Preliminary efforts to forecast Lower Columbia River Chum Salmon

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Ocean Indicators & Forecasting

- There has been a lot of research on how ocean conditions affect the growth and survival of juvenile salmon in the northern California Current
- Standardized physical and biological metrics have been developed to describe ocean conditions – known as "ecosystem indicators"
- These ecosystem indicators have been used to forecast adult returns for Chinook and coho salmon
- We are interested in whether these same ecosystem indicators could be used to forecast adult chum salmon returns to the Columbia River

	Year																	
Ecosystem Indicators	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
PDO (Sum Dec-Mar:Yr)	5.07	-1.75	-4.17	1.86	-1.73	7.45	1.85	2.44	1.94	-0.17	-3.06	-5.41	2.17	-3.65	-5.07	-1.67	1.24	9.26	6.69
PDO (Sum May-Sept)	-0.37	-5.13	-3.58	-4.22	-0.26	3.42	2.96	3.48	0.28	0.91	-7.63	-1.11	-3.53	-6.45	-7.79	-3.47	5.07	8.08	6.6
ONI (Average Jan-June)	1.12	-1.07	-1.07	-0.40	0.18	0.27	0.20	0.47	-0.30	0.08	-0.98	-0.23	0.55	-0.72	-0.43	-0.30	-0.28	0.67	1.48
46050 SST (°C: May-Sept)	13.66	13.00	12.54	12.56	12.30	12.92	14.59	13.56	12.77	13.87	12.39	13.02	12.92	13.06	13.26	13.37	13.43	14.05	13.88
Upper 20 m T (°C: Nov-Mar)	12.27	10.31	10.12	10.22	10.08	10.70	10.85	10.60	10.61	10.04	9.33	10.19	11.01	10.02	9.62	10.09	9.47	12.75	12.02
Upper 20 m T (°C: May-Sept)	10.38	10.13	10.19	9.77	8.98	9.62	11.39	10.73	9.97	9.99	9.30	9.90	10.14	10.05	9.95	10.63	10.97	10.04	10.20
Deep temperature (°C: May-Sept)	8.59	7.63	7.74	7.56	7.46	7.81	7.89	7.97	7.83	7.58	7.48	7.73	7.89	7.81	7.56	7.94	8.38	8.08	7.89
Deep salinity (May-Sept)	33.54	33.86	33.78	33.86	33.85	33.68	33.66	33.77	33.85	33.88	33.87	33.72	33.61	33.74	33.75	33.76	33.53	33.71	33.83
Copepod richness anom. (no. species: May-Sept)	4.54	-2.58	-3.41	-1.03	-1.12	1.99	1.42	4.39	2.68	-0.63	-0.76	-0.64	3.12	-2.13	-1.31	-2.51	-0.11	7.76	8.32
N. copepod biomass anom. (mg C m^{-3}: May-Sept)	-0.76	0.04	0.15	0.15	0.29	-0.13	0.06	-0.84	-0.01	0.14	0.26	0.15	0.16	0.44	0.39	0.28	0.26	-0.33	-0.90
S. copepod biomass anom. (mg C m^{-3}: May-Sept)	0.60	-0.23	-0.21	-0.21	-0.23	0.09	0.20	0.55	0.07	-0.07	-0.23	-0.19	0.21	-0.14	-0.19	-0.20	-0.02	0.43	0.52
Biological transition (day of year)	263	134	97	101	108	156	132	230	180	81	64	65	169	82	125	91	162	Never	Never
Ichthyoplankton biomass (log (mg C 1000 m^{-3}): Jan-Mar)	0.12	0.90	1.80	1.25	1.05	0.46	0.58	0.83	0.59	0.60	1.84	0.89	1.65	0.61	0.99	1.16	0.43	1.63	1.47
Ichthyoplankton community index (PCO axis 1 scores: Jan-Mar)	-2.13	10.40	-42.67	31.69	-36.80	1.39	49.41	47.23	-38.11	8.26	-40.10	15.31	26.19	7.60	-35.45	-27.36	-15.69	48.49	55.72
Chinook salmon juvenile catches (no. km^{-1}: June)	0.26	1.27	1.04	0.44	0.85	0.63	0.42	0.13	0.69	0.86	2.56	0.97	0.89	0.46	1.32	1.35	0.86	0.57	0.82
Coho salmon juvenile catches (no. km^{-1}: June)	0.35	2.29	1.50	2.87	2.51	3.58	1.13	0.23	1.13	3.49	3.37	1.87	1.84	1.26	1.12	4.91	1.63	1.95	1.38
Principal Component scores (PC1)	4.92	-2.16	-2.82	-2.09	-2.53	0.87	2.41	3.58	-0.08	-0.95	-4.71	-1.49	-0.88	-1.79	-2.65	-2.10	0.74	4.94	5.04
Principal Component scores (PC2)	1.53	-0.04	0.05	-0.85	-1.49	-0.53	2.31	0.25	-0.24	-0.09	-2.14	0.65	-0.44	1.60	0.63	0.58	3.09	-2.14	-2.74
Ecosystem Indicators not included in the mean of ranks or statistical analyses																			
Physical Spring Trans. UI based (day of year)	83	88	134	120	84	109	113	142	109	70	87	82	95	105	123	97	129	103	86
Physical Spring Trans. Hydrographic (day of year)	187	119	142	129	120	141	157	209	123	136	102	136	169	119	140	106	162	124	164
Upwelling Anomaly (April-May)	-14	19	-36	2	-12	-34	-27	-55	-14	9	0	-5	-35	-36	-35	-21	-37	50	28
Length of Upwelling Season UI based (days)	191	205	151	173	218	168	177	129	195	201	179	201	161	153	161	163	133	175	186
SST NH-5 (°C: May-Sept)	11.30	11.08	11.04	10.98	10.15	10.85	12.85	11.73	11.36	11.80	10.66	11.99	11.41	11.08	11.66	11.66	11.71	11.57	11.76
Copepod Community Index (MDS axis 1 scores)	0.65	-0.89	-0.90	-0.83	-1.02	-0.27	-0.23	0.46	-0.06	-0.72	-0.96	-0.86	-0.29	-0.77	-0.83	-0.91	-0.39	0.52	0.85
Coho Juv Catches (no. fish km^{-1}: Sept)	0.11	1.12	1.27	0.47	0.98	0.29	0.07	0.03	0.16	0.15	0.27	0.01	0.03	0.30	0.13	NA	NA	NA	NA

NOTE: The SST at 46050 for 2011 is an estimated value due to a lack of buoy data from January to July.

	Year																	
Ecosystem Indicators	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
PDO (Sum Dec-Mar:Yr)	16	5	1	12	7	14	11	10	13	9	3	1	15	4	2	8	10	16	12
PDO (Sum May-Sept)	10	4	6	5	11	15	14	16	12	13	2	9	7	3	1	8	12	17	16
ONI (Average Jan-June)	16	3	3	6	12	14	13	15	8	11	1	10	16	4	5	7	9	17	18
46050 SST (°C: May-Sept)	15	8	3	4	1	7	18	14	5	16	2	9	6	10	11	12	13	18	17
Upper 20 m T (°C: Nov-Mar)	14	11	8	10	6	2	15	12	13	5	1	9	18	4	3	7	2	16	17
Upper 20 m T (°C: May-Sept)	11	11	13	4	1	3	16	17	7	8	2	5	12	10	6	16	18	9	14
Deep temperature (°C: May-Sept)	10	6	8	4	1	10	12	16	11	5	2	7	18	9	3	15	18	17	13
Deep salinity (May-Sept)	18	3	8	4	5	16	16	9	6	1	2	13	12	12	11	10	18	14	7
Copepod richness anom. (no. species: May-Sept)	17	2	1	7	6	13	12	16	14	10	8	9	15	4	5	3	11	18	19
N. copepod biomass anom. (mg C m^{-3}: May-Sept)	17	13	9	10	3	15	12	18	16	11	4	8	7	1	2	4	5	16	19
S. copepod biomass anom. (mg C m^{-3}: May-Sept)	19	2	5	4	3	13	14	18	12	10	1	7	15	9	8	6	11	16	17
Biological transition (day of year)	17	11	6	7	8	12	10	16	15	3	1	2	18	4	9	5	13	18	19
Ichthyoplankton biomass (log (mg C 1000 m^{-3}): Jan-Mar)	13	10	2	6	8	17	9	12	15	14	3	11	4	13	9	7	18	4	5
Ichthyoplankton community index (PCO axis 1 scores: Jan-Mar)	9	13	1	6	4	10	18	16	3	12	2	14	17	11	5	7	8	19	20
Chinook salmon juvenile catches (no. km^{-1}: June)	18	4	5	16	10	13	17	19	12	8	1	6	7	15	3	2	9	14	11
Coho salmon juvenile catches (no. km^{-1}: June)	16	7	12	5	6	2	15	19	10	3	4	9	10	14	17	1	11	8	13
Mean of ranks	16.4	7.0	5.7	6.9	5.8	11.9	14.6	15.5	11.0	8.7	2.7	8.1	11.8	7.9	6.3	7.4	12.0	15.3	15.3
Rank of the mean rank	19	6	2	5	3	13	15	18	11	10	1	9	12	8	4	7	14	16	16
Ecosystem Indicators not included in the mean of ranks or statistical analyses																			
Physical Spring Trans. UI based (day of year)	3	7	18	15	4	12	14	19	12	1	6	2	8	11	16	9	17	10	5
Physical Spring Trans. Hydrographic (day of year)	18	5	13	8	5	12	14	19	6	9	1	8	17	3	11	2	15	7	20
Upwelling Anomaly (April-May)	9	3	16	5	8	13	12	20	9	4	6	7	14	16	14	11	18	1	2
Length of Upwelling Season UI based (days)	6	2	17	11	1	12	9	19	5	3	8	3	13	16	13	18	10	10	7
SST NH-5 (°C: May-Sept)	8	6	5	4	1	3	19	15	9	17	2	18	10	7	13	12	14	11	16
Copepod Community Index (MDS axis 1 scores)	16	5	4	8	3	13	14	16	12	10	1	6	12	9	7	3	11	15	19
Coho Juv Catches (no. fish km^{-1}: Sept)	11	2	1	4	3	6	17	14	8	9	7	15	13	5	10	NA	NA	NA	NA

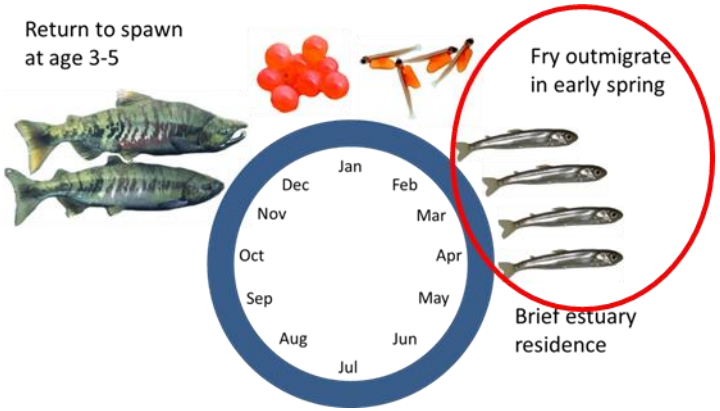
Why Forecast Chum Salmon Returns?

- Fisheries
  - No forecast needed because all fisheries are closed to chum salmon retention
  - Incidentally caught chum salmon are released in commercial and recreational fisheries
- Conservation
  - Forecast help with annual adjustments to the type and magnitude of supplementation, enhancement or captive broodstock programs if needed
- Monitoring
  - Forecast help with annual adjustments of resources for adult status and trend monitoring to meet NOAA monitoring guidelines on a fixed budget
    - Adjust sample rates of mark/recover programs for low or high forecasts
    - Prioritize populations monitored based on population viability objectives

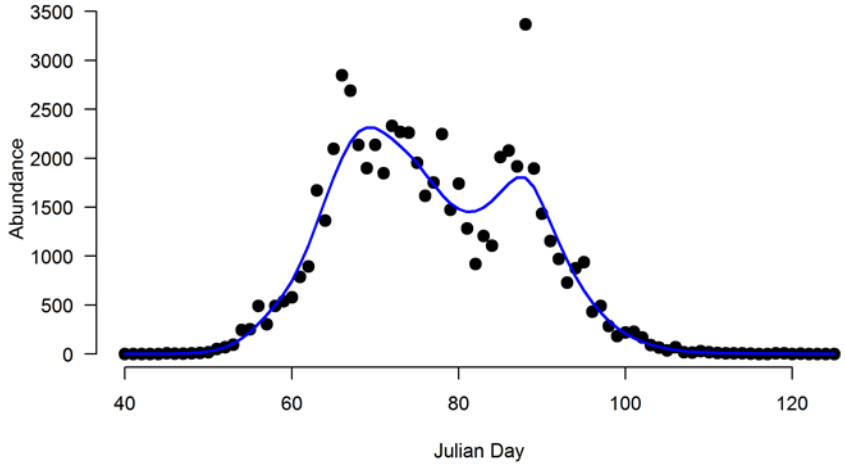
Early Life History for Chum Salmon

- Juveniles emigrate from February- early May
- Size 38-42mm (~1.6 inches)
- Working Hypothesis: Early marine (first year) survival explains most of the variability in ocean survival
- Data Analysis
  - Grays Hatchery releases & Duncan spawning channel production paired with broodyear adult returns are used to estimate smolt to adult return rates (SARs)
  - NOAA Ocean Ecosystem Indicators of outmigration year

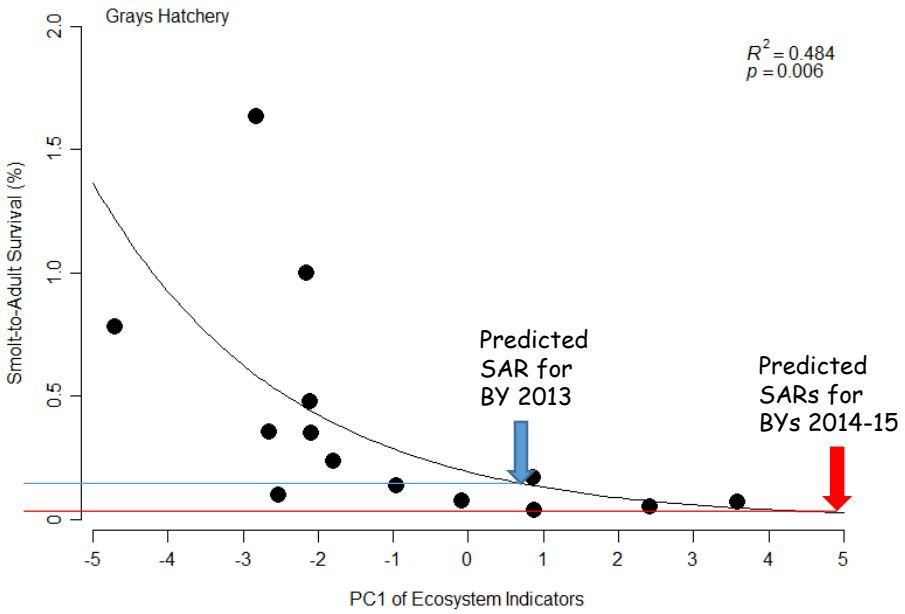
    (PC1 scores of Broodyear + 1)



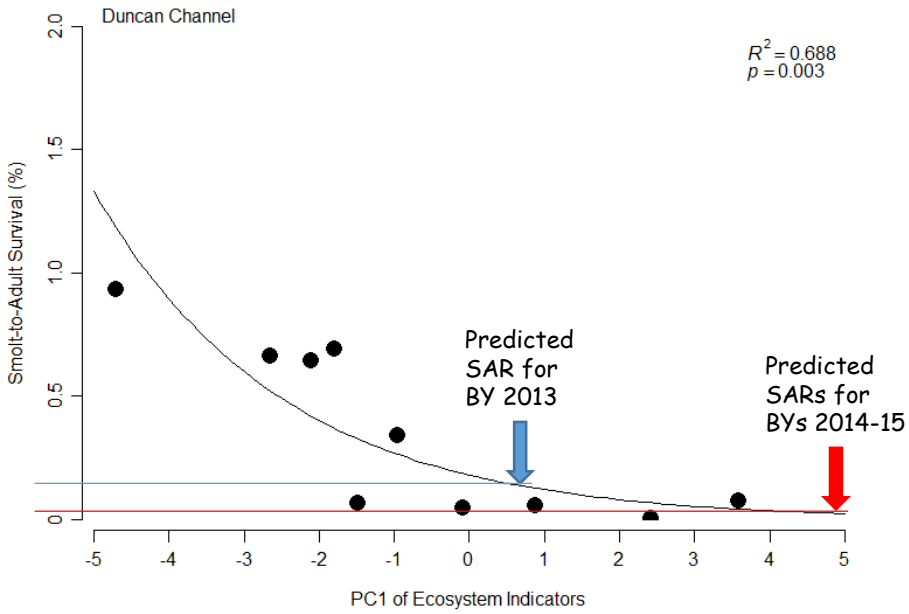
2016 Duncan Creek outmigration counts



Logistic Regression Results



Grays River Hatchery-origin,
Broodyears 1998-2007, 2009-2012
N=14, average SAR=0.39%



Duncan Spawning Channel-origin,
Broodyears 2003-2012
N=10, average SAR=0.35%

When SARs are near 0.1%, it takes ~2,000 outmigrants (fry), equivalent to ~60% or greater egg-to-fry survival, for replacement of a spawning pair.

Summary

- Preliminary analysis suggests:
  - Lower Columbia River chum salmon SARs are correlated with ocean ecosystem indicators data
  - Short time series suggest that the ocean ecosystem indicators are useful for predicting Grays River Hatchery- and Duncan spawning channel-origin SARs
- More work needed:
  - To explore if specific ocean ecosystem indicators can improve prediction of hatchery- and natural-origin chum salmon SARs
  - To develop predictors for hatchery- and natural-origin chum salmon SARs or returns
  - To explore adding Columbia River estuary ecosystem indicators to the analysis

Acknowledgements

Bonneville Power Administration

- Project 2001-053-00 – Reintroduction of Chum Salmon into Duncan Creek
- Project 2008-710-00 - Chum Salmon Restoration in the Tributaries below Bonneville Dam

Washington Department of Fish and Wildlife

- State Funded ESA programs

Photo credit Paul Vecsei

Questions?

Photo credit Paul Vecsei