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MEMORANDUM

TO: Ed Bowles, ODFW

FROM: Michele DeHart

DATE: February 18, 2009

RE: Review, NOAA, "Factors affecting sockeye salmon returns to the Columbia River in 2008"

In response to your request to review the subject NOAA paper in light of previous FPC analysis of 2008 adult sockeye returns, the FPC reviewed the NOAA Fisheries Document entitled, "Factors affecting sockeye returns to the Columbia River in 2008". The previous FPC analyses were summarized in memorandums dated, July 14, 2008, July 21, 2008, August 6, 2008 and August 18, 2008, available on the FPC web site. These memorandum addressed in-river migration conditions, transportation and ocean conditions. **After reviewing the NOAA analysis, we have determined that there is no technical basis to modify our conclusions in the previous FPC memorandums regarding the adult sockeye returns in 2008. There is no doubt that ocean conditions are important, but this does not reduce the importance of migration conditions and fish survival in-river. The NOAA conclusion that ocean conditions were the predominate factor in 2008 sockeye adult returns to the Snake River, does not follow logically from their analysis.** Summary conclusions are listed below followed by detailed discussion of each point.

- The NOAA conclusion that attributes the 2008 high return of sockeye salmon to marine/estuary conditions while discounting the effect of higher in-river survival, lower proportion transported and improved in-river conditions, **is flawed because it fails to recognize that fish must reach the ocean/estuary alive to benefit from good ocean conditions. Even the best ocean conditions will not resurrect dead fish.**

- Analyses of the same NOAA data, using the commonly accepted method of weighting variables to account for variance, resulted in a significant spill/ survival relationship for Snake River juvenile sockeye.
- Other sockeye stocks such as Lake Washington sockeye would be expected to have higher returns in 2008 if adult return was attributable, as indicated by NOAA, to ocean conditions. However Lake Washington returns of sockeye in 2008 were the lowest in recent history.
- The NOAA analysis is convoluted and includes contradictions that result in unclear logic paths to their conclusions.
- The NOAA conclusion that adult returns are solely due to ocean conditions contradicts the technical basis for downstream passage measures including spill for fish passage included in the NOAA Biological Opinion. The Biological Opinion recognizes the critical importance of in-river survival, flow and spill and includes measures to improve passage survival. The Biological Opinion and the NOAA analysis recognize that transportation is not beneficial for sockeye.
- The selection of variables in the NOAA linear regression analysis are not representative and affect the results of the NOAA analysis and conclusions. The variables are mismatched in both time and space.(e.g. matching annual survival estimates with environmental variables for the middle 50% of the migration and omitting key projects where spill has occurred).
- There are a myriad of ocean indices presented by NOAA. The definition of bad or good ocean varies by species over a wide range of conditions.

Discussion

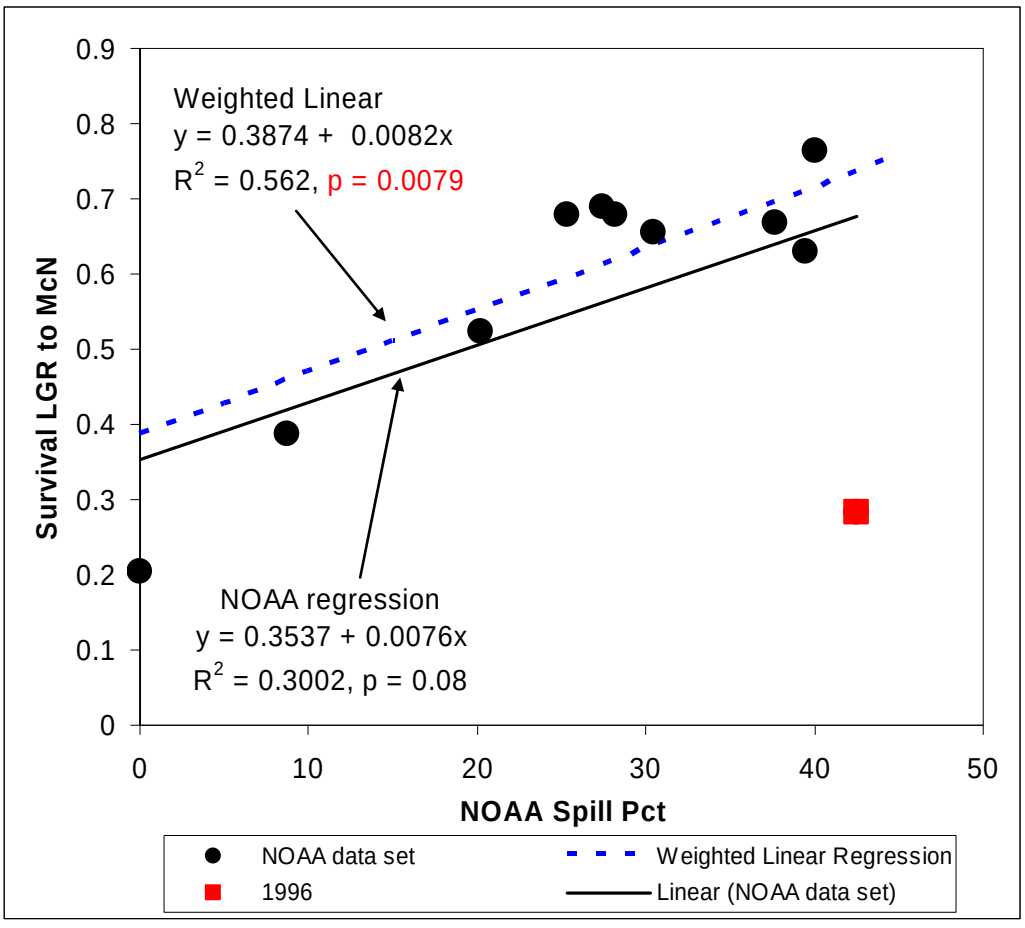
Analyses of the same NOAA data, using the commonly accepted method of weighting variables to account for variance, resulted in a significant spill/ survival relationship for Snake River juvenile sockeye.

NOAA states that the relationship between juvenile sockeye reach survival and environmental variables were not significant in their analysis. NOAA presented their simple linear regression analysis as the basis of this conclusion. This is problematic because it is evident from the survival data, provided, that standard errors of the survival estimates are quite variable. When such heterogeneity of variance is found in survival data, standard procedure is typically to weight the regression (Draper and Smith 1981, Myers 1990). Using NOAA's data and weighted regression, using inverse variance weights, as recommended by Burnham et al. 1987, Myers 1990, we found a significant relationship between reach survival and spill percent for the Snake River sockeye.

Using the NOAA dataset for Snake River Sockeye FPC analyzed the relation between survival and spill in the reach LGR to McN using weighted regression—using inverse variance weighting (See Figure 1). The weighted regression FPC estimated was similar in its slope to the NOAA non-weighted regression. However the FPC regression was significant at $p = 0.007$ and had a higher R^2. When we reran the NOAA unweighted regression without 1996, the data point in the lower right, we found the line nearly overlapped the weighted regression line. The weighted

regression accounts for the high standard error (0.184) of the 1996 data point in constructing the regression. This avoids placing a high level of reliance on highly uncertain data. Our analysis did not include data prior to 1998 since detection data below McNary Dam, necessary for estimating survival to McNary Dam, was sparse. At John Day Dam the airlift sampler was in place prior to 1998 and that resulted in low detection rates at that site. Also Bonneville Dam relied on the flat plate detector in Powerhouse I DSM, and limited detects at Powerhouse II. As such reach estimates prior to 1998 that ended at McNary Dam should be included with caution. Weighting the regression survival estimates by the variance accounts for the high standard errors for data from periods prior to 1998.

Figure 1. FPC weighted regression of NOAA Snake River sockeye spill/ survival data relationship compared to the NOAA unweighted linear regression. The 1996 data point is highlighted (red square).



Other sockeye stocks such as Lake Washington could be expected to have higher returns in 2008 if as proffered by NOAA, adult sockeye return in 2008 is primarily attributable to ocean conditions

If good ocean conditions were the primary reason for increased sockeye returns to the Snake River, similar improvement in adult returns should be evident for other sockeye populations along the northwest coast (Peterman et al 1998, Mueter et al. 2002). Not only have other stocks not improved, but they have shown considerable decline. Review of recent returns of sockeye populations does not show similar improvement in other stocks. Sockeye returns to Lake Washington counted at the Ballard Locks in 2008 totaled 33,629 adult sockeye, the lowest recorded since the 2000 count of 414,976 adult sockeye. NOAA has not offered rationale for why good ocean conditions would cause improvement in Snake and Columbia River stocks and not in other stocks of sockeye.

The NOAA analysis is convoluted and includes contradictions that results in an unclear logic path to their conclusion.

Transport Proportion

NOAA states that they found a significant negative relationship between transport proportion and SAR's for Snake River sockeye. However they discount this finding by presenting an analysis correlating Mid Columbia SARs with Snake River SARs inferring that the correlation discounts the negative finding on transportation. In examining NOAAs logic, we analyzed the relationship of in-river migration conditions occurring in the Mid Columbia with in-river migration conditions occurring in the Snake River. We regressed annual spring flows at Priest Rapids on the Mid Columbia River with Ice Harbor on the Snake River, for the years 1998 to 2008. The resulting relationship was highly correlated
($R^2 = 0.86$, $p<0.01$). This strong relation between outmigration conditions, flow, for the two rivers argues that the correlation between SARs found by NOAA could be due to climatic conditions resulting in higher migration flows in the two rivers.

Ocean Conditions

NOAA argues that all common year effects are due to the ocean. They use high correlation between SARs in the Mid Columbia and Snake Rivers to support this argument. NOAAs analysis and logic do not take into account the fact that there is a direct correlation between positive PDO indices and snow pack in Idaho and throughout the Pacific Northwest (Cayan,1966). Snowpack determines runoff volumes and flows. It follows logically that PDO indices may indicate more that just ocean productivity but also indicate inland climate effects such as snowpack and resulting river flow. Meuter et al., (2005) speculated that one explanation of correlations between wintertime ocean temperatures and sockeye salmon survival rates in British Columbia and Washington may have been due to the correlation between ocean conditions and inland climate conditions affecting fresh water habitat.

Smolt to Adult Returns

NOAAs estimates of SARs are based upon juvenile abundance estimates at McNary Dam and at Lower Granite Dam. We reviewed the Idaho Department of Fish and Games estimates of juvenile sockeye survival to and abundance at Lower Granite Dam. We also reviewed estimates

of juvenile survival developed by the Shoshone Bannock tribes. These estimates are based upon estimated survival of juvenile sockeye from point of release to Lower Granite Dam. The standard error and variance on these survival estimates are wide in many years. This would in turn result in a large variance in estimates of juvenile abundance and SARs for those years. NOAA does not address the impact of large variance in juvenile abundance estimates, in their estimates of SARs. Because NOAA bases their Mid Columbia SARs on juvenile abundance to McNary Dam, any juvenile sockeye mortality occurring upstream of McNary Dam is not accounted in the SAR calculation. This could have the affect of artificially inflating the SAR of Mid Columbia sockeye. NOAA does not identify assumptions in their SAR calculations and does not explain the implications of assumptions, confidence intervals on the underlying survival estimates and abundance estimates and resulting variance on their estimates of sockeye SARs.

SARs and Ocean Conditions

The SAR estimates are correlated with the monthly indices of the Pacific Decadal Oscillation. The authors conclude that the months with the highest correlation represent a relation between the ocean conditions and SARs. The NOAA results indicated a significant correlation with the cold water in August during the first year of life in the ocean and April in the second year. These observations are different from those previously observed for Chinook, steelhead and coho. NOAA just attributes this to an assumption that sockeye utilize different ocean productivity factors. While the role of the ocean is important in determining overall survival to adulthood of those juveniles that survive to enter the ocean, NOAA does not have a reliable biological explanation for this relation of monthly PDO indices with survival. There is the possibility that the significant relation observed in the analysis is an artifact of using several variables with a limited amount of observed data.

The NOAA conclusion that adult returns are solely due to ocean conditions contradicts the technical analysis basis for downstream passage measures including spill for fish passage included in all of the NOAA Biological Opinion. The Biological Opinion recognizes the critical importance of in-river survival, flow and spill, the uncertainty of transportation benefits and includes measures to improve passage survival specifically spill.

All of the NOAA Biological Opinions, as well as all of the other basinwide mitigation programs, have recognized that juvenile survival through the mainstem Columbia and Snake rivers migration corridor is critical to listed and non listed stocks of salmon and steelhead.

The selection of variables in the NOAA linear regression analysis are not representative and affect the results of the NOAA analysis and conclusions. The variables are mismatched in both time and space.(e.g. matching annual survival estimates with environmental variables for the middle 50% of the migration and omitting key projects where spill has occurred).

The analysis conducted by NOAA uses annual estimates of survival and passage timed (between 25^{th} and 75^{th} passage dates) estimates of environmental variables. It is most important when developing environmental variables describing migration conditions that they make logical sense. Environmental variables must match the parameter that you are measuring (here it is juvenile survival) as close as possible in both time and space. This assures that the

environmental variable actually represent the conditions experienced by the migrating fish. The variables chosen by NOAA do not meet these basic criteria, particularly for spill.

Snake River

The survival estimate for the NOAA analysis is the annual survival of Snake River fish based on PIT tagged sockeye released above Lower Granite Dam to McNary Dam. The survival from release to Lower Granite Dam is subtracted from the total survival to estimate survival from the tailrace of Lower Granite Dam to the tailrace of McNary Dam. The NOAA environmental variables are averaged for those dates between the 25th and 75th dates, which means that 50% of the fish that are used for the annual survival estimate migrate in conditions different than those estimated in the environmental variables. We know that environmental conditions vary widely over the passage period. The passage of sockeye past Lower Granite Dam, based on data collected since 1985 shows that sockeye pass Lower Granite from Late March through June. The average 25 percentile date is May 9 and the 75 percentile date is May 26 on average based on passage index data Consequently, it is likely inappropriate to use the conditions for the middle 50% to represent that experienced by the population included in an annual survival estimate.

In addition, the NOAA environmental exposure index for flow, temperature and spill are averaged over three dams, Lower Granite, Little Goose and Lower Monumental dams. However, the juvenile survival index is an annual estimate from Lower Granite Dam tailrace to McNary Dam tailrace. The NOAA indices do not include spill occurring at Ice Harbor or McNary dam. This is particularly important for the spill variable since the three projects that they have chosen to average for spill have generally seen a decrease in the overall amount of spill planned during the timeline studied, whereas the two projects omitted (Ice Harbor and McNary) have generally seen an increase in spill since the 2005 Court Order. Since the survival estimate is to McNary Dam tailrace, spill at these two projects would certainly have a large influence on these fish.

Mid Columbia

The same comment regarding the use of the 25th and 75th passage dates for environmental variable use and annual estimates of survival can be made for the Columbia River sockeye analysis. The environmental variables are only estimated for the middle 50% of the migrating juveniles, but do not describe the conditions experienced for the 50% of the migrants that contribute to the annual survival estimate that were outside of this window.

Similar to the Snake River, the environmental variables do not appear to represent the conditions over all dams passed for the survival estimate. Environmental indices for flow and temperature are measured at McNary Dam and do not necessarily represent the conditions experienced by fish migrating to McNary Dam. Additionally, the spill variable at the Mid Columbia projects is confounded by the decrease in spill over the past few years at Wanapum Dam. At Wanapum Dam the testing of the top spillway weir has significantly reduced the amount of spill and would explain the decrease in the spill percentage variable. The reduction in spill percentage at Wanapum Dam in the variable may help explain the negative correlation between spill and juvenile survival reported by the authors.

There are a myriad of ocean indices presented by NOAA. The definition of bad or good ocean conditions varies by species over a wide range of conditions. **These correlations with ocean conditions can conflict and present contradictory conclusions.**

For example, a NOAA paper, entitled, "Forecasting climate induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*)",(Scheuerell, and Williams, 2005.) addressed the impact of ocean conditions on adult return of spring Chinook. "Beginning with the 1994 ocean out migration however, the survival of salmon in the ocean started to climb again through 1999."

In the Scheuerell & Williams paper, NOAA relates increased smolt to adult returns with stronger ocean upwelling in April and September and October downwelling (negative upwelling). Examining Figure 2 in Scheuerell and Williams (2005), migration year 1998 was characterized by positive upwelling in April, nearly the highest upwelling observed over the time series in September and negative upwelling in October. Based on these three ocean indices the model coefficients estimated by Scheuerell and Williams indicate that 1998 was a "good" ocean year. These generally good ocean conditions were used to forecast increases in the SARs from migration years 1998-2003 (Figure 3a. Scheuerell and Williams, 2005). Clearly, Scheuerell and Williams characterize 1998 as above average ocean conditions.

The NOAA web site identifies 1998 as the lowest ranking for ocean conditions of the 10 years for which ranks were provided (1998 to 2007). However the web site also ranks adult returns for Columbia River spring/summer Chinook entering the ocean in 1998 (worst ocean ranking) as the fourth best adult return. The web site does not include rankings for sockeye.

Although it appears that there may be disparity between the two NOAA sources characterizing ocean conditions that occurred in 1998, the out migration conditions are a matter of record and there is no disagreement on the mainstem passage conditions that occurred. According to the FPC sockeye memo dated July 14, Snake River sockeye outmigrating in 1998 experienced an average percent spill of 43% and average flow of 197 kcfs between Lower Granite and McNary dams; this represents the second highest spill and highest flow for the years analyzed (1998 to 2007). At 0.72, the proportion of juvenile Snake River sockeye transported in 1998 was relatively low. Among the years we analyzed the second highest adult sockeye return to Lower Granite Dam occurred in 2000 with a return of 299 fish. These fish would have outmigrated in 1998 through high flow and high spill conditions. If as indicated by the NOAA web site, 1998 ocean conditions were the worst of the last decade, the adult returns from the 1998 outmigration illustrate the importance of flow and spill passage conditions during the downstream migration because in this scenario downstream passage conditions appear to have been good enough to overcome the bad ocean conditions. If the alternative NOAA characterization of 1998 ocean conditions as above average (Scheuerell &Williams) is accepted, the relatively high adult returns from 1998 support the importance of downstream passage conditions and juvenile survival during the juvenile outmigration in combination with good ocean productivity, since smolts need to arrive to the ocean alive in order to benefit from good ocean conditions. The two alternative NOAA characterizations of ocean conditions for 1998 are disparate spanning the range from worst to above average indicating that caution should be applied in utilizing these indices in predicting adult returns or attributing adult returns solely to the ocean segment of the salmon life

cycle. Our review of the NOAA ocean condition alternative indices did not indicate any basis to change the discussion or conclusion in our previous memorandum.