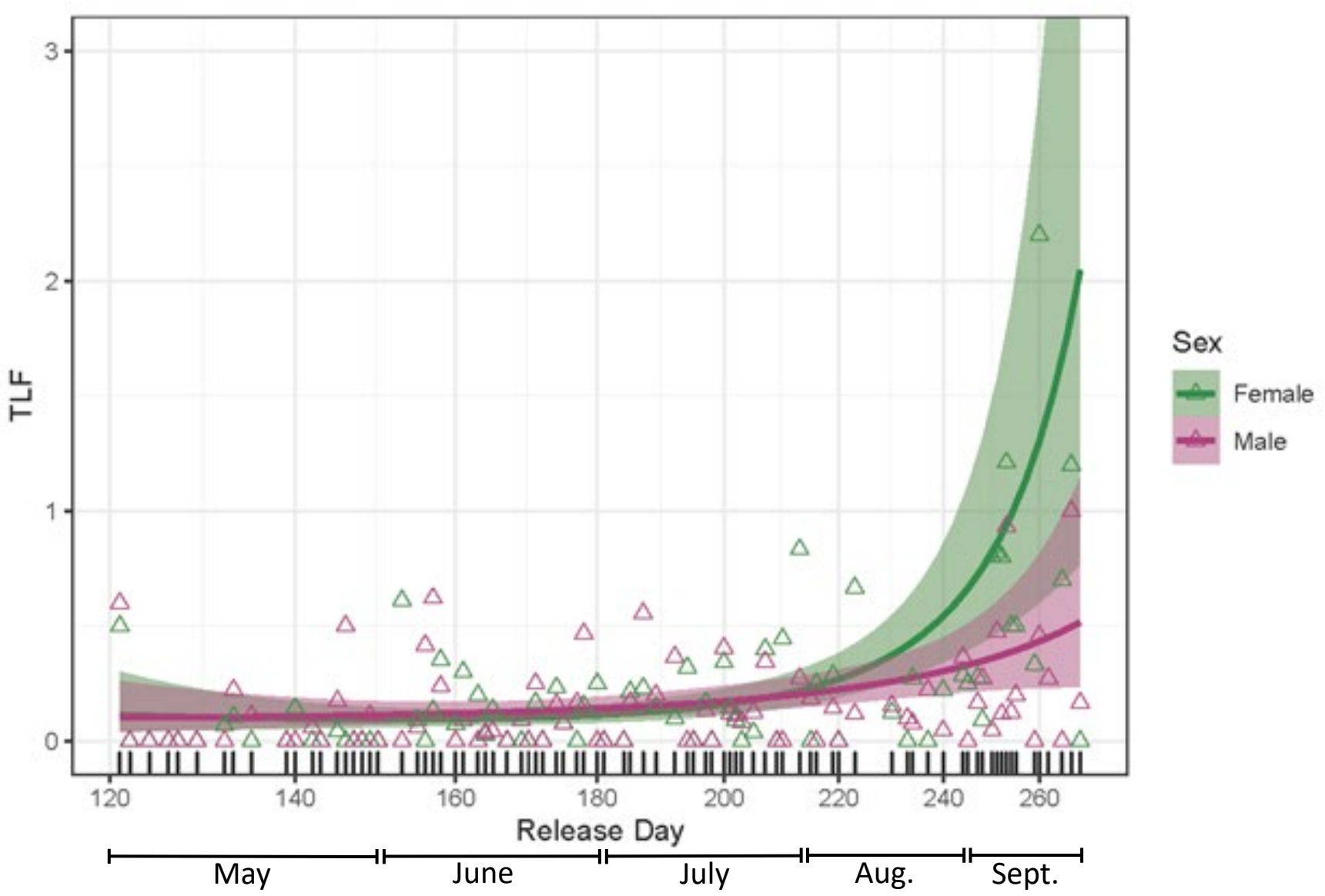

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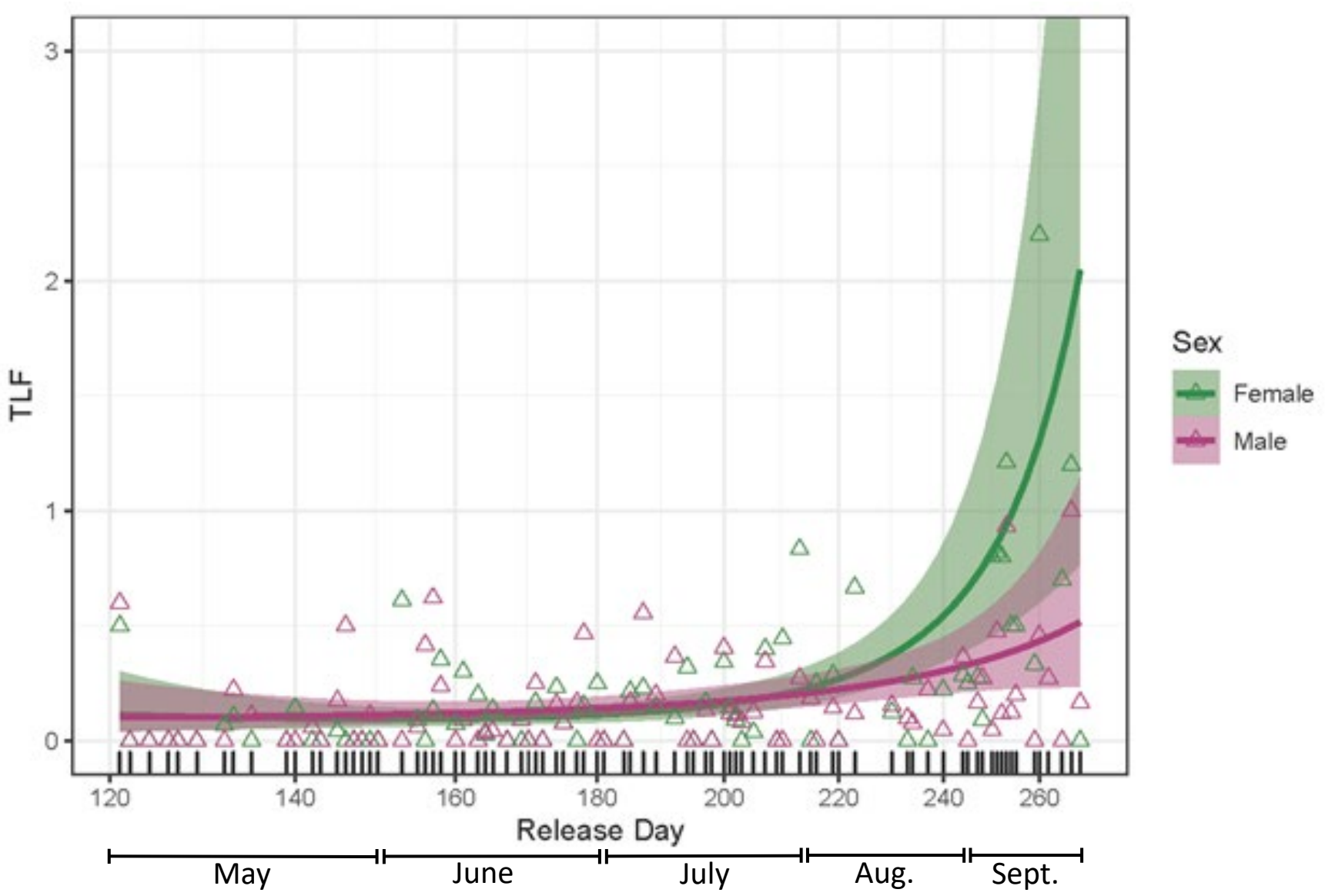

Objective 6:
Cohort Replacement Rate (CRR) of salmon released above Foster Dam

CRR = number of future spawners produced by a spawner[1]

$$\text{CRR 2011} = \frac{\text{Total \# of adult offspring (2014 – 2016) assigned to salmon released in 2011}}{\text{Total \# of salmon released in 2011}}$$

CRR ≥ 1 indicates replacement has been met

[1]Botsford and Brittnacher (1998)

Objective 6 Results:
Estimate CRR for salmon above Foster Dam in 2011 – 2015

Release year	# Offspring assigned	# Parents released	Sex ratio (M:F)	CRR
2011	129	1202	1.3 : 1.0	0.11
2012	143	1010	1.4 : 1.0	0.14
2013	149	932	1.3 : 1.0	0.16
2014	17	419	1.0 : 1.0	0.04
2015	67	610	1.2 : 1.0	0.11

Objective 7 Results:
Estimate effective number of breeders (N_b) for salmon above Foster Dam in 2011 – 2015

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Release year	# Offspring assigned	# Parents released	#Successful parents	N_b
2011	129	1202	102	96.8
2012	143	1010	104	87.6
2013	149	932	105	74.8
2014	17	419	18	7.0
2015	67	610	61	76.7

Summary

- Assignment rates of returning Chinook salmon were highly variable among years

  Unassigned salmon may be (1) unmarked HOR salmon (2) offspring of salmon that spawned below Foster, or (3) strays from another river

- Assignment rates may increase given continued incorporation of hatchery broodstock samples to identify unmarked HOR salmon and modifications to improve adult collection at the Foster Facility

- Given the >99% mark rate of juveniles released from the hatchery, number of unmarked HOR salmon detected should be proportional to hatchery releases

Summary

- From 2011 – 2015, the number of salmon released above Foster, percentage of salmon that produced offspring, and maximum number of offspring/individual all declined

- Overall decrease in above-dam production could be attributed to several factors:

  Reduced trap efficiency, pre-spawn mortality, fewer adult returns

- Modelling results indicate that in both sexes, TLF increased with later release, but this association was markedly stronger for females

Summary

- CRR did not exceed 0.16 in all years from 2011 – 2015 indicating that the above-dam population is far from replacing itself
- Trend has continued since 2010 and is likely attributed to a combination of factors
- N_b continues to decline revealing very low genetic diversity in the reintroduced population
- Continued declines in genetic diversity threaten the stability of the reintroduced population above Foster Dam

Proposed Next Steps

- Determine if above-dam productivity increases after modifications to the Foster Facility
    - Estimate TLF, CRR, and N_b for future cohorts
- Evaluate the impact of the extremely low N_b observed for the 2014 cohort
    - Estimate TLF, CRR, and N_b for returning adult offspring in 2017 – 2019

Proposed Next Steps

- Determine the number of unmarked HOR salmon transported above Foster each year
    - Continue to incorporate hatchery broodstock samples
- Evaluate the productivity of salmon released above Green Peter Dam
    - ~800 HOR salmon released in 2022 and 2023, respectively

Acknowledgments

- Funding: U.S. Army Corps of Engineers
- Sample collection: ODFW and other groups

Dayan, D.I., Sard, N.M., Johnson, M.A., Fitzpatrick, C.K., Couture, R., O'Malley, K.G. (2023) A singe generation in the wild increases fitness for descendants of hatchery-origin Chinook salmon (*Oncorhynchus tshawytscha*). Evolutionary Applications

2023 OCEAN CONDITION INDICATORS TREND

good fair poor

	ECOSYSTEM INDICATORS	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CLIMATE & ATMOSPHERIC	PDO (Sum Dec-March)	23	9	5	17	10	25	16	21	18	13	7	2	20	6	4	11	14	26	24	22	15	19	12	8	3	1
	PDO (Sum May-Sept)	14	5	11	8	13	23	18	21	17	19	7	16	9	4	3	10	24	26	25	20	15	22	12	6	2	1
	ONI (Average Jan-June)	25	1	1	9	17	19	18	21	10	15	3	13	22	6	8	10	12	23	26	16	7	24	20	5	4	14
LOCAL PHYSICAL	SST NDBC buoys (°C; May-Sept)	21	7	9	5	6	13	26	14	2	17	1	12	3	8	10	19	24	23	22	15	18	25	11	4	20	16
	Upper 20 m T (°C; Nov-Mar)	25	14	11	13	8	19	20	16	17	7	1	12	22	6	4	9	3	26	24	23	18	21	2	10	15	5
	Upper 20 m T (°C; May-Sept)	18	12	14	5	1	3	26	21	10	11	2	7	19	9	8	20	24	15	16	13	17	25	23	4	22	6
	Deep Temp (°C; May-Sept)	25	7	10	5	1	12	15	17	13	6	2	9	8	11	4	16	24	21	14	19	20	18	26	3	23	22
	Deep Salinity (May-Sept)	25	4	12	5	7	21	22	13	8	2	3	18	17	15	16	14	26	20	10	9	6	11	24	1	23	19
LOCAL BIOLOGICAL	Copepod richness (May-Sept anom)	24	3	1	11	10	19	18	23	20	14	12	13	22	6	9	4	15	25	26	21	17	16	7	5	2	8
	N copepod biomass (May-Sept anom)	24	19	14	15	6	21	18	25	20	16	9	13	11	3	5	7	8	22	26	23	10	4	2	1	17	12
	S copepod biomass (May-Sept anom)	26	2	7	4	3	18	20	25	17	14	1	9	21	13	10	8	15	23	24	22	16	19	12	5	6	11
	Biological transition	24	13	9	8	11	19	15	23	18	5	1	2	21	3	12	6	6	24	24	22	17	19	14	10	4	16
	Nearshore Ichthyoplankton (Jan-Mar)	21	4	14	8	1	25	26	20	11	22	3	17	2	10	5	13	23	18	19	16	12	24	9	6	15	7
	Near & offshore Ichthyoplankton (community index Jan-Mar)	11	6	4	8	10	13	20	24	1	16	3	12	18	5	2	7	9	22	25	26	21	23	19	15	14	17
	Chinook salmon juvenile catch	23	2	7	20	6	10	18	25	14	12	1	8	5	16	3	4	9	17	22	26	21	15	24	13	11	19
	Coho salmon juvenile catch	24	13	21	5	7	6	23	25	19	2	4	10	11	20	15	1	12	18	17	26	3	16	22	14	9	8
MEANS & RANKS	Mean of ranks	22.1	7.6	9.4	9.1	7.3	16.6	19.9	20.9	13.4	11.9	3.8	10.8	14.4	8.8	7.4	9.9	15.5	21.8	21.5	19.9	14.6	18.8	14.9	6.9	11.9	11.4
	Rank of the mean rank	26	5	8	7	3	19	21	23	14	13	1	10	15	6	4	9	18	25	24	21	16	20	17	2	12	11
NOT INCLUDED IN THE MEAN OF RANKS OR STATISTICAL ANALYSES	Physical Spring Trans (UI based)	4	8	24	21	5	15	18	25	15	1	7	3	10	13	22	11	23	12	6	20	13	15	9	2	26	19
	Physical Spring Trans. Hydrographic	25	4	14	9	6	13	17	26	7	10	1	10	21	4	12	2	19	8	20	24	17	16	22	2	22	15
	Upwelling Anomaly (sum April-May)	12	4	21	8	11	18	16	25	12	6	9	10	19	21	19	14	23	1	3	24	7	5	16	2	26	15
	Length of Upwelling Season (UI based)	6	2	22	14	1	16	12	26	5	3	9	3	18	21	18	17	24	13	8	15	7	10	20	10	24	23
	Copepod Community Index (May-Sept)	25	5	7	10	4	20	18	24	21	13	1	9	17	12	8	6	15	23	26	22	16	19	14	3	2	11