Importance of spill in Juvenile Hydro-system Survivals and SARs

Preliminary Analysis

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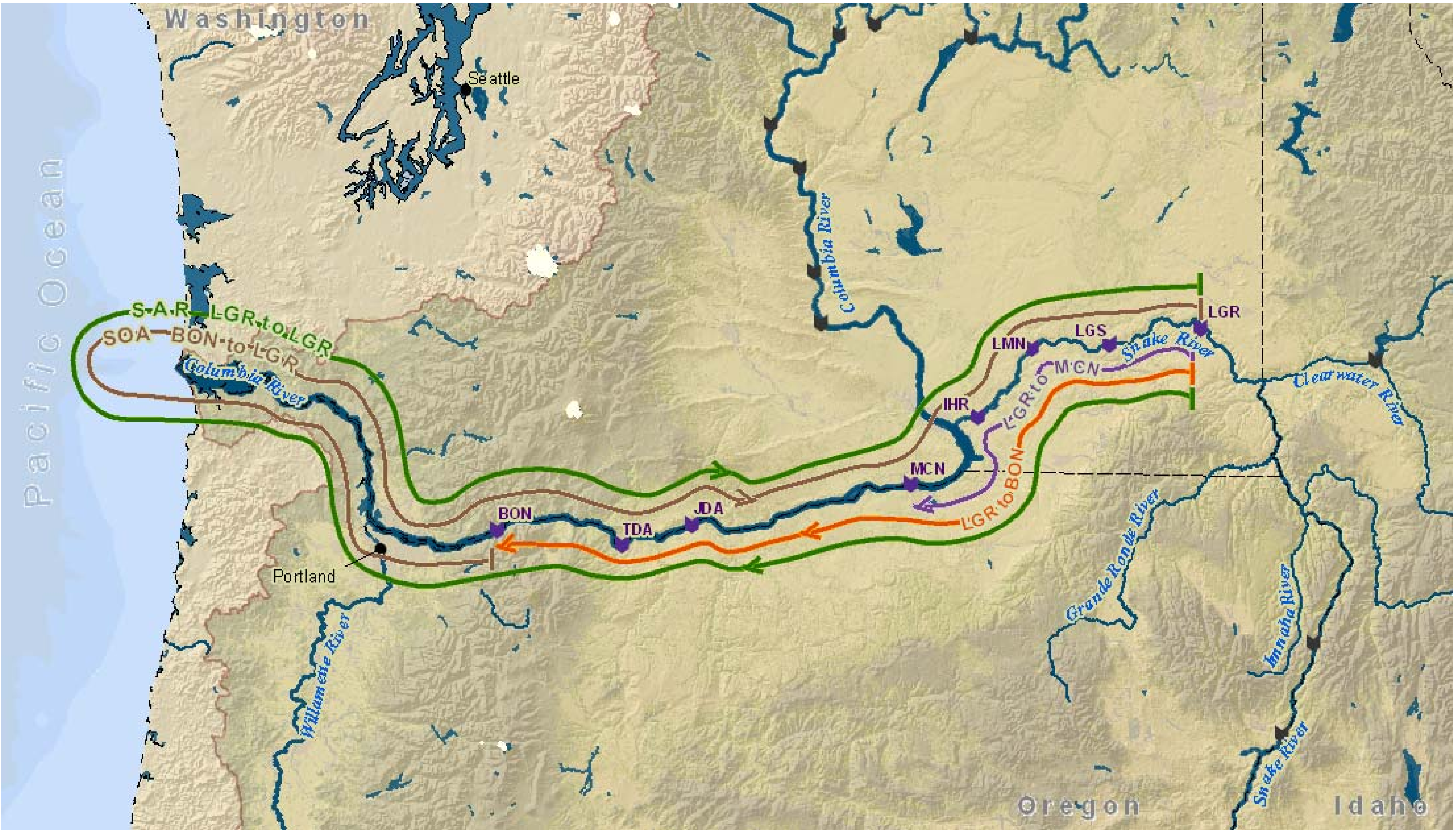
- Smolt reach survival analyses for Snake River yearling spring/summer Chinook, steelhead and fall Chinook
- Relation between juvenile survival and adult return rates (SAR)
- Use of ocean indices to account for effects of varying ocean productivity on adult returns
- Combination of In-river and ocean indices used to explain variability in SARs and SOAs



Washington
Seattle
Pacific Ocean
Columbia River
S.A.R. LGR to LGR
SOA BON to LGR
LGR
LGS
LMN
Snake River
LGR to MCN
IHR
LGR to BON
MCN
JDA
TDA
BON
Portland
Clearwater River
Grande Ronde River
Imnaha River
Willamette River
Snake River
Oregon
Idaho

Juvenile Salmon Reach Survival Analyses

Results of Information Theoretic and multiple regression analyses

In-river variables

- Date_Grp, number from 1 to 5 representing two-week time of passage for PIT-tag cohort at Lower Granite Dam from April 8 to June 16.
- Average Spill Proportion (average percent spill (based on operations during passage of cohort)
- Water Transit Time (sum of WTT for each pool through reach during period of passage)

Model selection results for lnSURV_R (LGR to BON) of Snake River spring/summer Chinook versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite. Smolt migration years were 1998 to 2005, n=29.

Variables in Models	AICc	delta AICc	weight
AV_SPIL_PROP,WTT	60.405	0.0	0.589
AV_SPIL_PROP,WTT,DATE_GRP	62.33	1.9	0.225
AV_SPIL_PROP	63.604	3.2	0.119
AV_SPIL_PROP,DATE_GRP	66.048	5.6	0.035
WTT,DATE_GRP	66.865	6.5	0.023
WTT	68.681	8.3	0.009
DATE_GRP	97.283	36.9	0.000

Model selection results for lnSURV_R (LGR to BON) of Snake River steelhead versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite. Smolt migration years were 1998 to 2005, n=23.

Variables in Models	AICc	delta AICc	weight
AV_SPIL_PROP,WTT,DATE_GRP	75.634	0.0	0.938
AV_SPIL_PROP,DATE_GRP	82.187	6.6	0.035
WTT,DATE_GRP	82.925	7.3	0.024
AV_SPIL_PROP	88.247	12.6	0.002
AV_SPIL_PROP,WTT	89.808	14.2	0.001
DATE_GRP	95.112	19.5	0.000
WTT	95.546	19.9	0.000

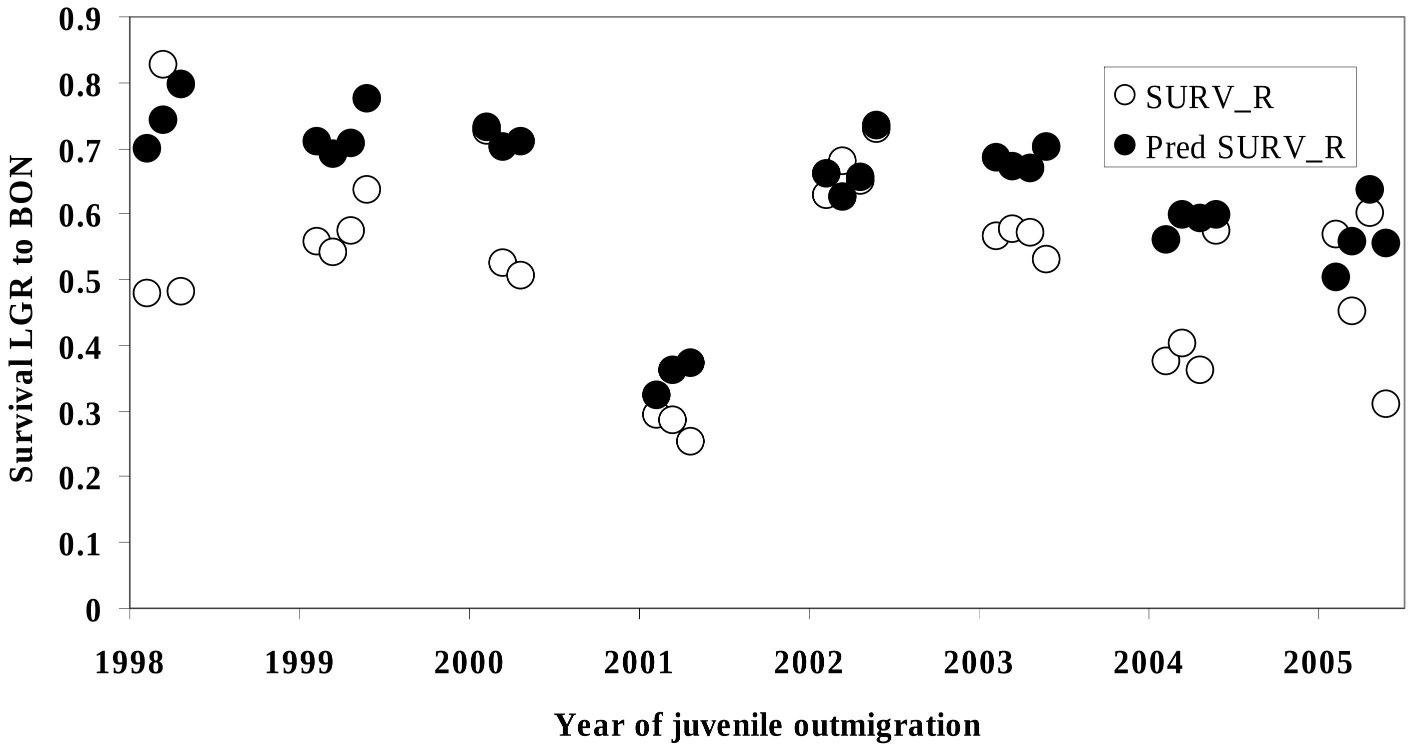
Weight of evidence for each variable in explaining ln SURV_R for Snake River spring/summer Chinook and steelhead.

	Relative Weight of Evidence for each variable by Species	
Variable	Spr/Smr Chinook	Steelhead
AvgSpillProp	0.97	0.98
WTT	0.85	0.96
Date_Grp	0.28	1.00

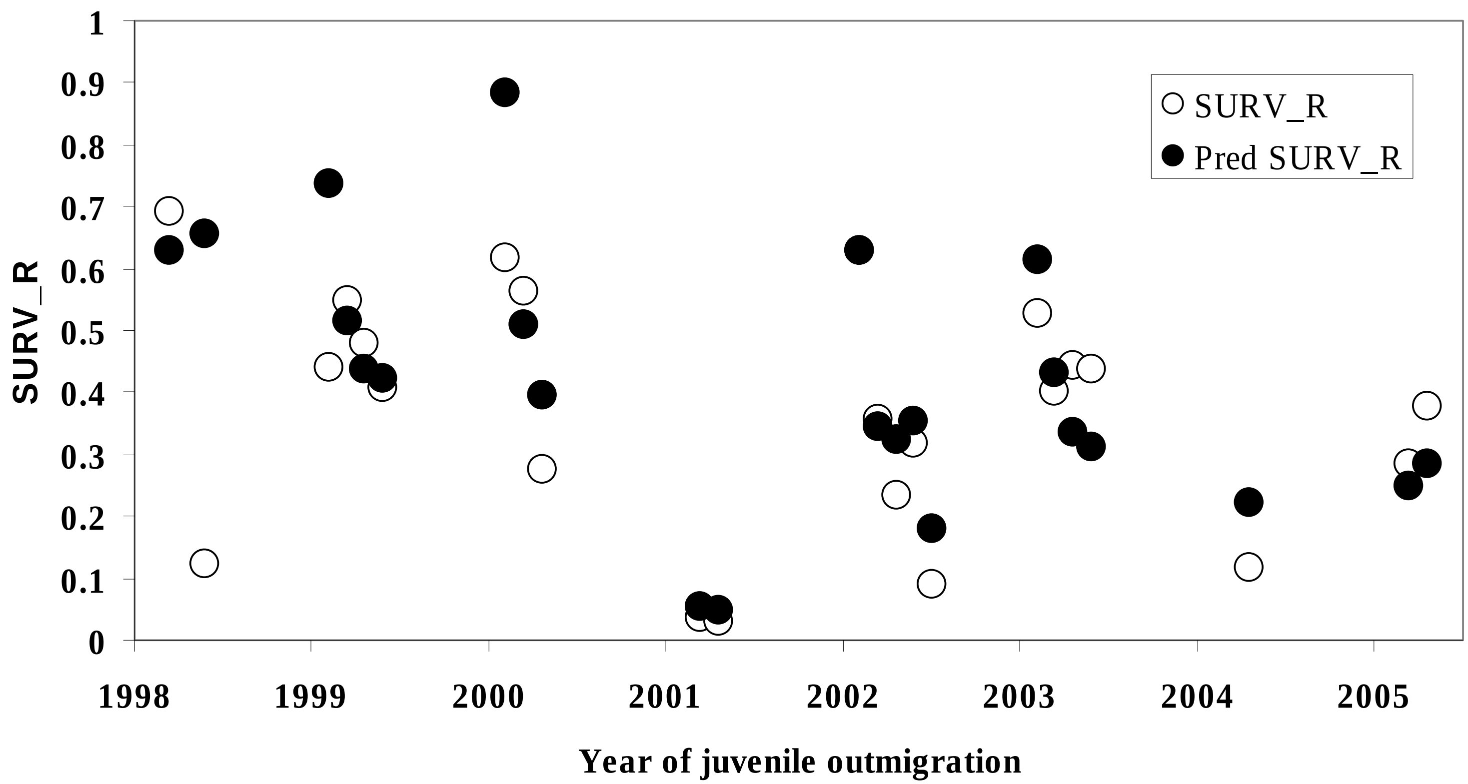
Model averaged coefficients for Snake River yearling spring/summer chinook and steelhead lnSURV_R versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite.

Species and Dependent Variable	Constant	Average Spill Prop	WTT	Date_Grp
Yearling Chinook	-0.78785	0.015292	-0.02089	-0.00888
Steelhead	-0.75027	0.046638	-0.07795	-0.3095

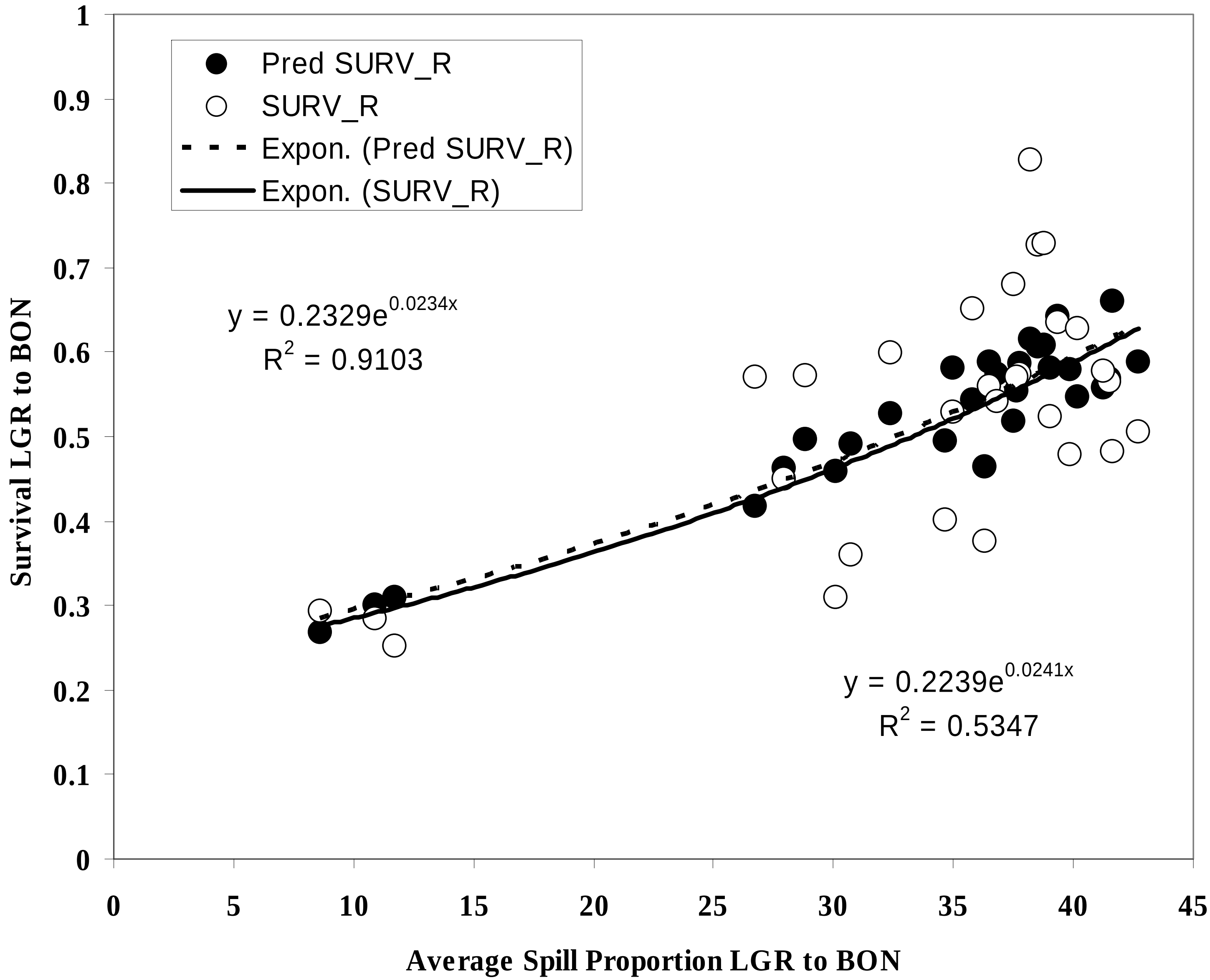
SURV_R compared to Predicted SURV_R (survival from Lower Granite Dam to Bonneville Dam), for Snake River yearling spring/summer Chinook (R^2 = 0.5198).



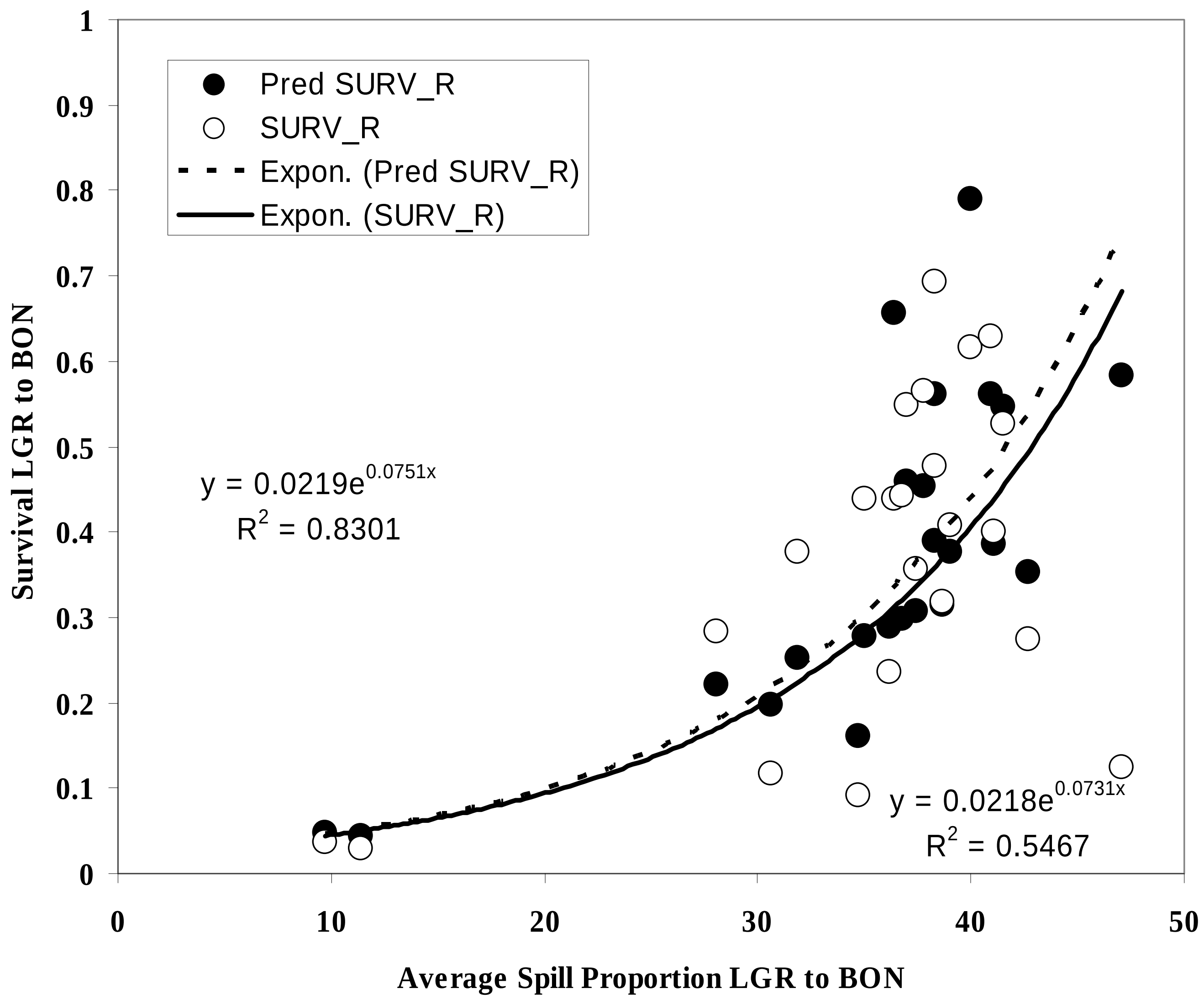
SURV_R compared to Predicted SURV_R (survival from Lower Granite Dam to Bonneville Dam), for Snake River steelhead (R^2 = 0.534).



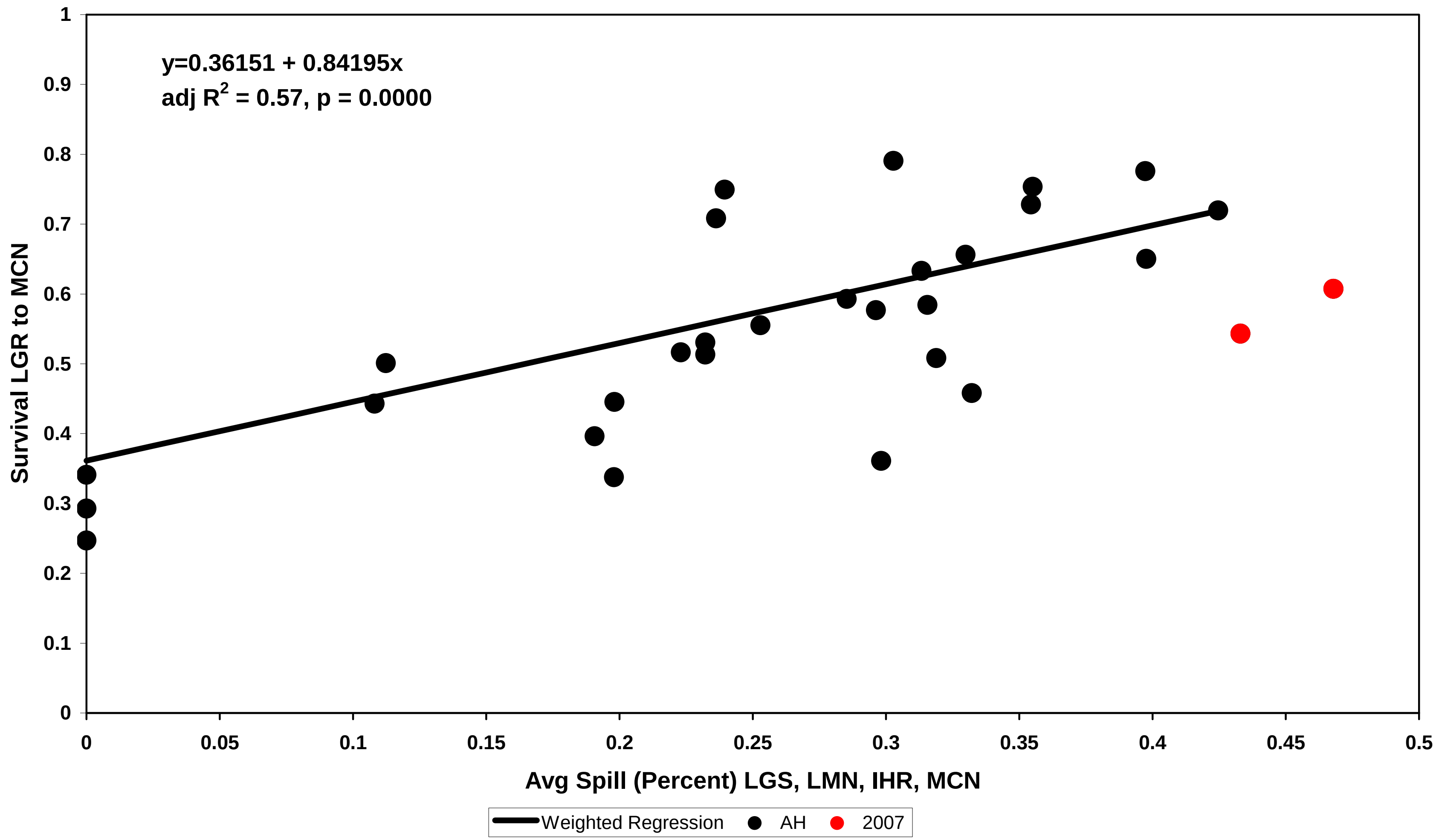
Predicted Survival LGR to BON for Snake River spring/summer Chinook compared to observed data



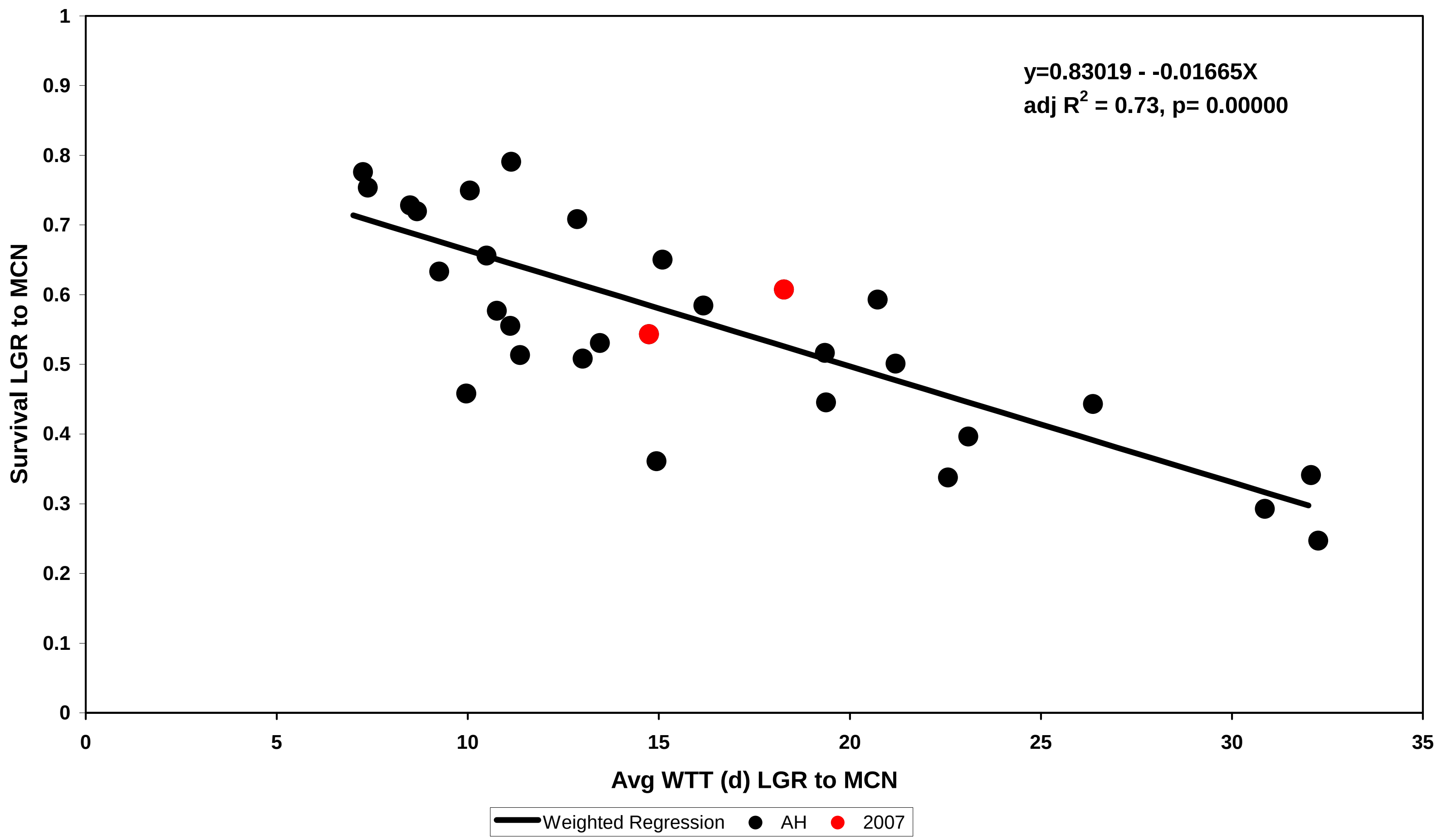
Predicted Survival LGR to BON for Snake River steelhead compared to observed data



AH Subyearling Chinook Survival vs Avg Spill Pct LGS, LMN, IHR, McN



Hatchery Subyearling Chinook Survival vs sum WTT LGS, LMN, IHR, McN



Summary Smolt Analyses

- Smolt Survival analyses continue to show a strong relation between reach survival and spill both multiple regression and information theoretic approaches.
- Predictive models suggest increased spill would result in increased in reach survival.

Juvenile Salmon Reach Survival and Relation to Smolt to Adult Returns

- Assign Ocean Indices to account for variability in ocean productivity
- Plot juvenile reach survivals versus SARs

Ocean Indices

Combination of indices described and used by Williams and Scheuerell (2005), Schaller and Petrosky (2007 & unpublished)

- April upwelling

  -Monthly upwelling indices as measured at Lat. 45°N, 125 W (Near Columbia mouth). Units are cubic meters/second/100 meters of coastline. NOAA Pacific Fisheries Environmental Laboratory at the following link: www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/upwelling.html

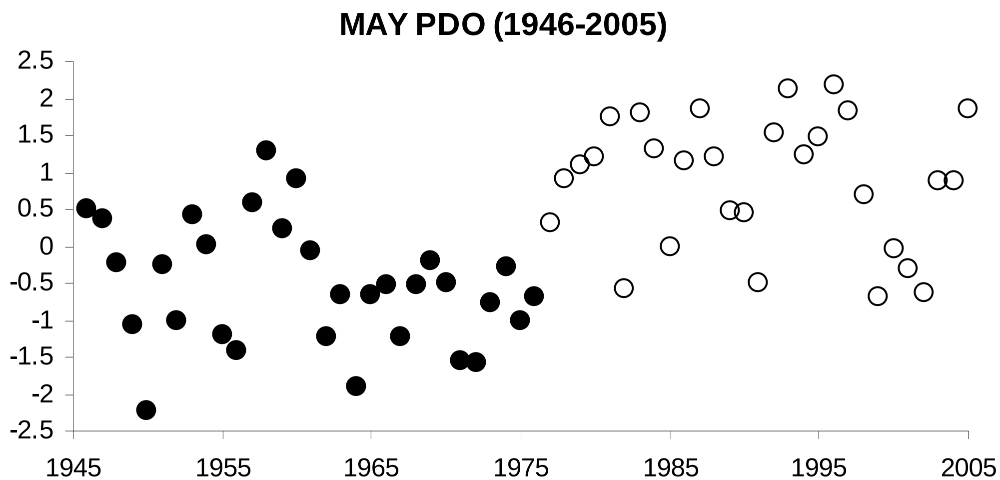
- May PDO

  -The Pacific Decadal Oscillation (PDO) Index is defined as the leading principal component of North Pacific monthly sea surface temperature variability (poleward of 20N for the 1900-93 period) http://jisao.washington.edu/pdo/. (Joint Institute for the Study of the Atmosphere and Ocean)

- September PDO
- October upwelling

Regime Shift

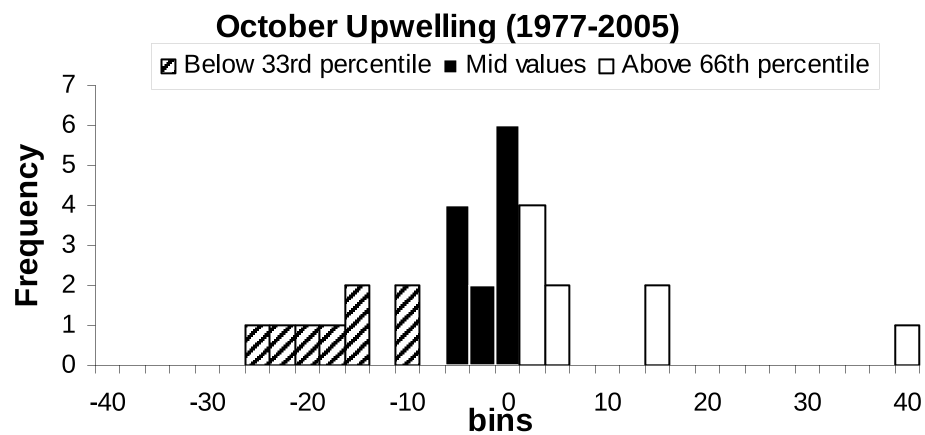
- Limited years considered in ocean data set to time period after regime shift in 1976-77 identified by Hare and Mantua 2000



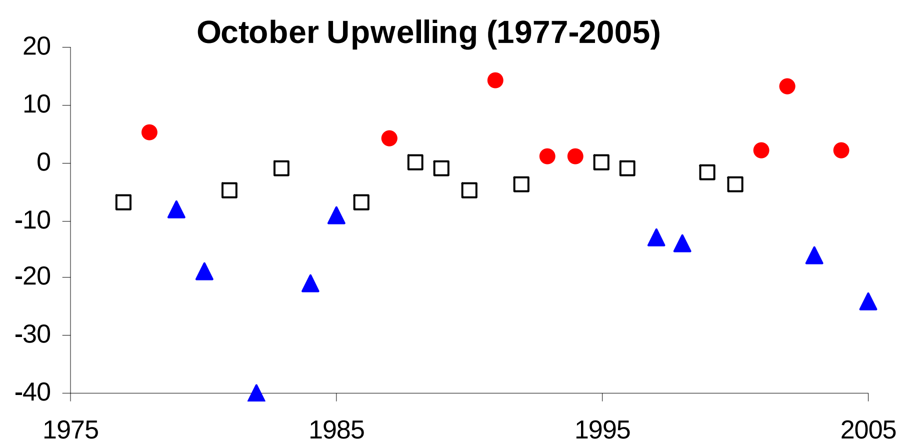
1977 regime shift identified in Hare and Mantua (2000)

Developed ranking system to categorize relative ocean productivity/condition by year

- Each index was divided into thirds over 30 year span



- Each third of data was used as a category to “score” ocean year

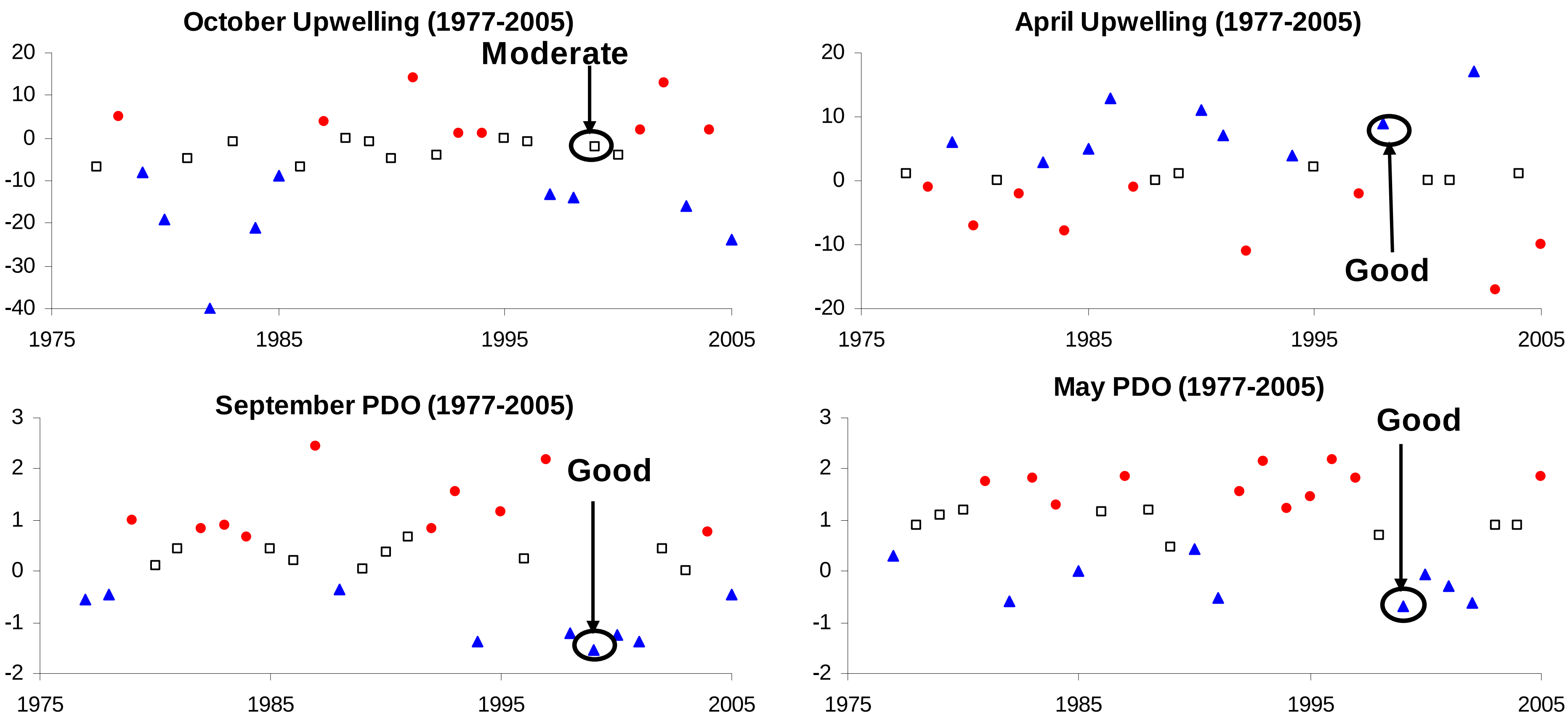


Summarizing the logic used to classify each year

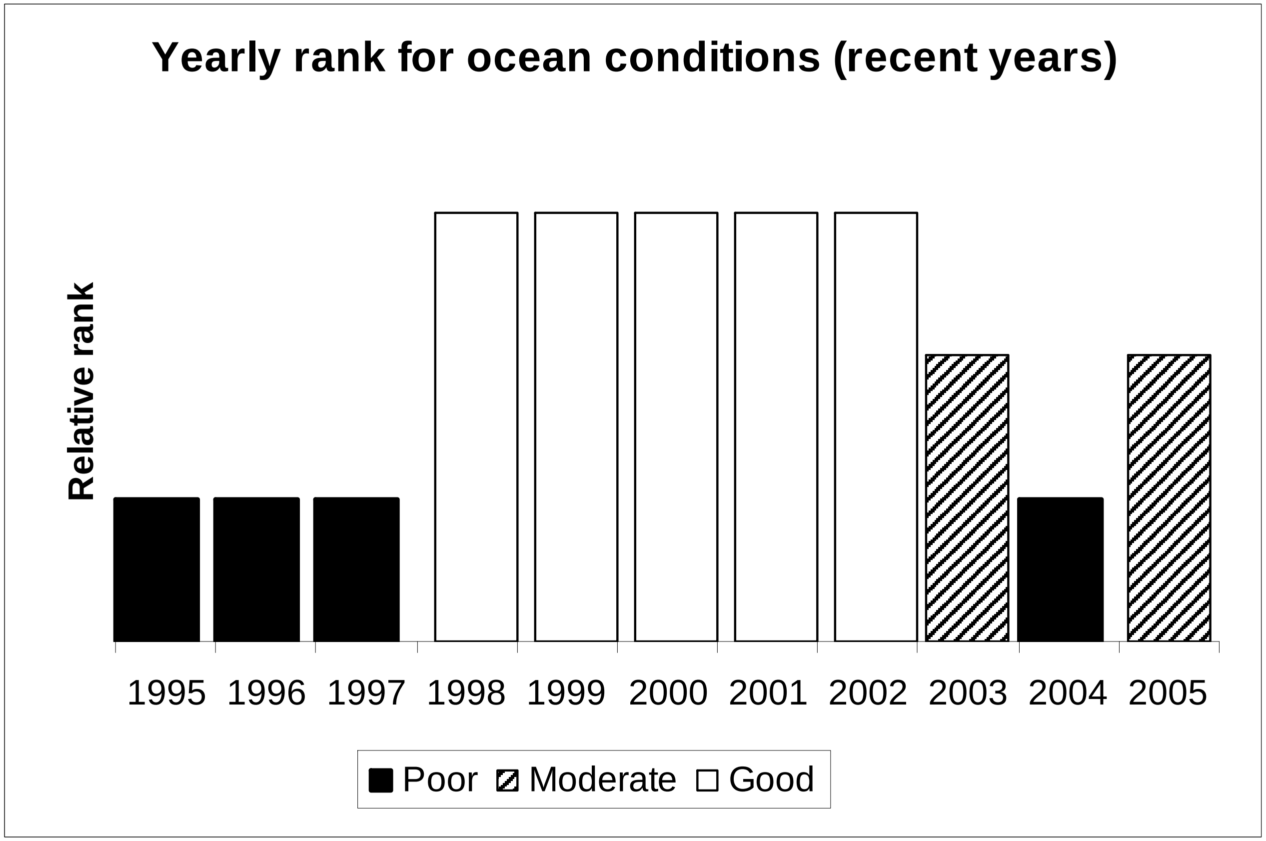
Good (3)	Moderate (2)	Poor (1)	Overall Category
3	1	0	good
3	0	1	good
2	2	0	good
2	1	1	good
1	**2**	1	moderate
1	**3**	0	moderate
0	**3**	1	moderate
2	0	2	moderate
1	0	**3**	poor
0	1	**3**	poor
0	2	**2**	poor
1	1	**2**	poor

Example of categorization method

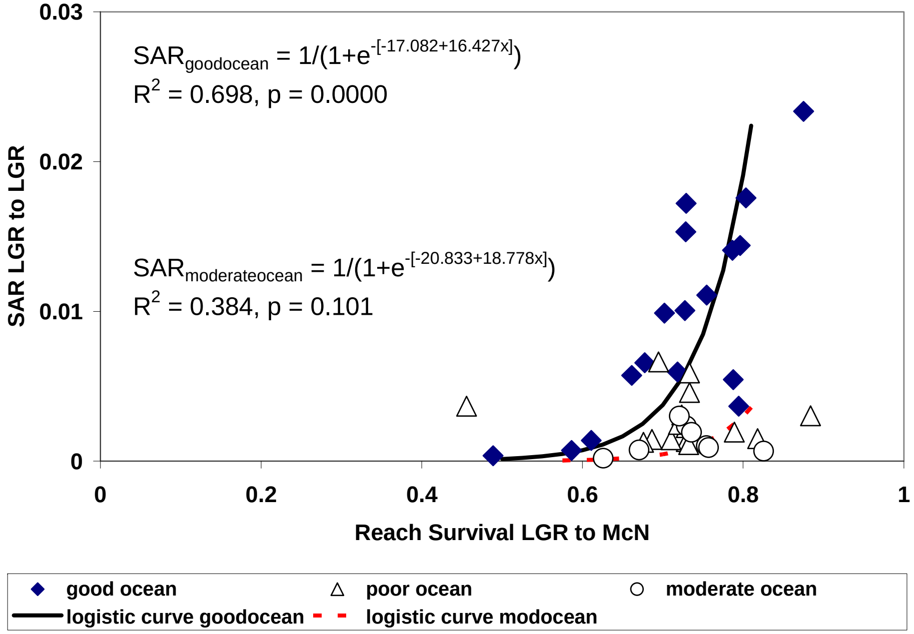
- 1999 categorized as “good” 3-rank “good” (3), 1-rank “mod.” (2)



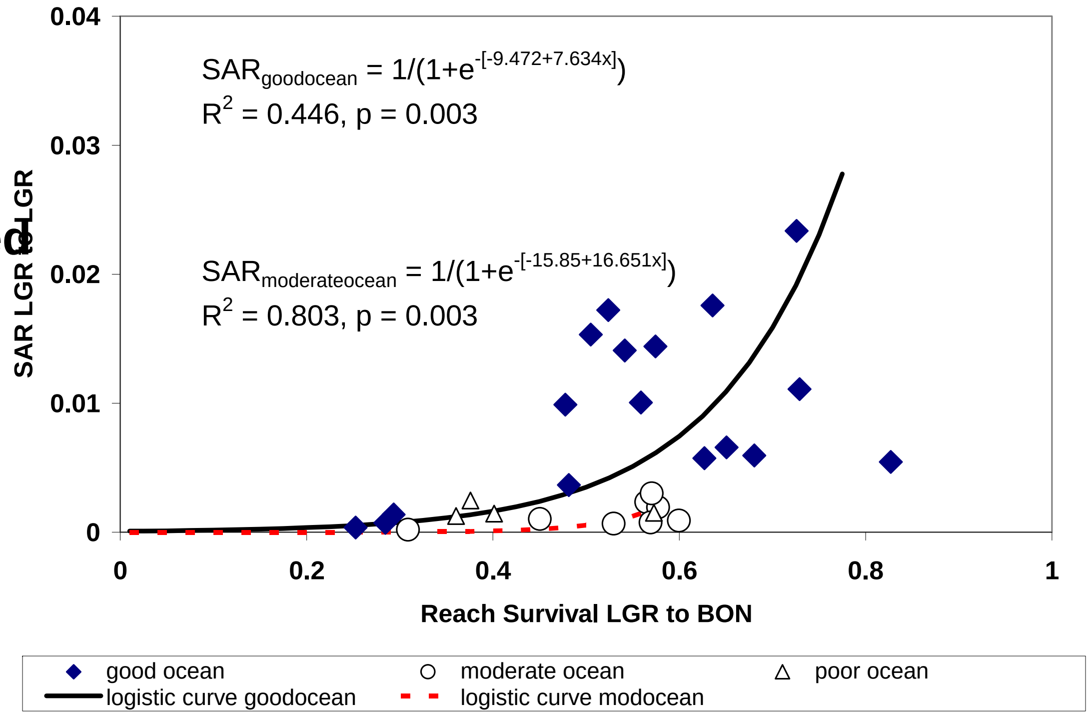
Results of rankings



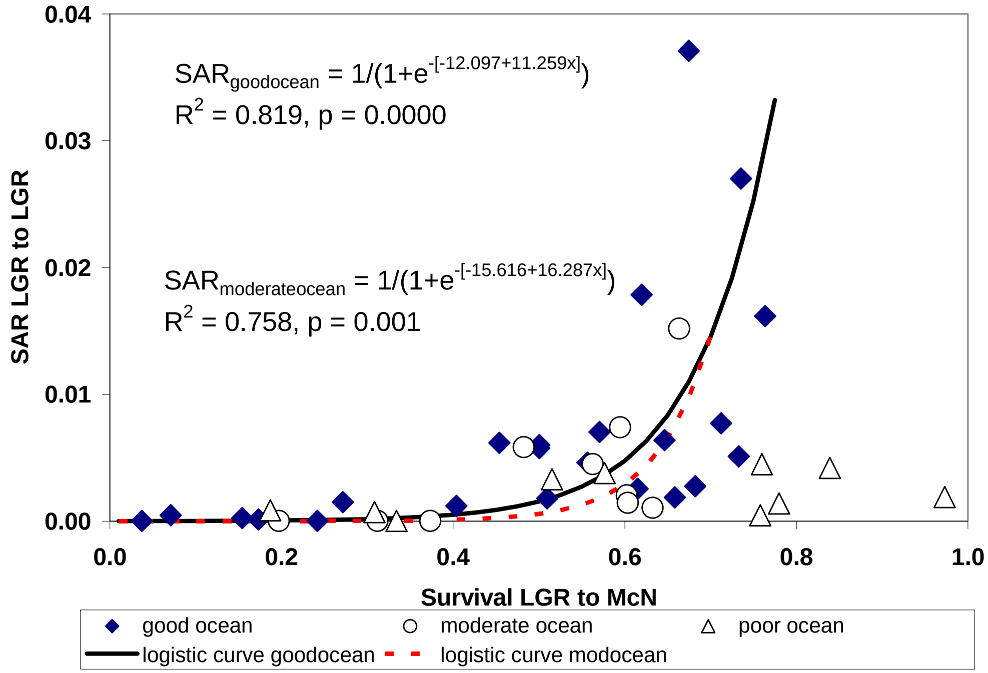
Years listed would be associated with year of juvenile salmon outmigration



Yearling spring\summer Chinook reach survival LGR to McN plotted against SAR LGR to LGR for the years 1995 to 2005 under good, moderate and poor ocean productivity categories.

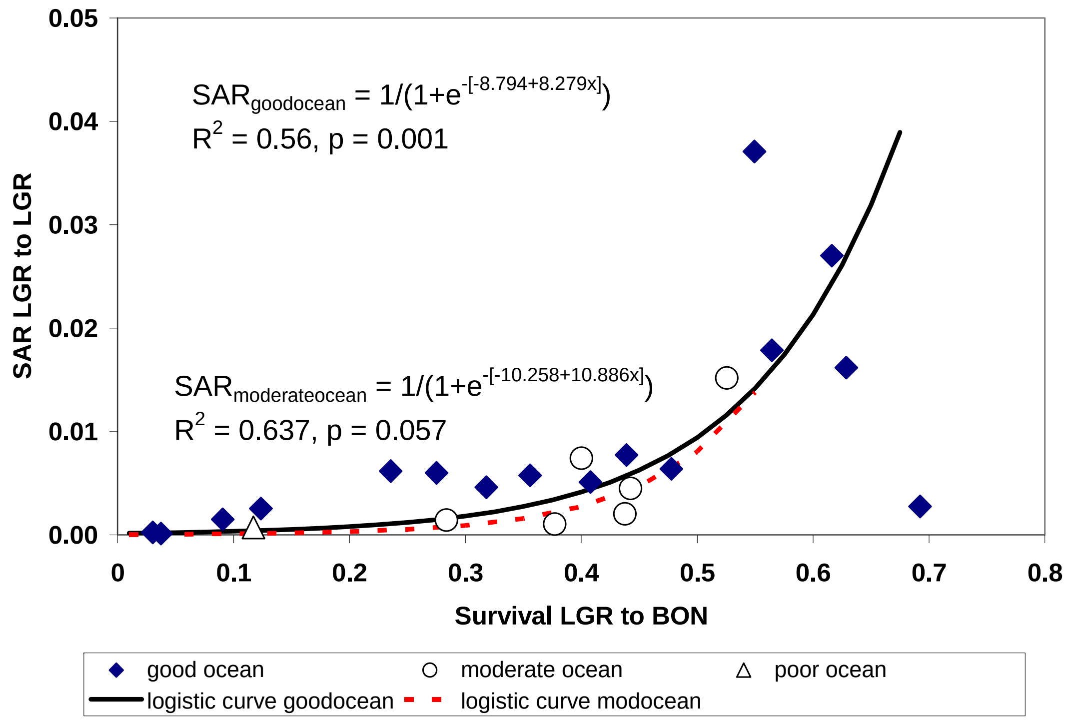


Yearling spring\summer Chinook reach survival LGR to BON plotted against SAR LGR to LGR for the years 1998 to 2005 under good, moderate and poor ocean productivity categories.



Steelhead reach survival LGR to McN plotted against SAR LGR to LGR for the years 1995 to 2005 under good, moderate and poor ocean productivity categories.

Steelhead reach survival LGR to BON plotted against SAR LGR to LGR for the years 1998 to 2005 under good, moderate and poor ocean productivity categories.



Summary of the Relation between Smolt Reach Survival and SARs

- Developed a system for ranking annual ocean productivity using indices from literature
- Plotting relation between SAR and reach survivals at different ocean productivity levels we demonstrated a significant relation exists between reach survival and adult returns for shorter reach LGR to MCN and longer reach LGR to BON

Relation between SARs (and SOAs) and both In-river and Ocean variables

- Regress average spill proportion, Water Transit Time, Date_Grp, April_Upwell, May_PDO, Sept_PDO, and Oct_Upwell against lnSARs and lnSOAs
- Use Information Theoretic Approach to select models, calculate weighted average variables, and weight of evidence of relative importance of each variable in explaining adult return data

Model selection results for **lnSARs** of Snake River spring/summer Chinook versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite, April Upwelling, May and Sept. PDO. Smolt migration years were 1998-2005.

Variables in Models	AICc	delta AICc	weight
AvgSpillProp,Date_grp,May_PDO,Sep_PDO	57.995	0	0.297
AvgSpillProp,May_PDO,Sep_PDO	58.271	0.276	0.259
AvgSpillProp,WTT,Date_grp,May_PDO,Sep_PDO	59.082	1.087	0.172
AvgSpillProp,Date_grp,Apr_Upwell,May_PDO,Sep_PDO	60.84	2.845	0.072
AvgSpillProp,Apr_Upwell,May_PDO,Sep_PDO	61.098	3.103	0.063
AvgSpillProp,WTT,May_PDO,Sep_PDO	61.439	3.444	0.053
AvgSpillProp,WTT,Date_grp,Apr_Upwell,May_PDO,Sep_PDO	62.833	4.838	0.026
AvgSpillProp,May_PDO	63.004	5.009	0.024
AvgSpillProp,Date_grp,Apr_Upwell,May_PDO	63.747	5.752	0.017

Model selection results for **lnSOAs** of Snake River spring/summer Chinook versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite, April Upwelling, May and Sept. PDO. Smolt migration years were 1998-2005.

Variables in Models	AICc	delta AICc	weight
AvgSpillProp,WTT,Date_grp,May_PDO,Sep_PDO	56.933	0	0.360
AvgSpillProp,Apr_Upwell,May_PDO,Sep_PDO	57.222	0.289	0.312
AvgSpillProp,Date_grp,May_PDO	59.141	2.208	0.119
AvgSpillProp,May_PDO	60.372	3.439	0.065
AvgSpillProp,WTT,Date_grp,Apr_Upwell,May_PDO,Sep_PDO	60.399	3.466	0.064
AvgSpillProp,Date_grp,Apr_Upwell,May_PDO	60.919	3.986	0.049
AvgSpillProp,Apr_Upwell,May_PDO	62.315	5.382	0.024

Model selection results for **lnSARs** of Snake River steelhead versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite, April Upwelling, May and Sept. PDO. Smolt migration years were 1998-2005.

Variables in Models	AICc	delta AICc	weight
AvgSpillProp,Date_grp	59.921	0	0.254
AvgSpillProp,Date_grp,May_PDO	60.399	0.478	0.200
AvgSpillProp,WTT,Date_grp	60.873	0.952	0.158
AvgSpillProp,WTT,Date_grp,May_PDO	61.297	1.376	0.128
AvgSpillProp,WTT,Date_grp,May_PDO,Sep_PDO	62.778	2.857	0.061
AvgSpillProp,WTT,Date_grp,Apr_Upwell	63.146	3.225	0.051
AvgSpillProp,Date_grp,Sep_PDO	63.191	3.27	0.050
AvgSpillProp,WTT,Date_grp,Sep_PDO	63.451	3.53	0.044
AvgSpillProp,WTT,Date_grp,Apr_Upwell,May_PDO	65.12	5.199	0.019
AvgSpillProp,WTT,Date_grp,May_PDO,Sep_PDO,Oct_Upwell	65.931	6.01	0.013

Model selection results for **lnSOAs** of Snake River steelhead versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite, April Upwelling, May and Sept. PDO. Smolt migration years were 1998-2005.

Variables in Models	AICc	delta AICc	weight
AvgSpillProp,Date_grp,May_PDO	46.209	0	0.185
AvgSpillProp,WTT,May_PDO	46.316	0.107	0.175
AvgSpillProp,Date_grp,Apr_Upwell,May_PDO	47.046	0.837	0.122
AvgSpillProp,May_PDO	47.387	1.178	0.103
AvgSpillProp,Apr_Upwell,May_PDO	47.579	1.37	0.093
AvgSpillProp,WTT,Date_grp,May_PDO	48.403	2.194	0.062
AvgSpillProp,WTT,May_PDO,Oct_Upwell	48.802	2.593	0.051
AvgSpillProp,WTT,Apr_Upwell,May_PDO	49.308	3.099	0.039
AvgSpillProp,Apr_Upwell,May_PDO,Sep_PDO	50.216	4.007	0.025
AvgSpillProp,May_PDO,Oct_Upwell	50.468	4.259	0.022
AvgSpillProp,May_PDO,Sep_PDO	50.513	4.304	0.022
AvgSpillProp,May_PDO,Apr_Upwell,Oct_Upwell	50.783	4.574	0.019
AvgSpillProp,WTT,Date_grp,Apr_Upwell,May_PDO	51.112	4.903	0.016
AvgSpillProp,Date_grp,May_PDO,Apr_Upwell,Oct_Upwell	51.123	4.914	0.016

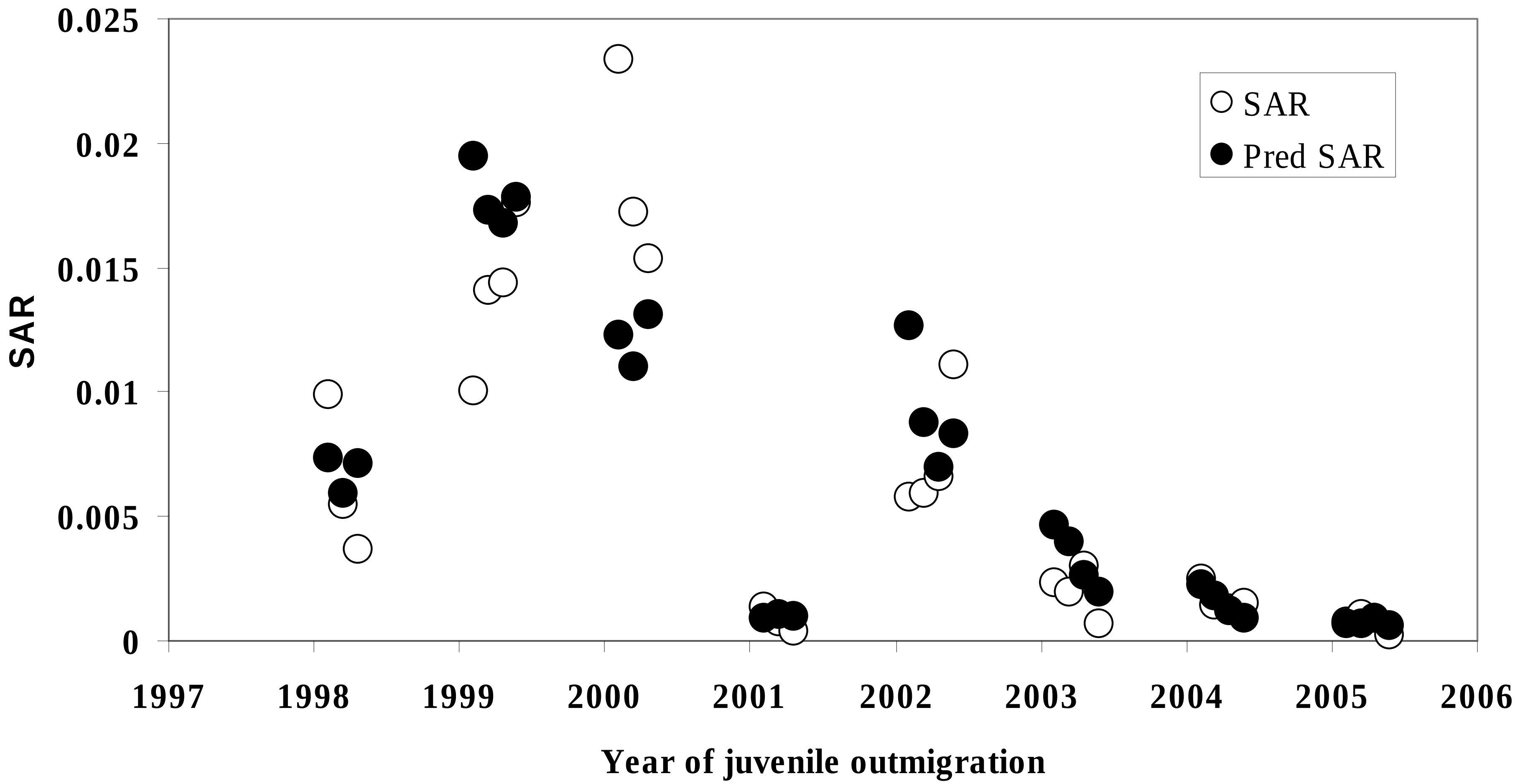
Weight of evidence for each variable in explaining variability in adult return data for Snake River spring/summer Chinook and steelhead.

	Relative Weight of Evidence for each variable by Species and Reach			
Variable	Yearling Chinook lnSAR	Yearling Chinook lnSOA	Steelhead lnSAR	Steelhead lnSOA
AvgSpillProp	0.996	0.999	1.000	0.991
May_PDO	0.999	0.999	0.431	0.981
Date_Grp	0.588	0.593	0.985	0.423
Sep_PDO	0.946	0.736	0.178	0.062
WTT	0.258	0.430	0.483	0.375
Apr_Upwell	0.191	0.455	0.081	0.349
Oct_Upwell			0.016	0.130

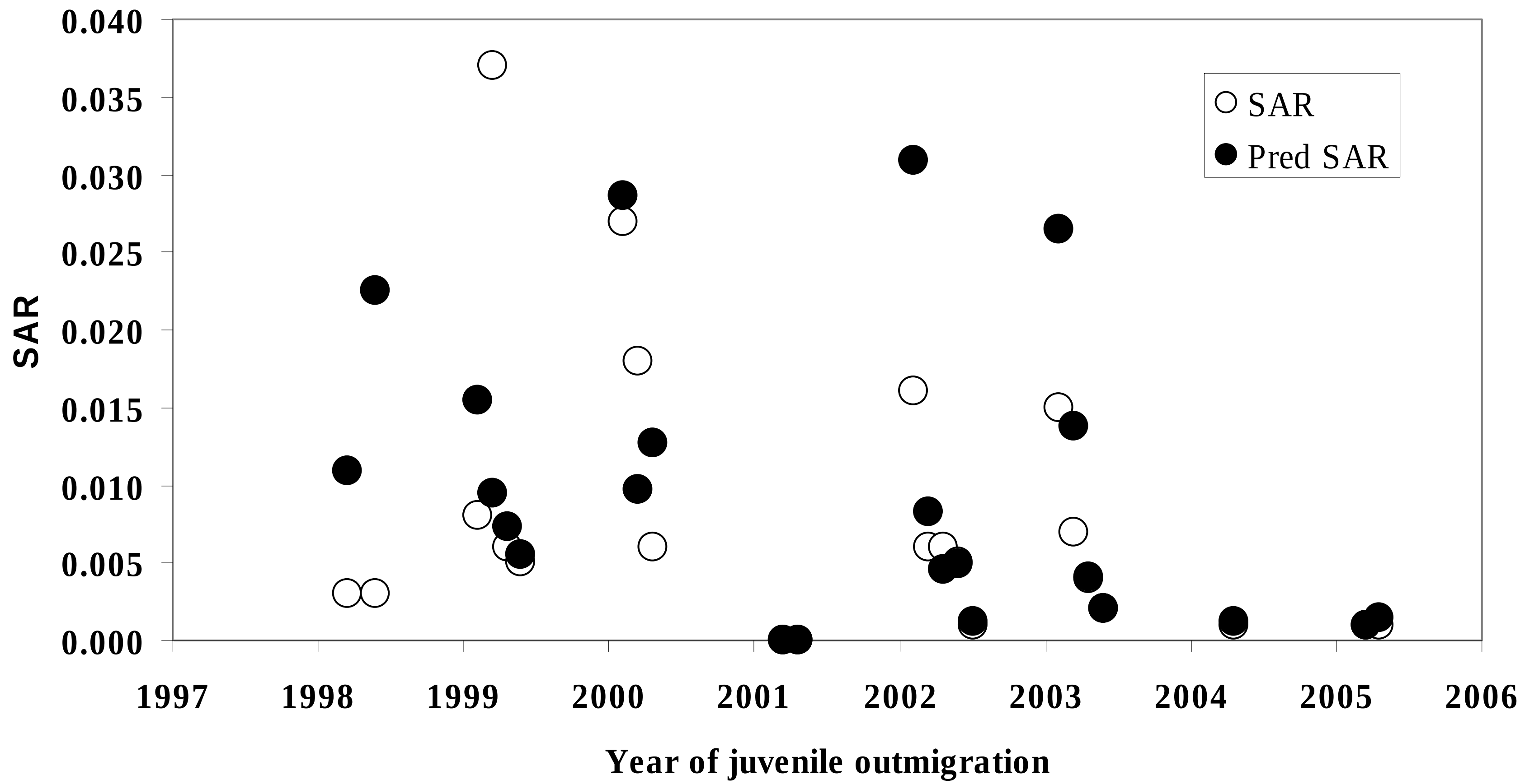
Model averaged coefficients for Snake River yearling spring/summer chinook and steelhead lnSARs and lnSOAs versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite, April Upwelling, May PDO, Sept. PDO and Oct. Upwelling.

Species and Dependent Variable	Constant	Avg Spill Prop	WTT	DateGrp	April Upwell	May PDO	Sept PDO	Oct. Upwel
Yearling Chinook ln SOA	-6.784	0.065	-0.005	-0.117	0.003	-0.750	-0.257	NA
Yearling Chinook ln SAR	-8.080	0.088	-0.012	-0.128	0.002	-0.796	-0.313	NA
Steelhead Ln SOA	-6.663	0.064	0.026	-0.080	-0.006	-0.630	-0.007	-0.001
Steelhead Ln SAR	-10.276	0.192	-0.050	-0.564	0.000	-0.147	0.041	-0.001

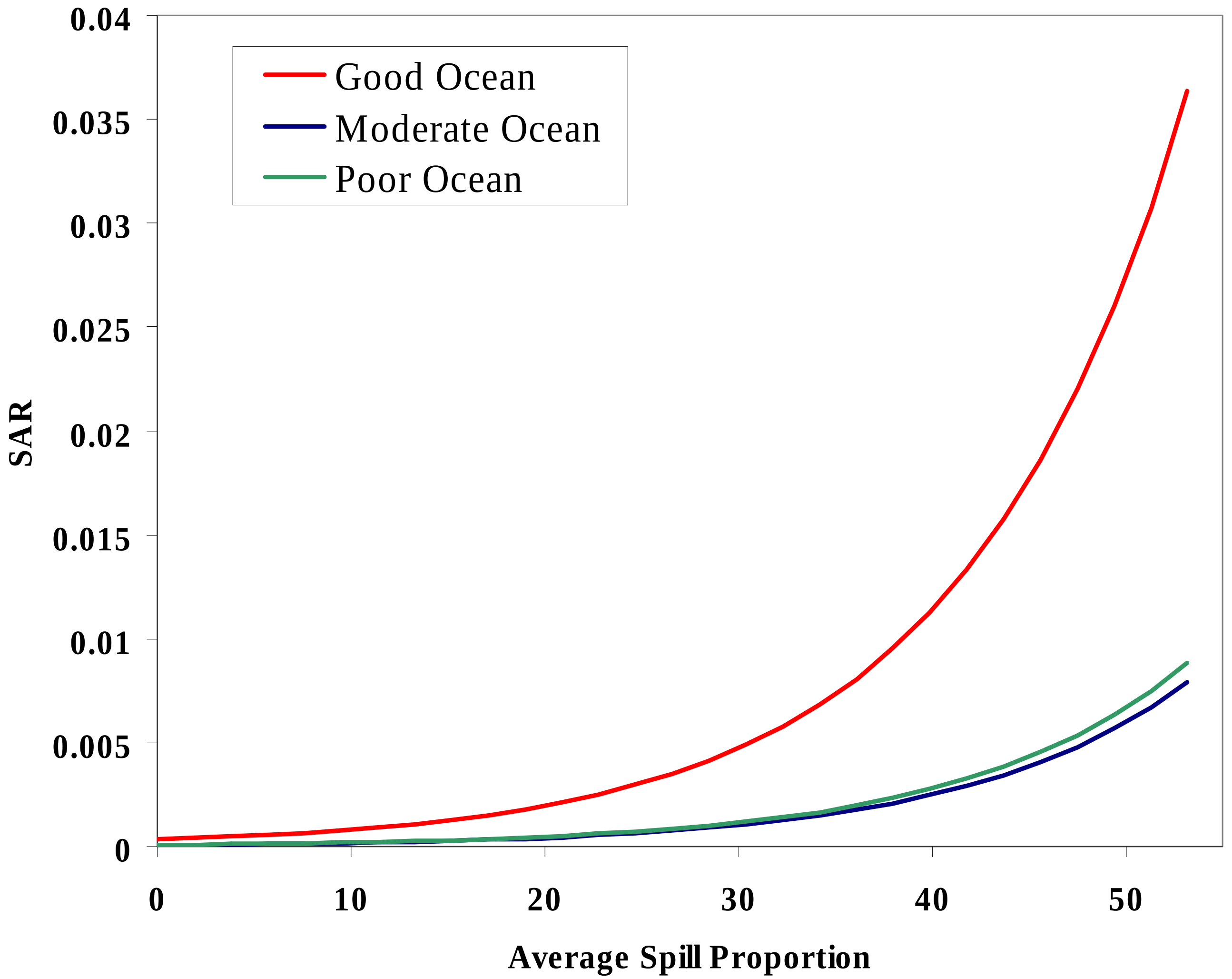
SAR compared to Predicted SAR (survival from Lower Granite Dam to Lower Granite Dam), for Snake River spring/summer Chinook (R^2 = 0.7019).



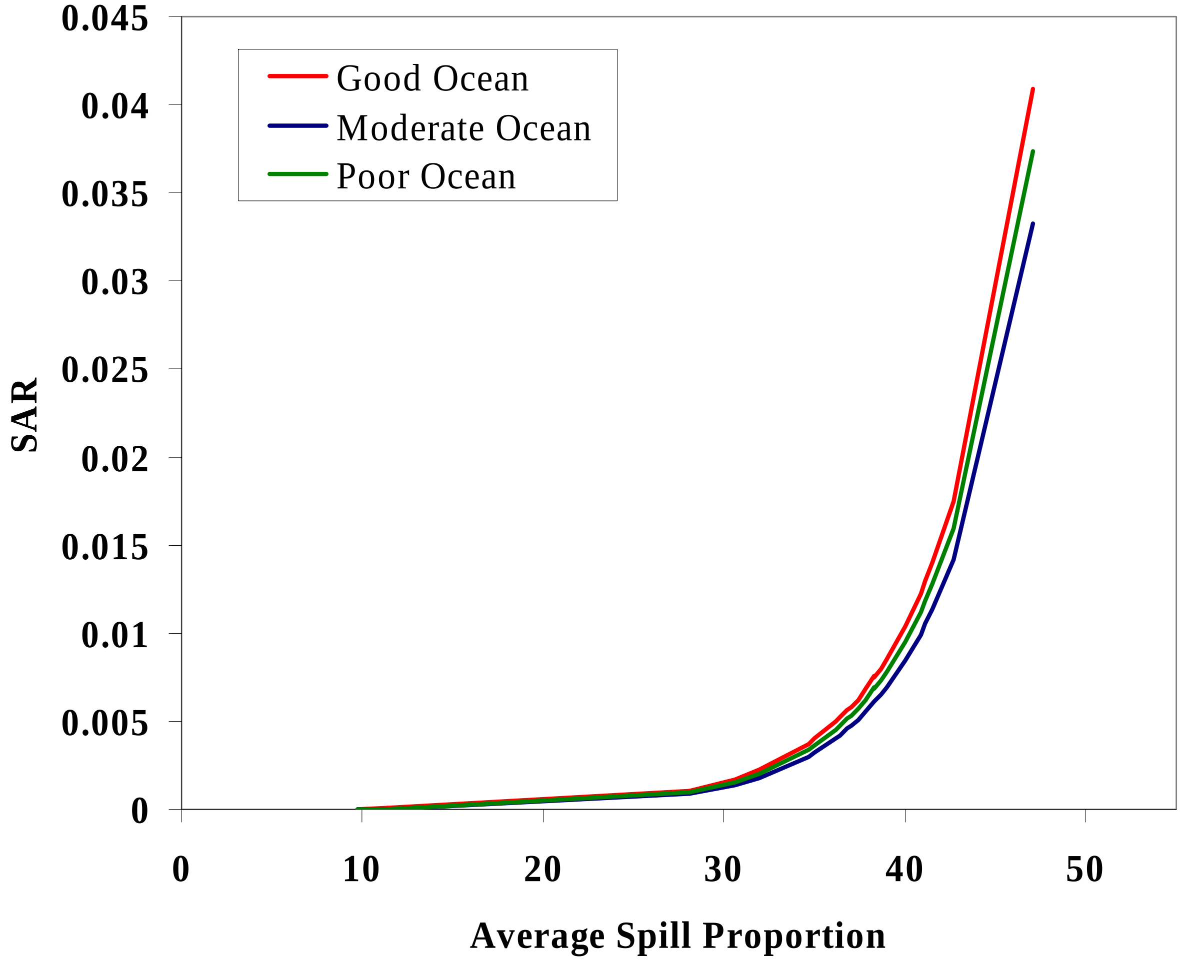
SAR compared to Predicted SAR (survival from Lower Granite Dam to Lower Granite Dam), for Snake River steelhead (R^2 = 0.309).



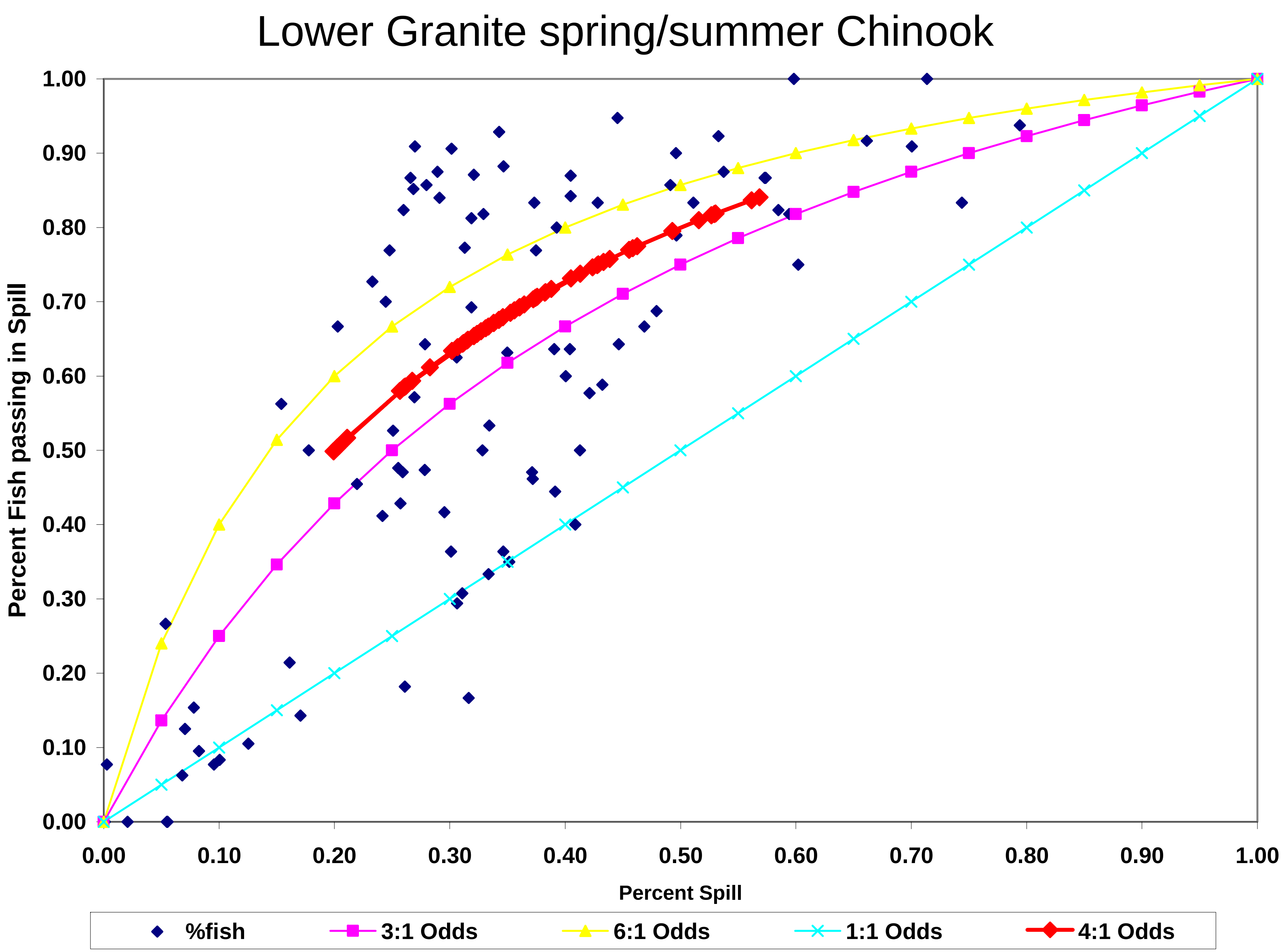
Predicted response to increasing spill volumes of SAR's for spring/summer Chinook salmon under good, moderate and poor ocean productivity levels.



Predicted response to increasing spill volumes of SAR's for steelhead under good, moderate and poor ocean productivity levels.

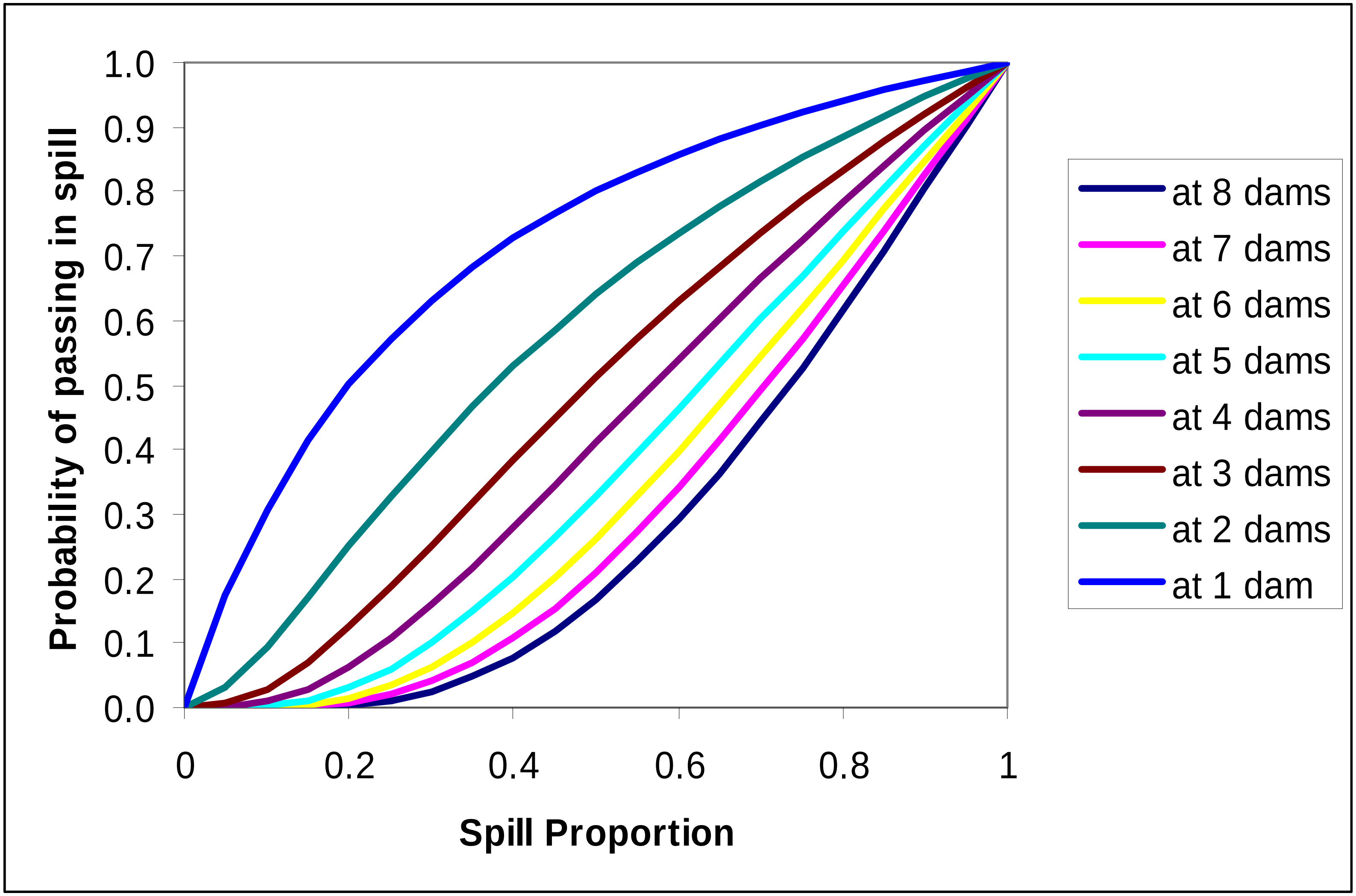


Avg_Spill_Prop e.g.



Avg_Spill_Prop e.g. continued

Probability of passing in spill at 8 dams with 4:1 spill odds



Conclusions

- Smolt Survival analyses continue to show a strong relation between reach survival and spill using either multiple regression or information theoretic approaches
- Predictive models suggest increased spill would result in increased in reach survival
- Plotting relation between SAR and reach survivals at different ocean productivity levels we demonstrated a significant relation exists between reach survival and adult returns for shorter reach LGR to MCN and longer reach LGR to BON

Conclusions continued

- Analysis of SOA and SAR data shows that spill proportion is an important explanatory variable—comparible to ocean indices suggesting delayed hydro-system effects
- Predictive modelling shows increasing benefit to spill as average spill proportion increases above 40%.
- One likely mechanism is the probability of fish passing via spill increases dramatically as average spill proportion goes above 40%