Aggregate hypotheses for spring chinook

notes by Anderson

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These notes detail combined hypotheses for the extra mortality and *D* and the hypothesis on predation rate with drawdown.

Additional mortality hypothesis

The combined additional mortality is defined by the equation:

$$\alpha = -\ln(DP + 1\text{-}P) + \alpha_n + -\ln(DP + 1\text{-}P) + \alpha_n \tag{1}$$

where α_n is the extra mortality in the non-transported fish, *D* is the ratio of extra mortality of transported to non-transported fish, and *P* is the Bonneville fraction of transported fish. All these parameters vary from year to year. In this aggregate a number of factors are considered that have been shown to have changed between the pre- and post-Snake River hydrosystem development. These factors include changes in hydrosystem flow related to the construction of storage reservoirs, changes in ocean and climate conditions, changes in estuary predator populations, changes in hatchery production, change in post migration stress of fish from transportation and hydrosystem passage, and changes in estuary arrival timing of fish due to transportation and dams.

Note that this aggregate hypotheses, unlike the initial hypotheses in PATH, is functionally neutral -- that is, it contains both hydrosystem and climate elements and the significance of each factor is established by retrospective fit of the model to the data.

To develop an aggregate hypothesis, equations for *D* (the transport effectiveness parameter) and α_n (the non-transport fish extra mortality parameter) must be defined.

Extra mortality

The extra mortality hypothesis involves all time-dependent factors that affect the survival of non-transported fish excluding the direct mortality in dam passage. The forces that determine the extra mortality can occur in the habitat above the hydrosystem, as a delayed effect related to the hydrosystem, in the estuary, or in the ocean or as a function of the number of hatchery smolts that pass with the wild fish. The aggregate hypothesis for the extra mortality becomes:

$$\alpha_n = c_0 + c_1/F + c_2 E + c_3 B + c_4 V_n + c_5 H \tag{2}$$

where all parameters have inferred year indices and a region or stock indices where noted:

F = flow at Bonneville or Astoria.

E = latitude of ocean trajectory after a 90 day drift from ocean weather station Papa, which is in the central North East Pacific. The ending latitude of the drift characterizes the climate regime.

B = avian predator population in estuary.

V_n = in-river survival of non-transported fish.

H = density of hatchery fish in the estuary.

The coefficients in eq(2) scale the various processes identified in the aggregate hypothesis. They are estimated from fitting retrospective spawner-recruitment data. Their definitions are:

c_0 = base value of the non-transported fish extra mortality. Because of the definition of eq(1) it is not significant in determining α.

c_1 = scales the impact of estuary flow and the freshwater plume in the ocean on non-transport fish extra mortality.

c_2 = scales the impact of climate changes on non-transport fish extra mortality.

c_3 = scales the impact of estuary avian predation on non-transport fish extra mortality.

c_4 = scales the impact of hydrosystem passage stress on non-transport fish extra mortality.

c_5= scales the impact of hatchery smolts on non-transport fish extra mortality.

The justification for selecting these five factors rest on two criteria: 1) they have experienced significant changes coincident with the construction of the hydrosystem, and 2) there are ecological bases for how they may affect the extra mortality of the non-transported fish.

River discharge as it affect the dynamics of the estuary and the dynamics of the river plume in the ocean have been shown to correlate with early-ocean survival (Pearcy 1992).

Ocean and climate regimes shifts are correlated with the survival and catch of a large number of salmonid species (Anderson 1996 and in press). The drift parameter is an index of climate regime shifts (Ebbesmeyer et al. 1998).

Avian predators in the Columbia River estuary have been shown to consume more smolts than in-river fish predators (Roby et al. 1998).

The explanation for the impacts of the hydrosystem on extra mortality was developed in the PATH report (1998).

The effect of hatchery smolt interactions with wild smolts could occur though several mechanisms, including competition for food and transfer of hatchery-borne disease into wild populations. This hypothesis is being developed by the NMFS.

Transportation factor ***D***

The ratio of post-Bonneville survival of transport to non-transported fish is expressed by *D*. This parameter can be supplied as a time dependent factor in eq(1) or estimated along with the c_i coefficients. If it is supplied independently, it is estimated from TCR data; if it is estimated as a functional form, an equation for D is developed. The two approaches are discussed below.

Independent estimated *D*

Independent estimates of *D* are based on TCR data and estimates of the in-river survival of control fish. Because some of the control fish were subsequently transported at lower dams in early years of the experiments the estimation of *D* must account for these errors. This can be done by assuming that transported control fish experienced the same delayed mortality as fish transported from upper projects. The equation for *D* becomes

$$D = (1\text{-}f)/\{V_T /((\text{TCR } V_T) - f) \} \tag{3}$$

where f = fraction of control fish in Bonneville tailrace that were transported there, obtained from passage model simulations of the transportation experiments, and V_c and V_T are direct hydrosystem survivals of non-transported control fish and transported fish, also estimated from a passage model.

Equation estimated *D*

Based on an initial analysis of Anderson (January 1998) an equation for *D* takes the form

$$\log D = a_0 + a_1 \Delta x_T + a_2 \Delta T \tag{4}$$

which states that the survival difference of the transported and non-transported fish below Bonneville dam depends on the difference in condition of the fish, as characterized by a descaling measure, and the difference in the arrival time of the fish into the estuary. The terms are defined

ΔT = arrival delay of the non-transport fish relative to the transported fish.

Δx = difference in descaling of transported vs. non-transported in estuary.

The coefficients of the equation are defined

a_0 = difference in the intrinsic survival of transport vs. non-transported fish.

a_1 = scales the significance of stress as indexed through the level of descaling in transported and non-transported fish in the estuary.

a_2 = scales the significance of arrival time on the survival of fish in the estuary.

The coefficients in this approach can be estimated in two ways. They can be estimated by first estimating D from TCR and model passage survivals. This approach was done in Anderson (January 1998). The second approach is to include eq(6) into eq(1) and this is used in a retrospective analysis of the spawner-recruit data.

Further note on the analysis. Since the ΔT is essentially a constant between transported and non-transported fish over all years this term may be collapsed into the constant term a_0 in the analysis. Initial analysis suggests this is in fact the case in that adding the ΔT term does not improve the predictive power of the regression. A separation of terms is important to obtain some estimate of the impact of arrival time on survival. This estimate is important since it can be compared to estimates of the impact of arrival time that can be developed from the SAR of different transport groups. The work of Hinrichsen et al. (1998) and the recent NMFS transportation studies show that survival of transport groups did increase with later arrival times. Furthermore the difference in the up-river and down-river stock productivity could in part be a result of a decrease in the up-river stock travel time produced by the switch for in-river passage to transportation passage. This change in travel time has not been appreciated in the PATH analysis since many of the state-tribal hypotheses are based on the premise that increasing travel time has driven the mortality.