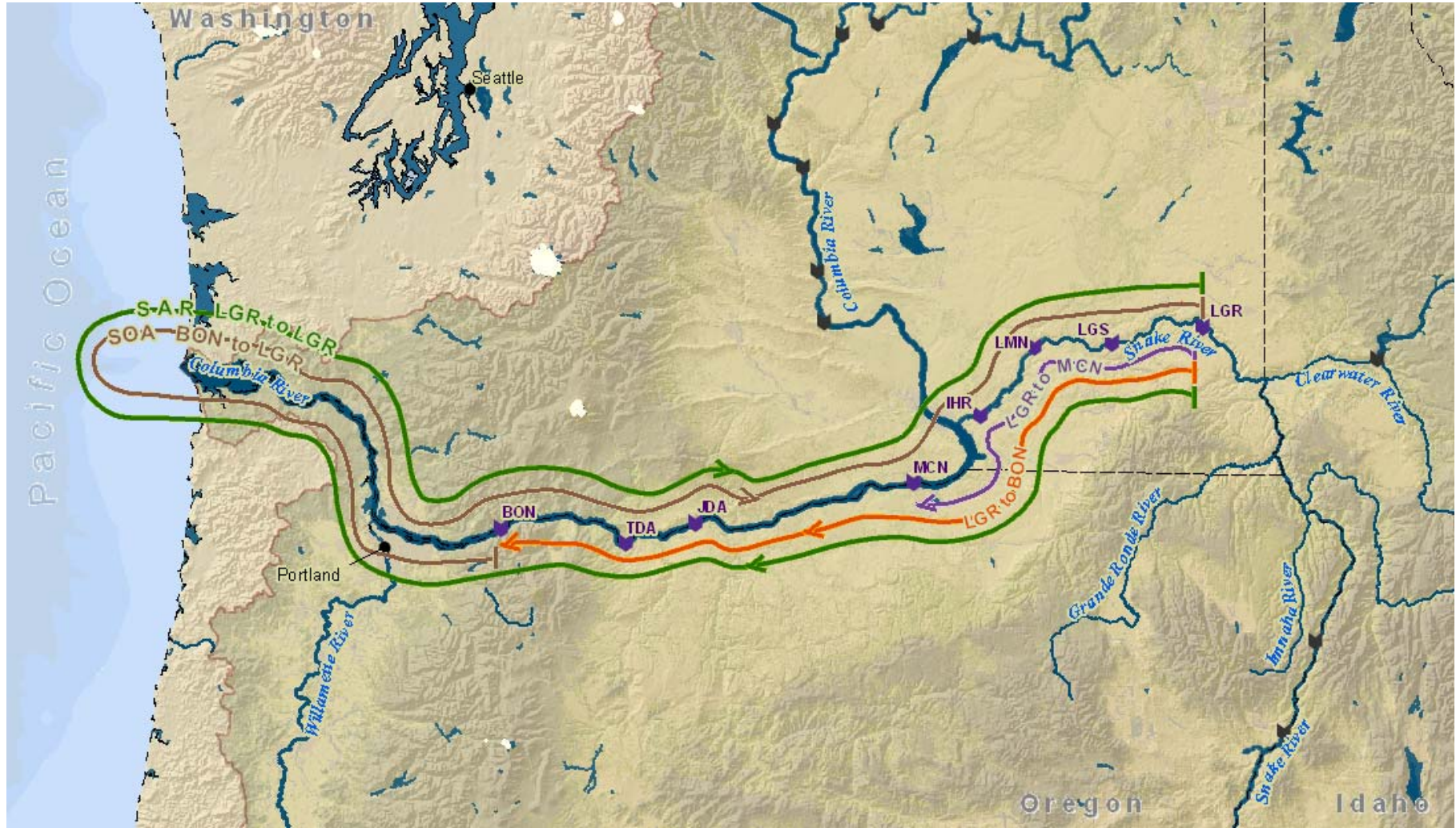


Importance of spill in Juvenile Hydro-system Survivals and SARs

Preliminary Analysis

Jerry McCann
Fish Passage Center
February 2008

- 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



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.

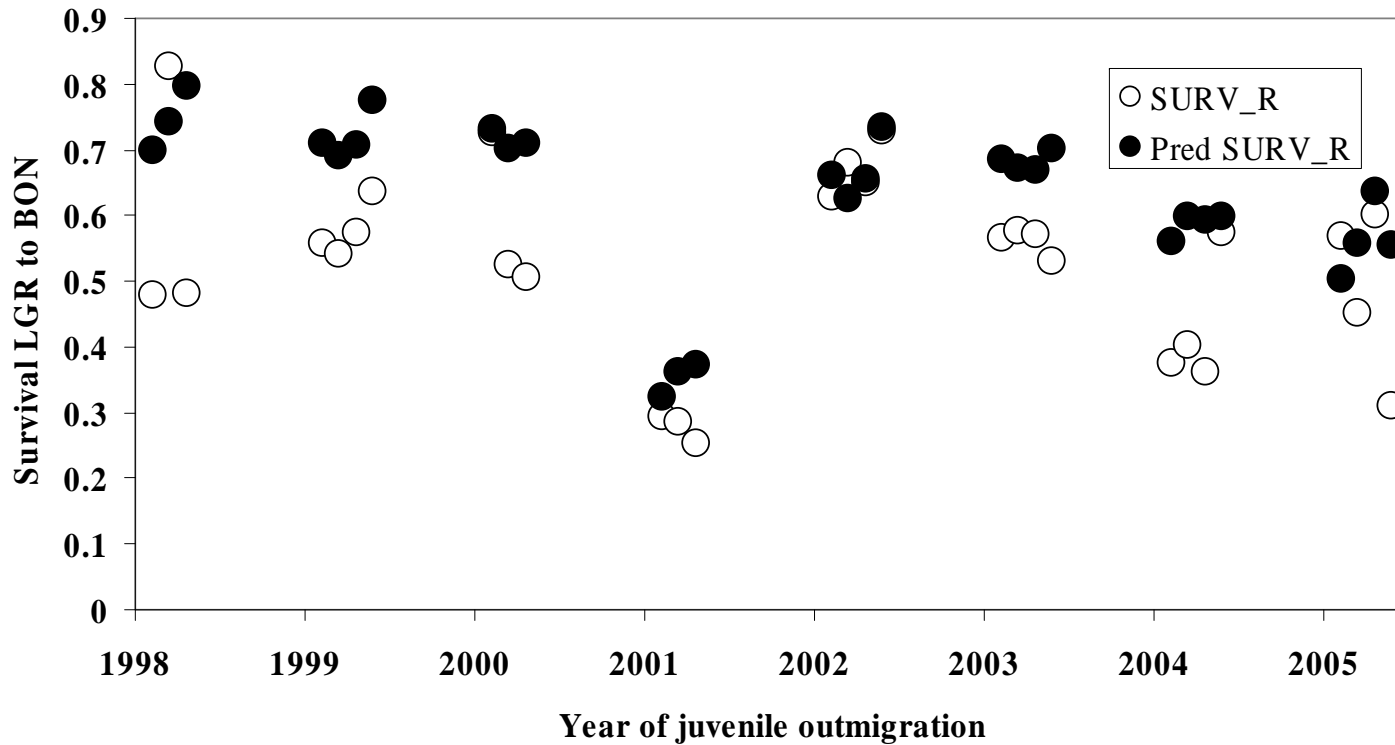
Relative Weight of Evidence for each variable
by Species

| Variable | Spr/Smr Chinook | Steelhead |
|--------------|-----------------|-----------|
| AvgSpillProp | 0.97 | 0.98 |
| WTT | 0.85 | 0.96 |
| Date_Grp | 0.28 | 1.00 |

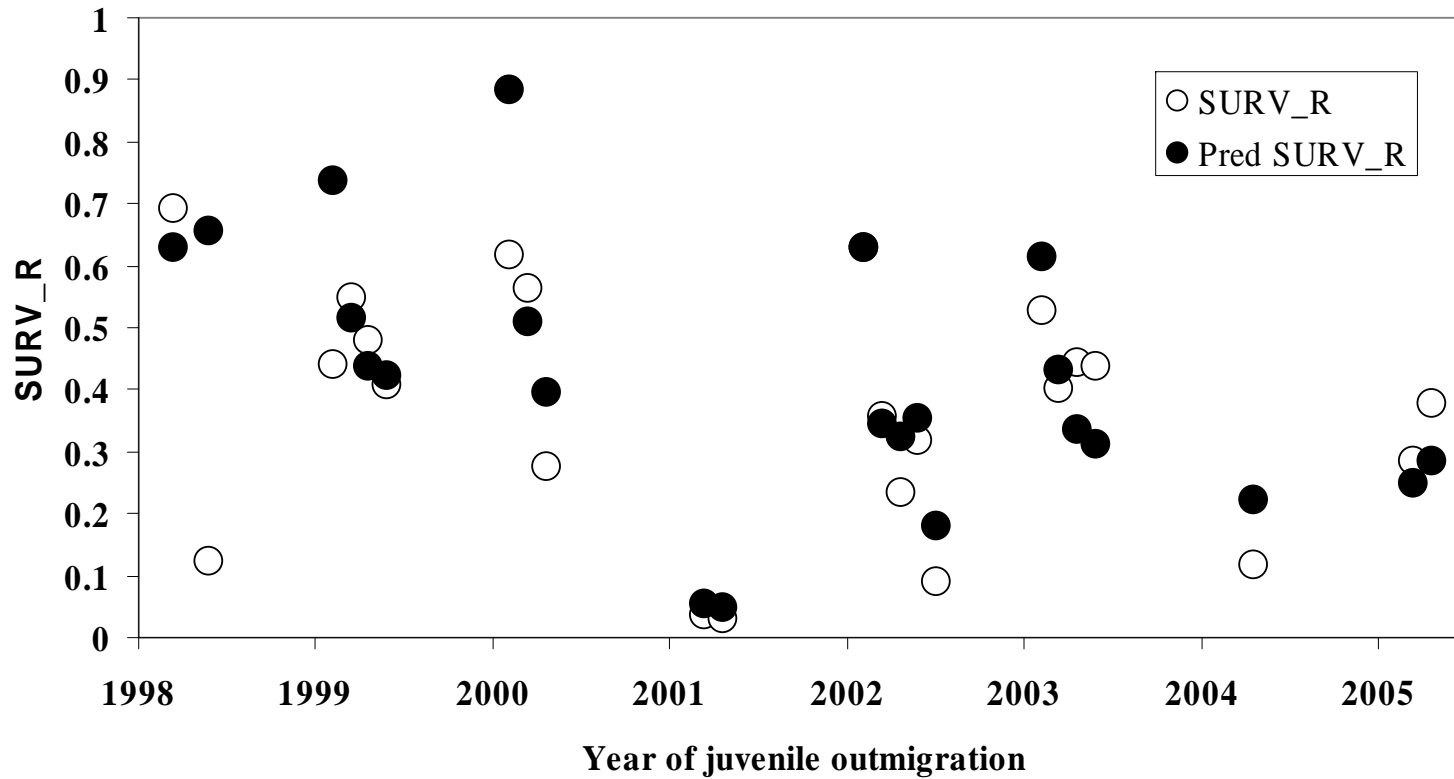
Model averaged coefficients for Snake River yearling spring/summer chinook and steelhead lnSURV_R versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite.

| 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 |

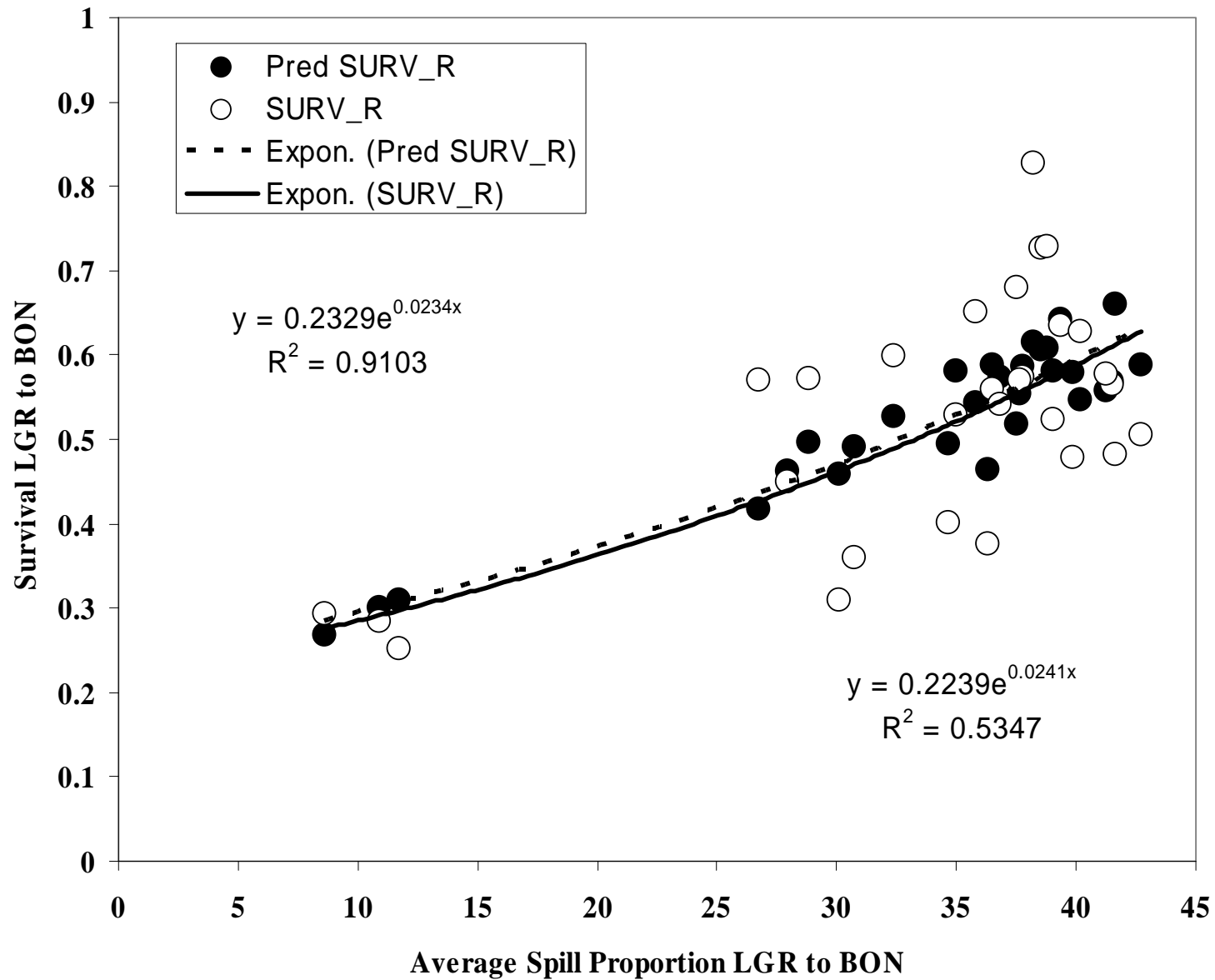
SURV_R compared to Predicted SURV_R (survival from Lower Granite Dam to Bonneville Dam), for Snake River yearling spring/summer Chinook ($R^2 = 0.5198$).



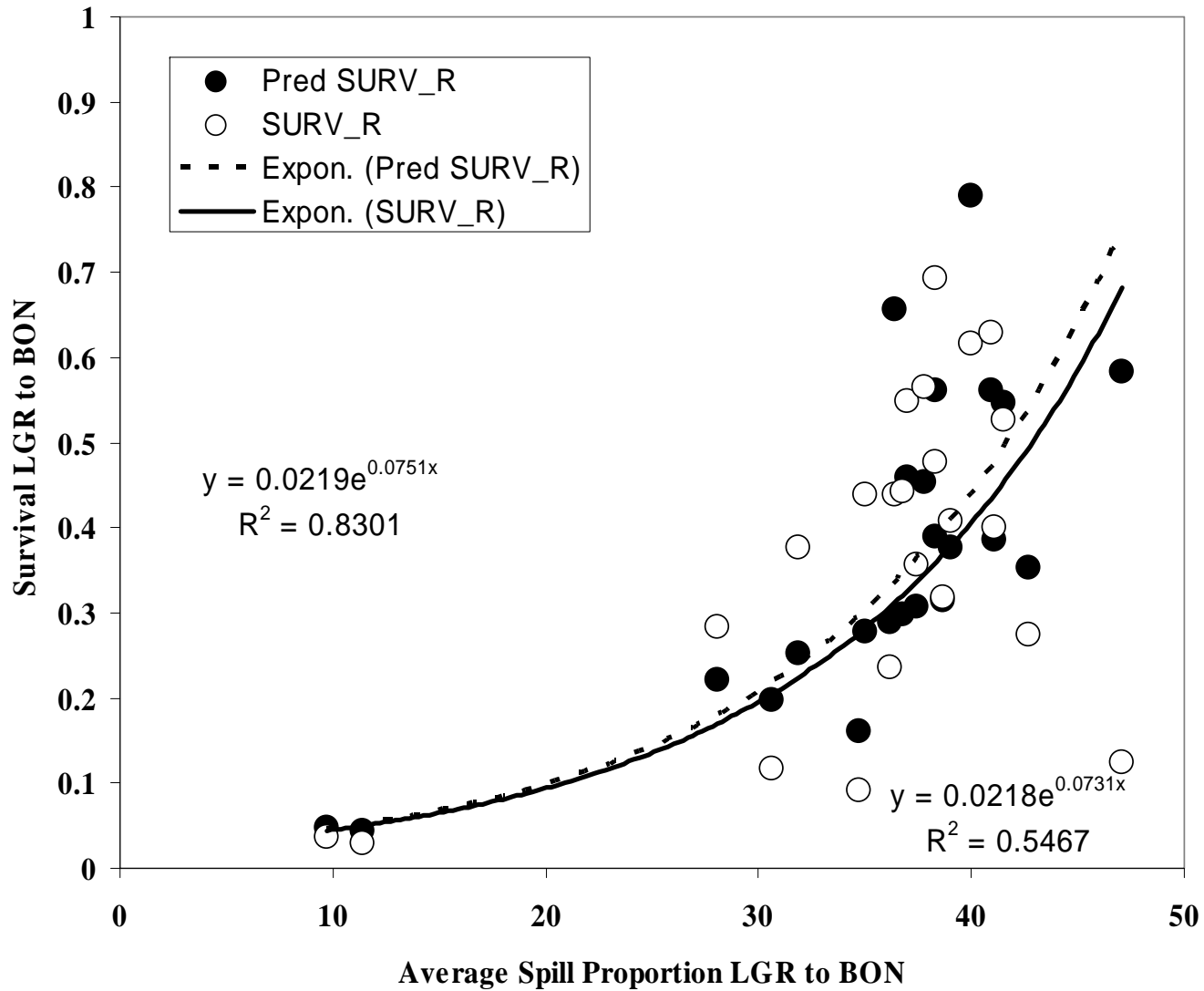
SURV_R compared to Predicted SURV_R (survival from Lower Granite Dam to Bonneville Dam), for Snake River steelhead ($R^2 = 0.534$).



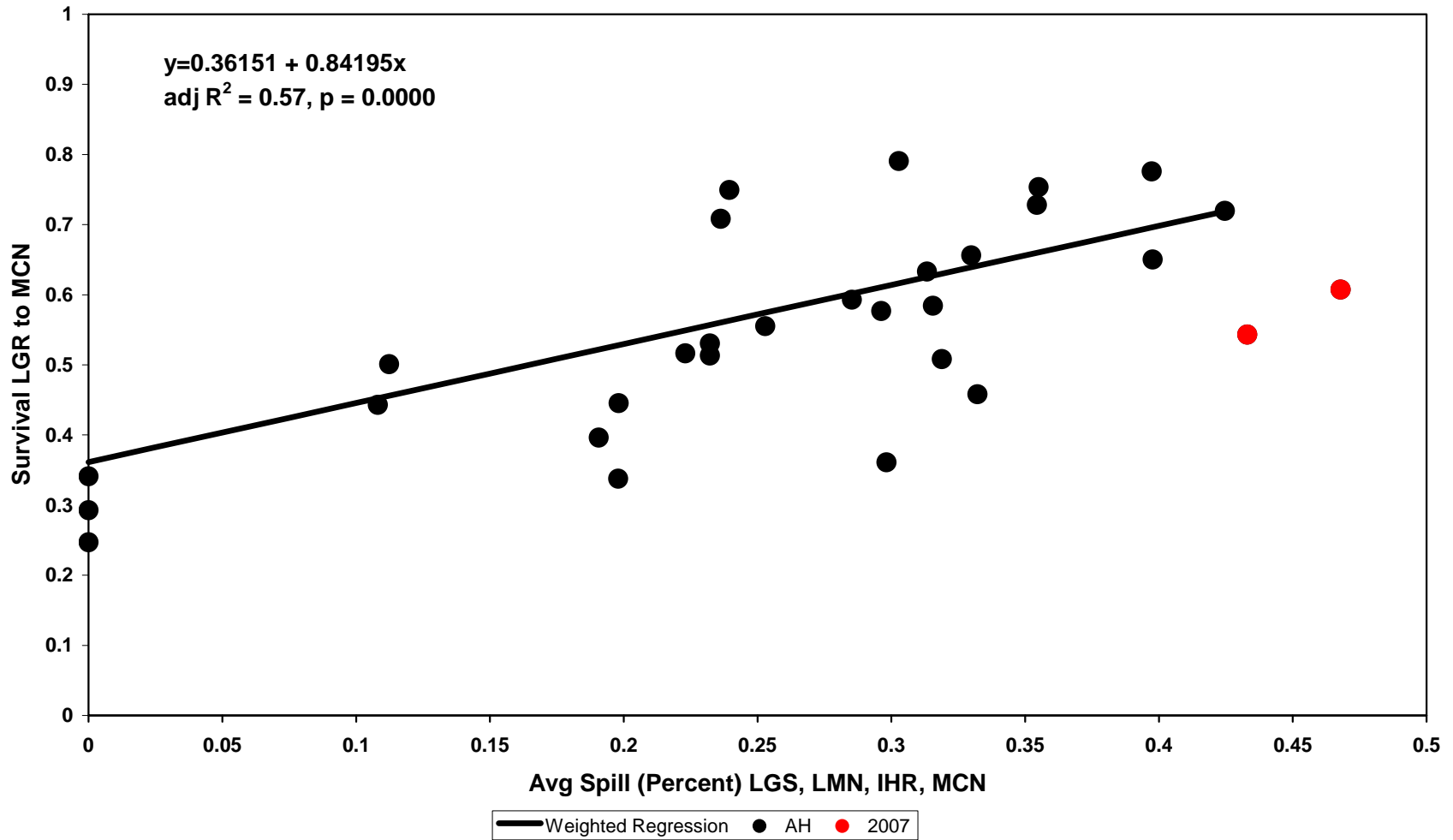
Predicted Survival LGR to BON for Snake River spring/summer Chinook compared to observed data



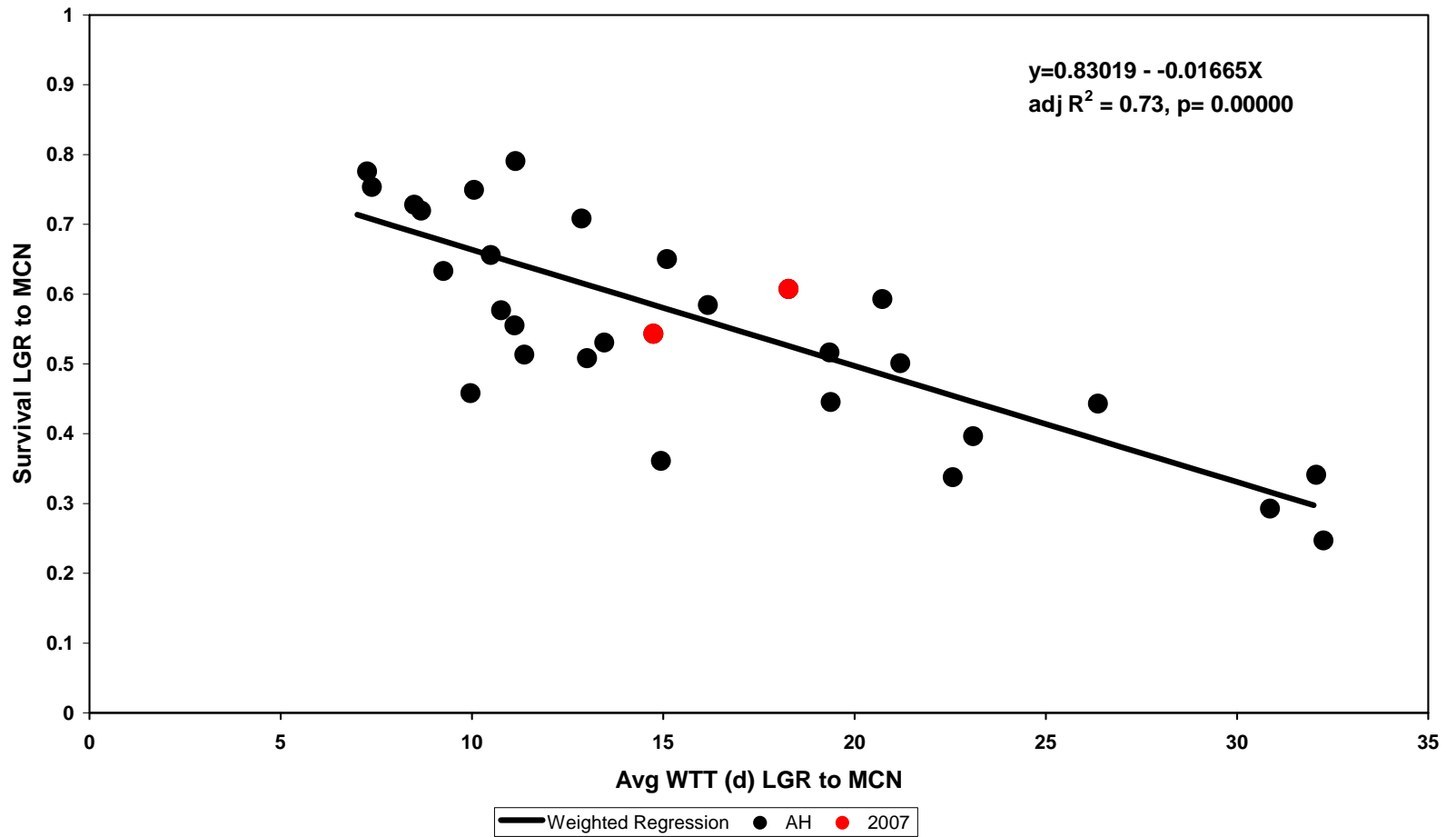
Predicted Survival LGR to BON for Snake River steelhead compared to observed data



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

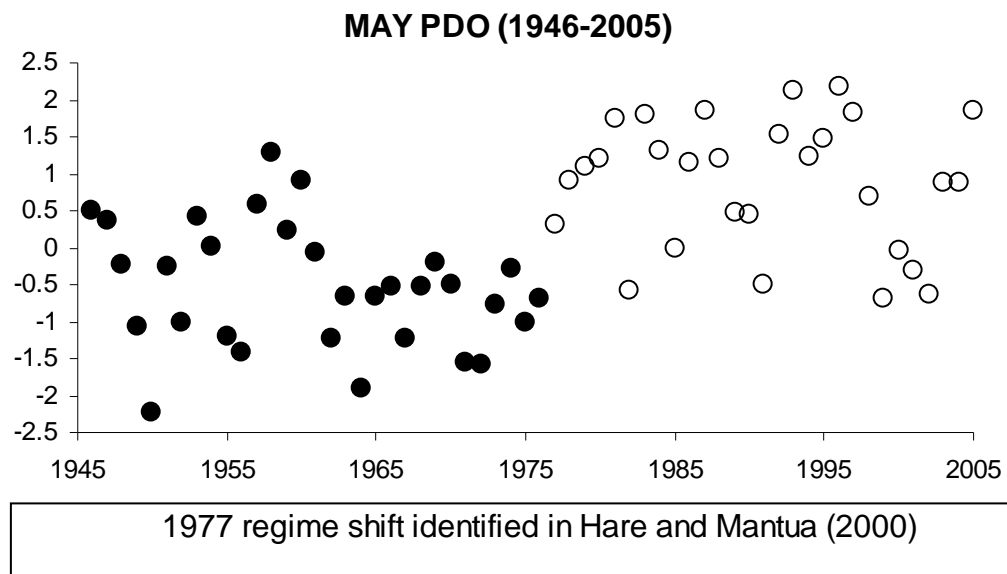
Ocean Indices

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

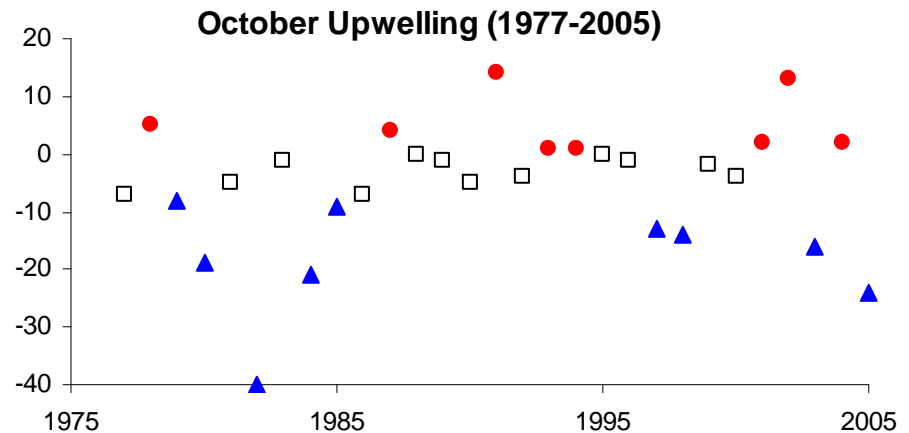
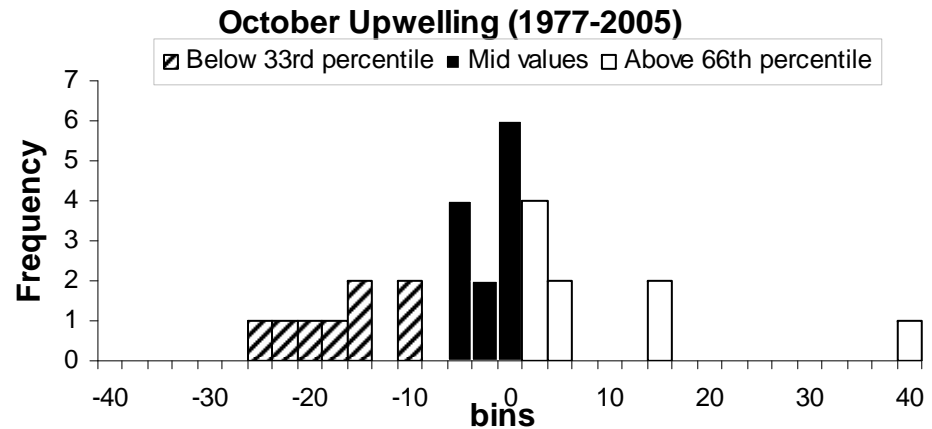
Regime Shift

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



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

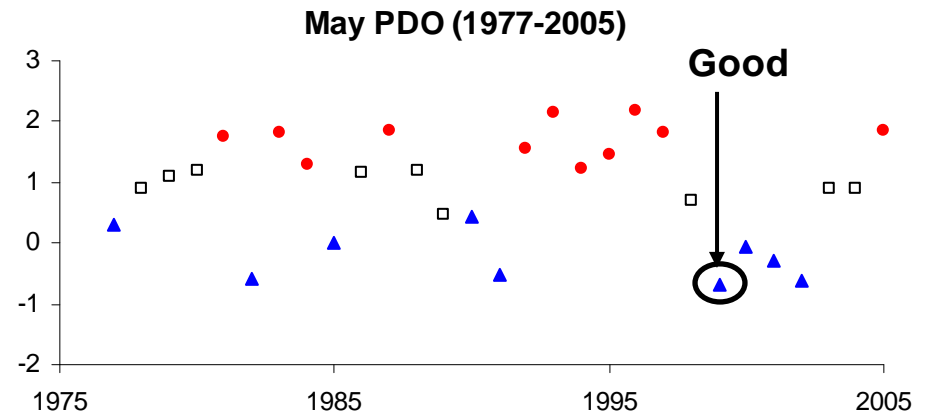
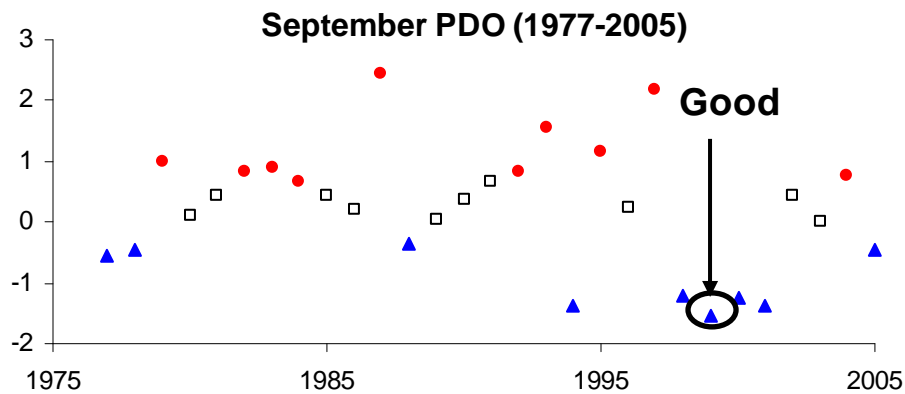
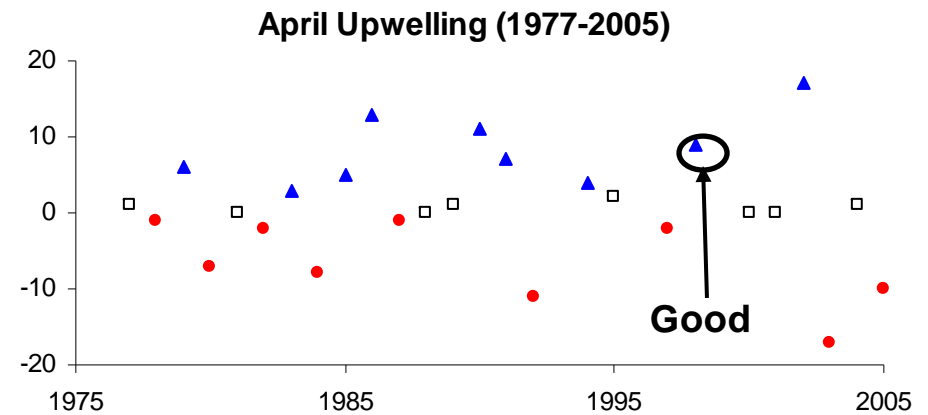
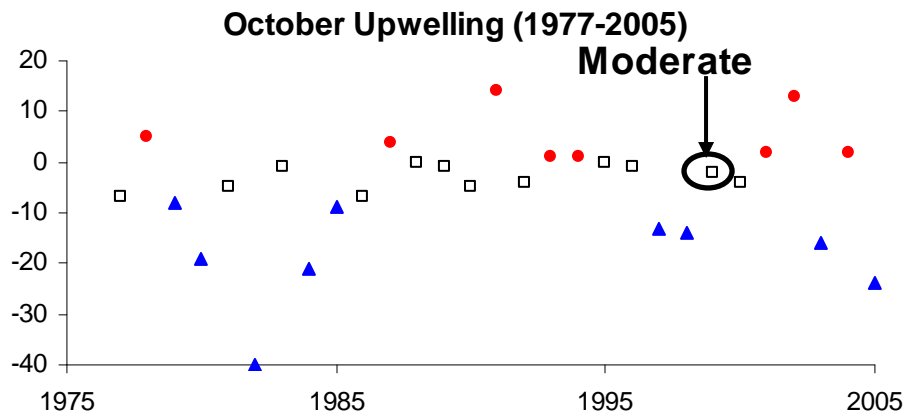


Summarizing the logic used to classify each year

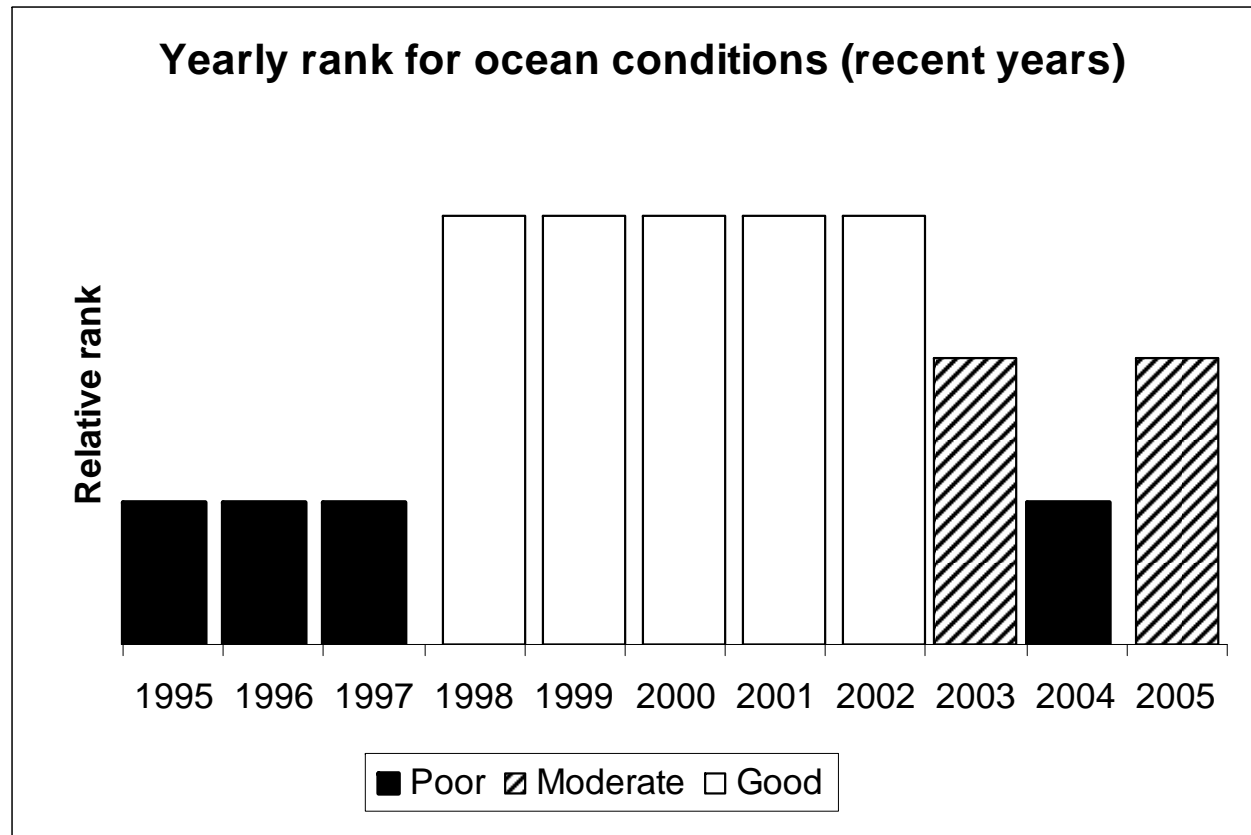
| Good (3) | Moderate (2) | Poor (1) | Overall Category |
|----------|--------------|----------|------------------|
| 3 | 1 | 0 | good |
| 3 | 0 | 1 | good |
| 2 | 2 | 0 | good |
| 2 | 1 | 1 | good |
| 1 | 2 | 1 | moderate |
| 1 | 3 | 0 | moderate |
| 0 | 3 | 1 | moderate |
| 2 | 0 | 2 | moderate |
|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

Example of categorization method

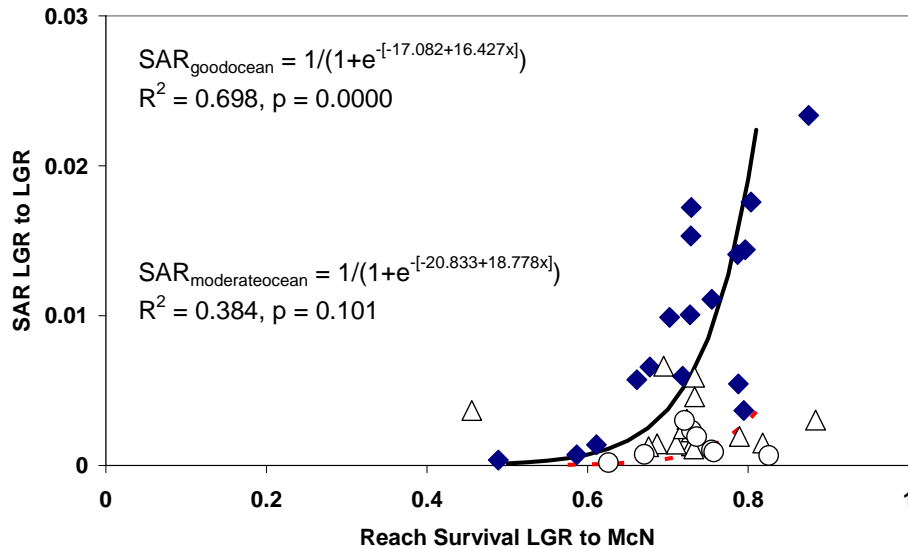
- 1999 categorized as “good” 3-rank “good” (3), 1-rank “mod.” (2)



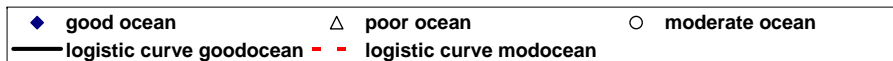
Results of rankings



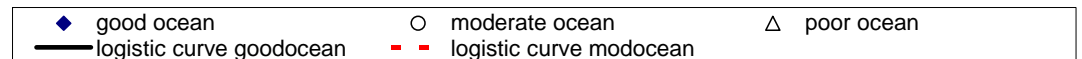
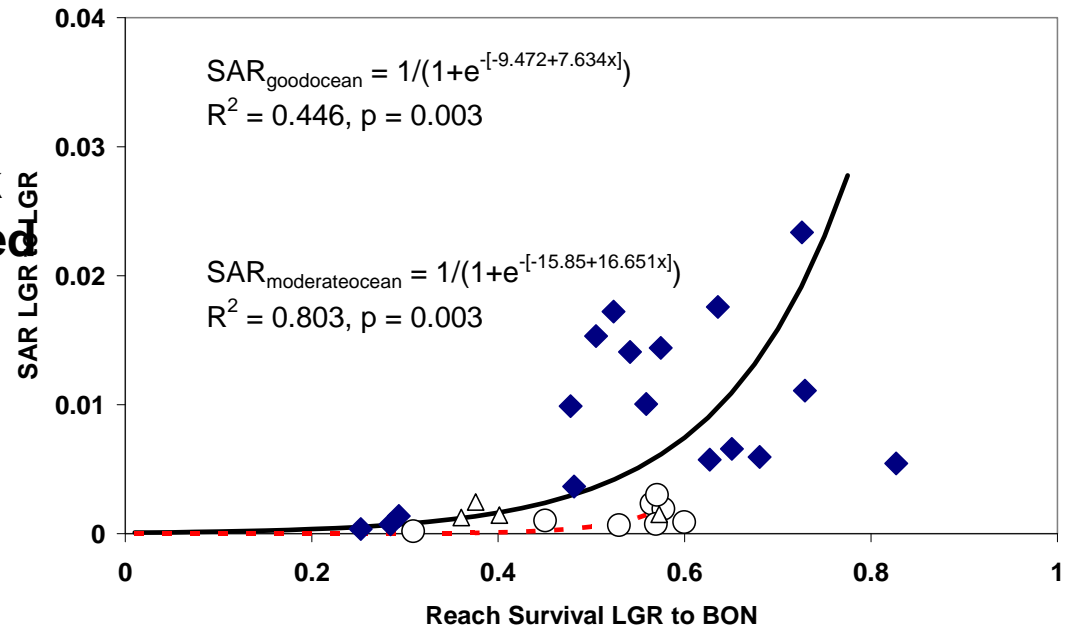
Years listed would be associated with year of juvenile salmon outmigration

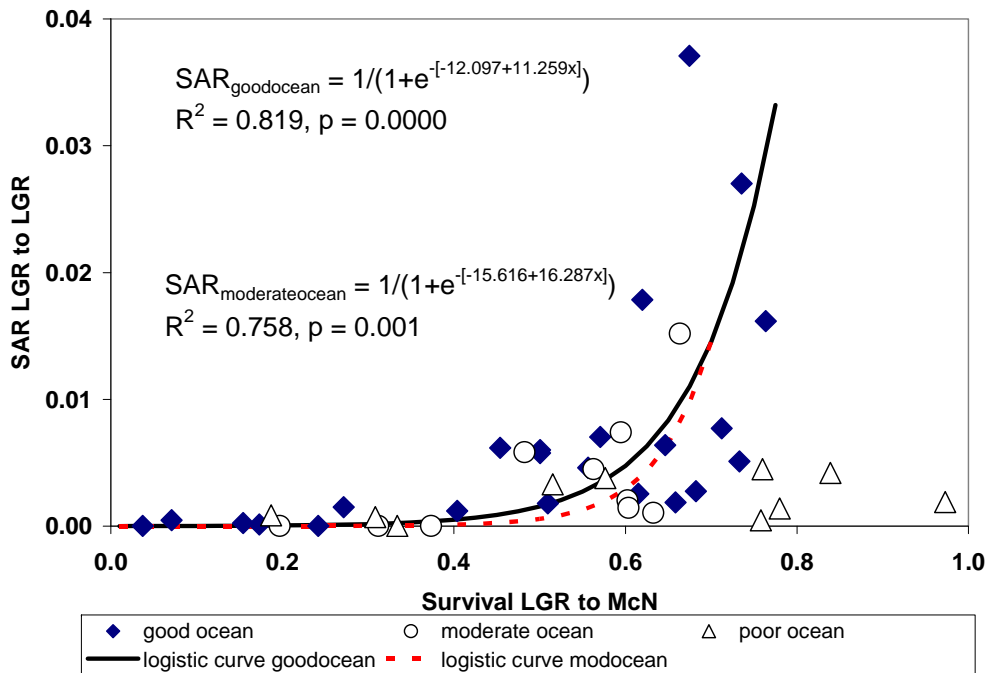


Yearling spring\summer Chinook reach survival LGR to McN plotted against SAR LGR to LGR for the years 1995 to 2005 under good, moderate and poor ocean productivity categories.



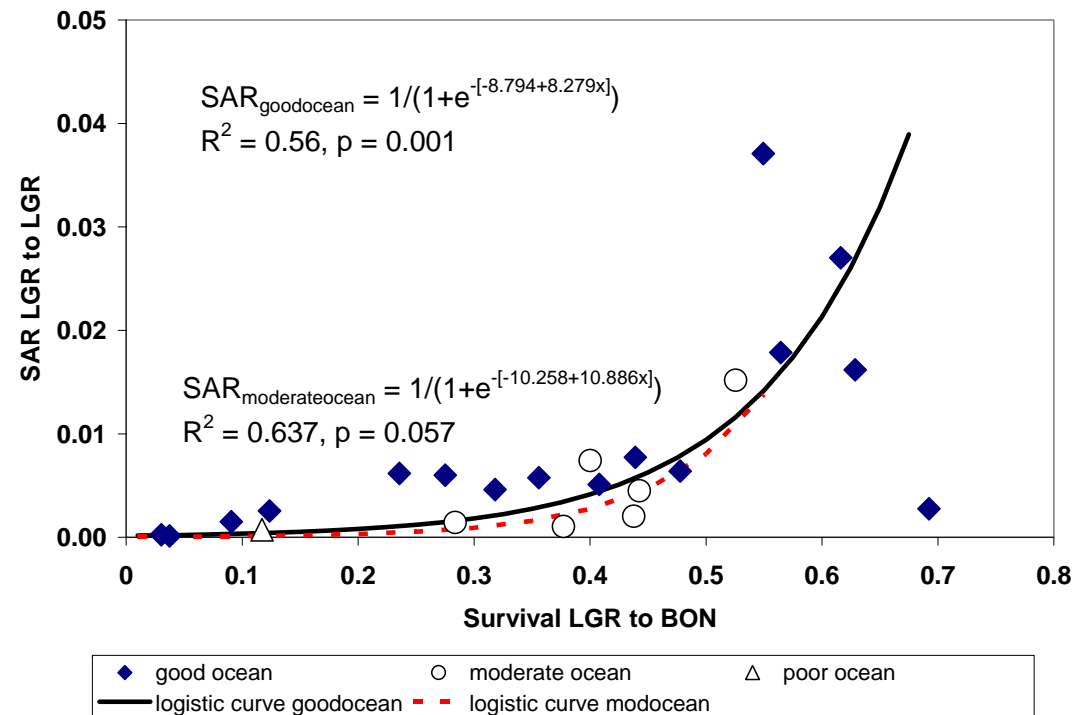
Yearling spring\summer Chinook reach survival LGR to BON plotted against SAR LGR to LGR for the years 1998 to 2005 under good, moderate and poor ocean productivity categories.





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 InSARs and InSOAs
- 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 **InSARs** 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 **InSOAs** 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,Se p_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 **InSARs** 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 **InSOAs** 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 |

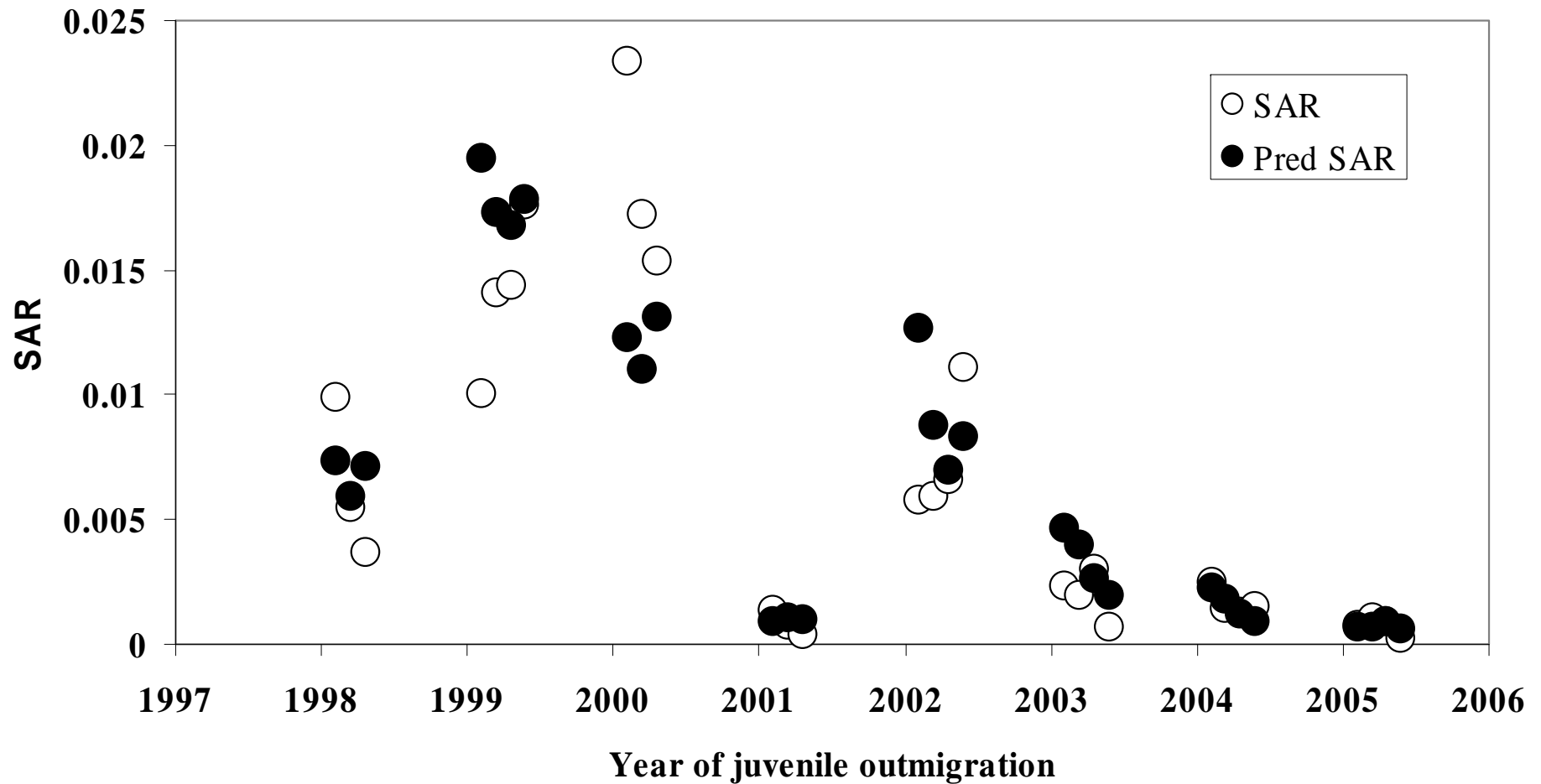
Weight of evidence for each variable in explaining variability in adult return data for Snake River spring/summer Chinook and steelhead.

| 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 |

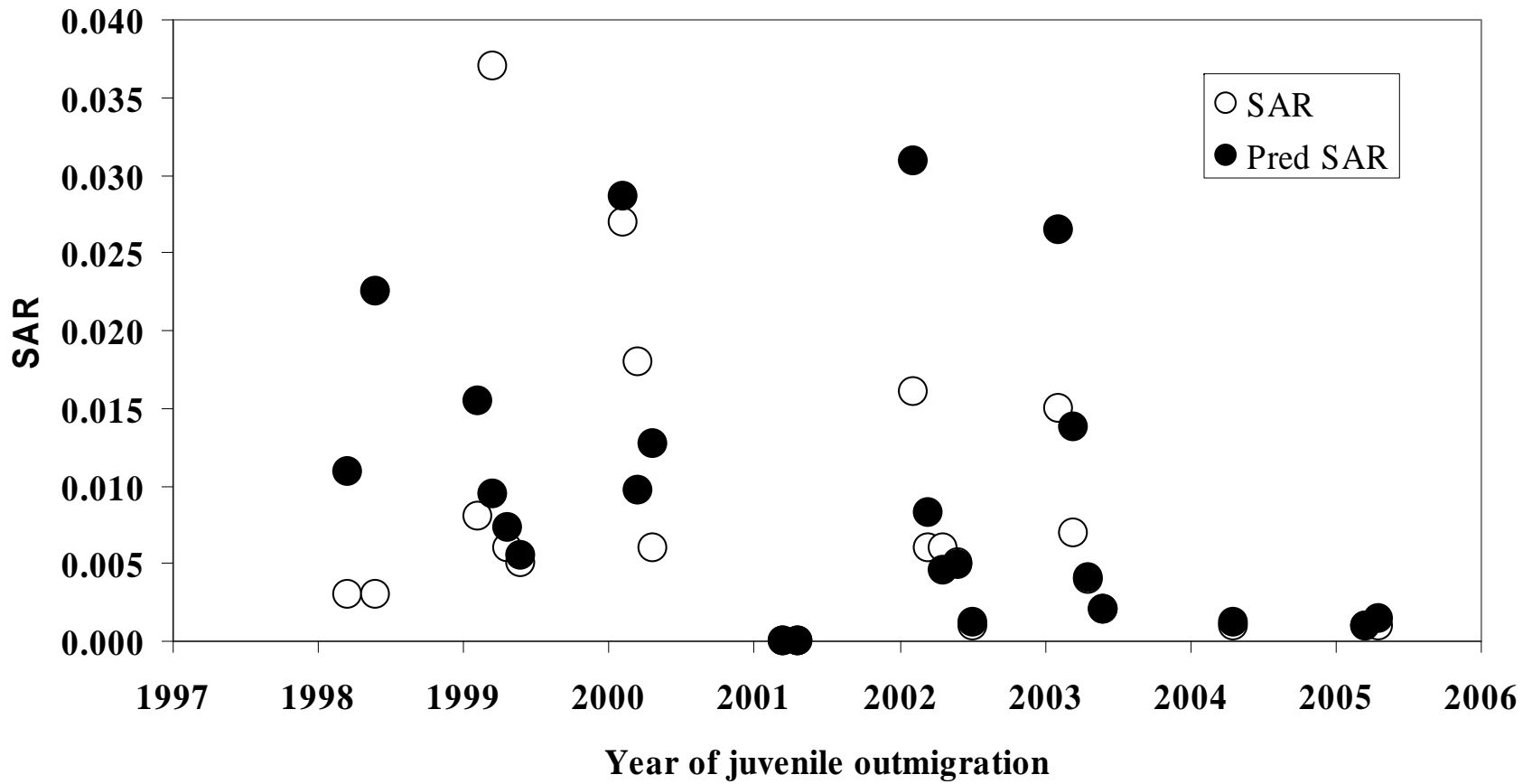
Model averaged coefficients for Snake River yearling spring/summer chinook and steelhead lnSARs and lnSOAs versus environmental variables; Average Spill Proportion, Water Travel Time (days), Date at Lower Granite, April Upwelling, May PDO, Sept. PDO and Oct. Upwelling.

| 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 |

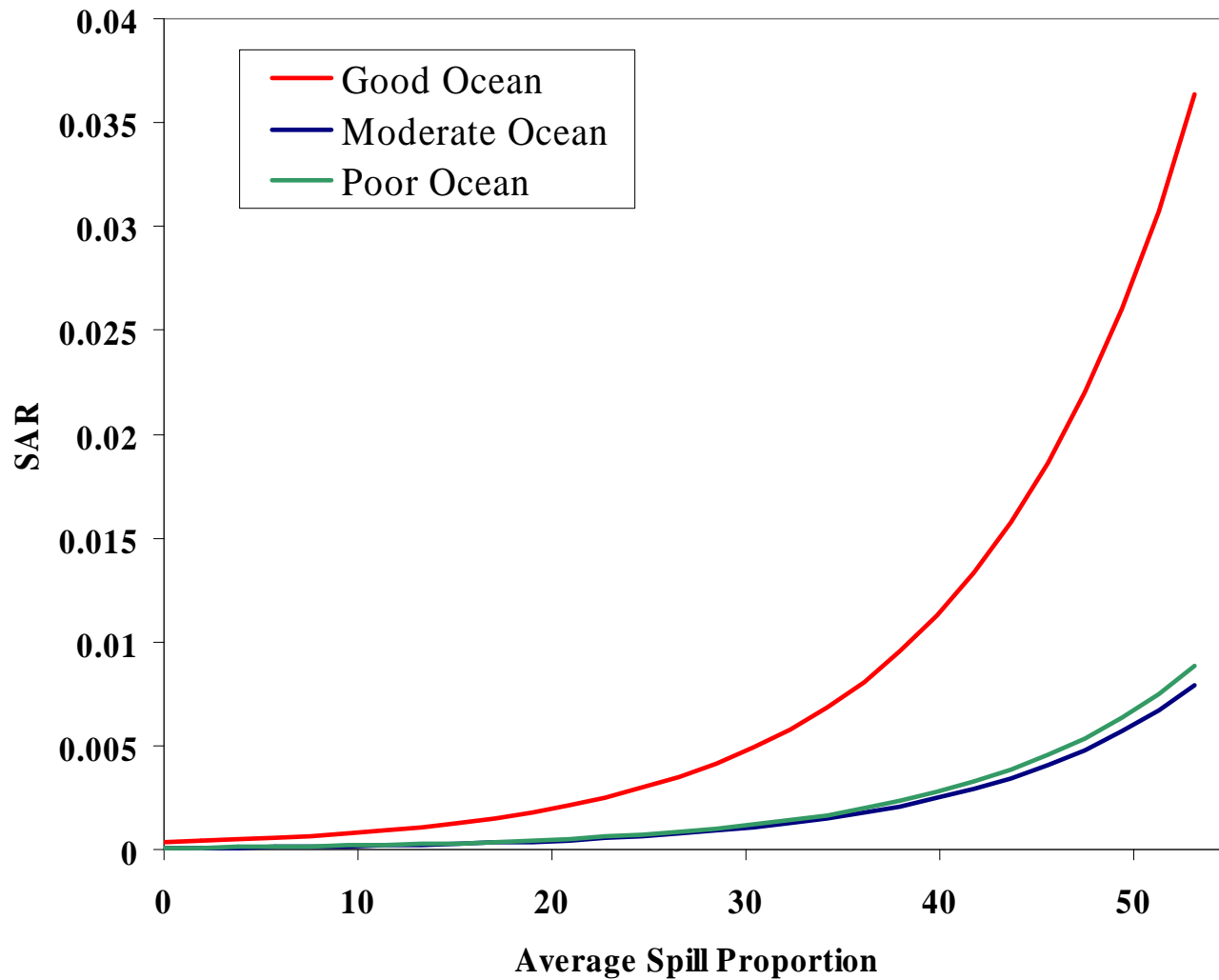
SAR compared to Predicted SAR (survival from Lower Granite Dam to Lower Granite Dam), for Snake River spring/summer Chinook ($R^2 = 0.7019$).



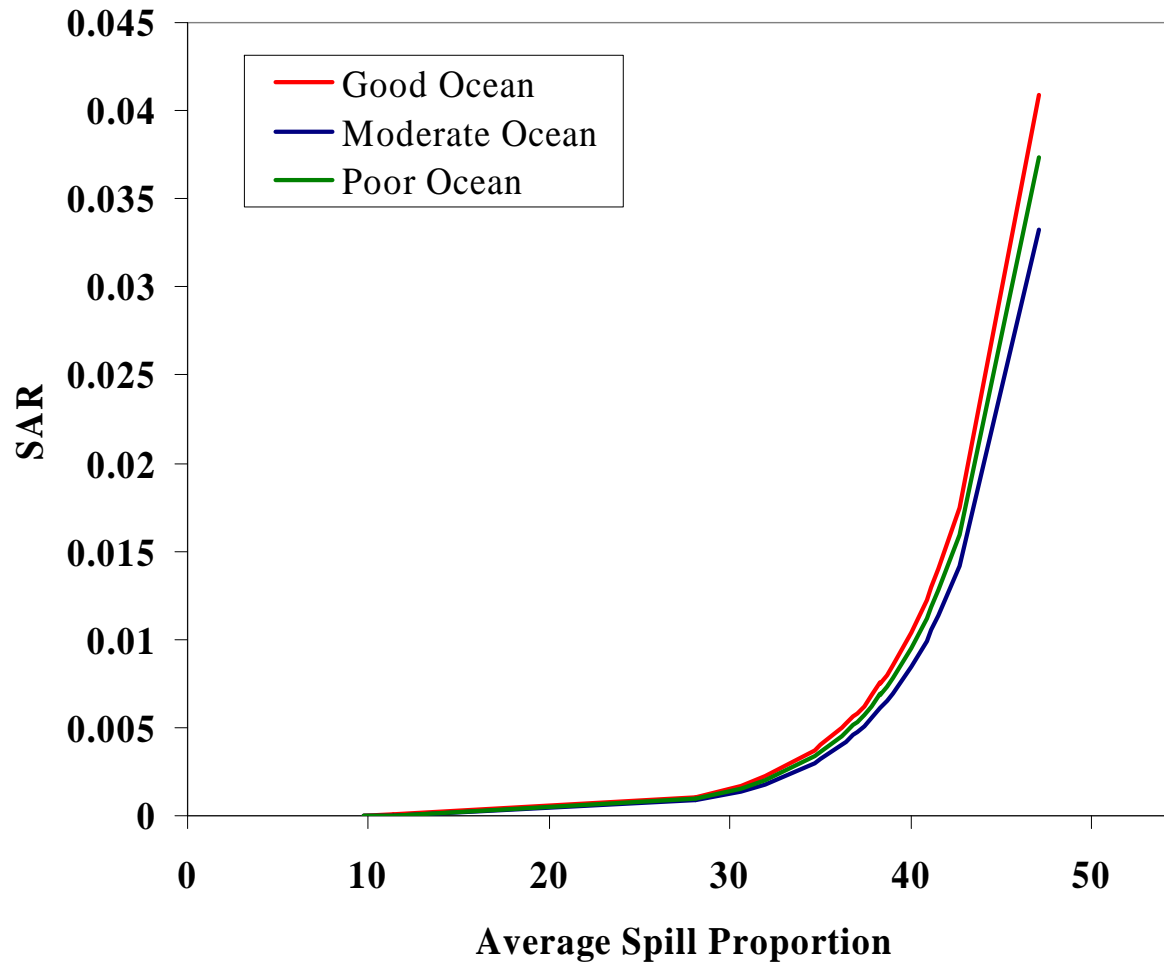
SAR compared to Predicted SAR (survival from Lower Granite Dam to Lower Granite Dam), for Snake River steelhead ($R^2 = 0.309$).



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

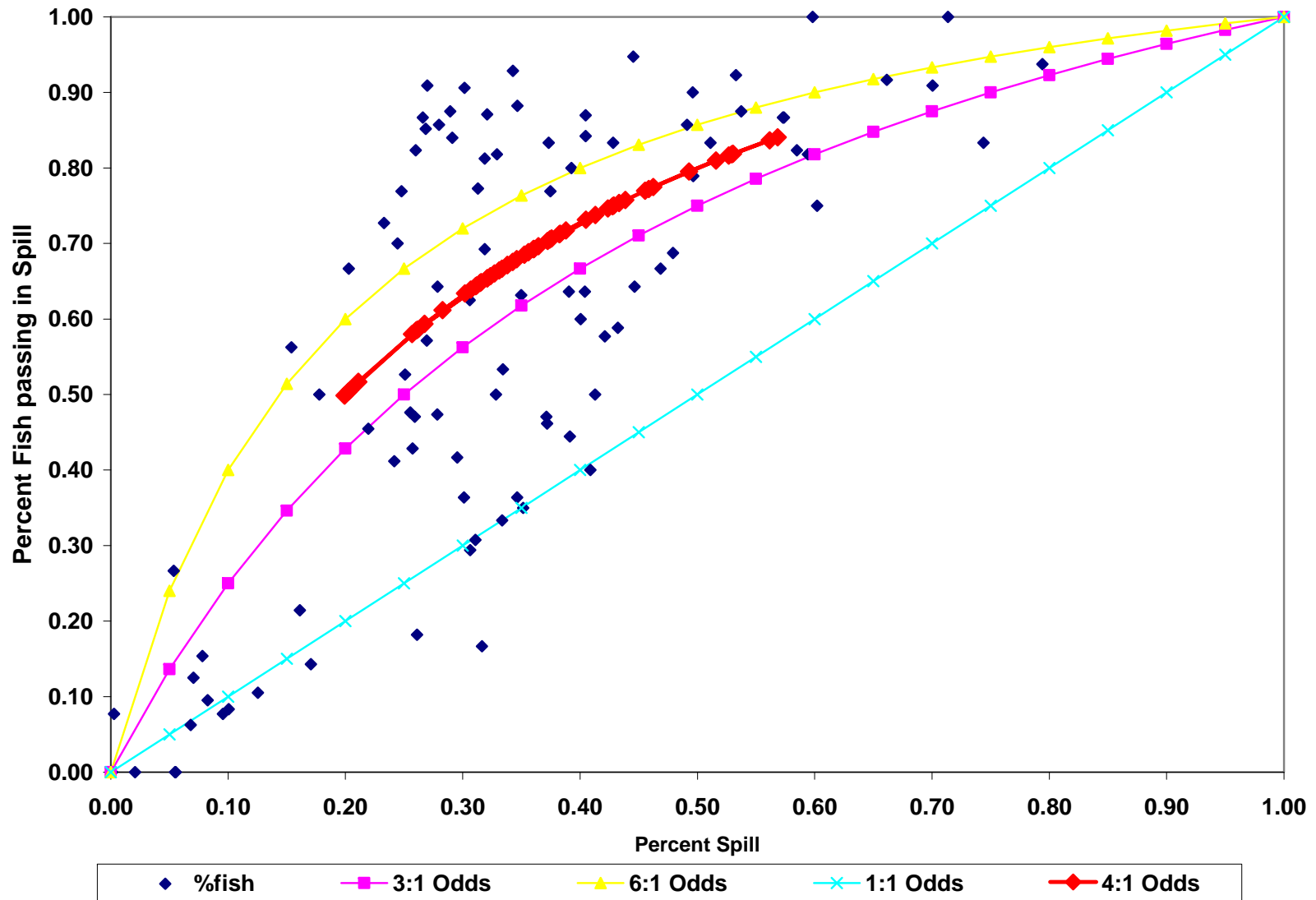


Predicted response to increasing spill volumes of SAR's for steelhead under good, moderate and poor ocean productivity levels.



Avg_Spill_Prop e.g.

Lower Granite spring/summer Chinook



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—comparable 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%