MEMORANDUM

TO: Tucker Jones, ODFW

FROM: Michele DeHart, FPC

DATE: February 14, 2019

RE: Diel juvenile fish passage characteristics at hydroelectric projects relative to the potential risk of implementation of flex spill

In response to your request the Fish Passage Center staff has reviewed the available literature regarding juvenile fish passage at hydroelectric projects. Juvenile passage at hydroelectric projects has been monitored for decades. Our review of the literature, and past analyses resulted in the following conclusions regarding the potential risk of implementation of flex spill. Our conclusions are not a prediction of the response of juvenile fish to the implementation of flex spill. Instead, our review of past years monitoring and studies may highlight potential for unintended adverse effects on juvenile downstream migrants. This review may be useful as the details of implementation of flex spill are being discussed. The following list of conclusions is followed by a brief summary of the history of juvenile fish hydroelectric project passage and discussions of past findings.

- The purpose of spill for fish passage, including flex spill, is to avoid powerhouse passage. There is potential that powerhouse passage could increase with flex spill, depending on when periods of decreased spill occur and the duration of these lower spill periods.
- Juvenile passage characteristics at hydroelectric projects have been documented throughout the hydrosystem over several decades. Juvenile passage characteristics have been found to be consistent in these studies. Juvenile fish approach the project all 24 hours of the day and delay sounding to pass through the powerhouse until dark. These studies of passage behavior, led to the implementation of 24 hour a day spill for fish passage and the development of juvenile fish surface passage structures. These juvenile
migration characteristics are the reason that daytime spill is the most effective means of avoiding juvenile powerhouse passage.

- If adequate daytime spill is not provided, fish could delay in the forebay rather than passing the powerhouse during the day. These delayed fish will pass through the powerhouse at night. If decreased spill periods cause fish to delay in forebay they will pass through the powerhouse at dark, instead of passing through spill routes during the day therefore increasing powerhouse passage. If the decreased spill periods followed by higher spill periods during the day do not cause fish to delay in the forebay, powerhouse passage encounters should not increase.

- The effect of lowering daytime spill could vary among projects, due to project configuration.

- The passage studies that are available indicate that powerhouse passage is greatest at dusk. If fish are delayed during the day light hours due to lower spill until dusk, they are likely to enter the powerhouse just after dusk.

**Background**

Under the auspices of the Northwest Power and Conservation Council, Whitney et al (1997) completed a summary of existing downstream salmon passage studies, focused on the Columbia River hydrosystem. In that summary, Whitney et al. (1997) emphasize that historical passage studies, summarized in Eicher (1998), which included studies of passage behavior back to 1957 by Regenthal and Rees concluded that “fish sound to greater depths as a last resort and if an alternative such as an artificial outlet is available they will use it preferentially.” These studies indicated that juvenile fish delay in forebays during the day and will only sound to pass through powerhouse during the dark.

Fish passage characteristics and surface orientation of juvenile downstream migrants was noted in early monitoring and studies at hydroelectric projects. (Long 1968; Wagner and Ingram 1973; Mighetto and Ebel 1995). Early monitoring was conducted by dip netting powerhouse gatewells on an hourly basis and fyke net sampling. Subsequently, hydro acoustic monitoring was implemented at several projects. Hydro acoustic monitoring showed that daytime spill was highly effective at passing fish and avoiding powerhouse passage. Hourly powerhouse gatewell sampling (Long 1968, Brege 1996) showed that peak passage of juvenile migrants through the powerhouse increased just after dark, and that a smaller proportion of the total daily passage entered the powerhouse during daylight hours. These studies and observations of fish passage behavior indicate that daytime spill is the best operation to avoid powerhouse passage. In addition these studies show that if an adequate level of daytime spill is not provided, fish will hold in the forebay during daylight hours and sound to pass through the powerhouse in the evening. This combination of fish behavior and spill operations could increase daily fish powerhouse encounters.

More recent studies (Beeman et al. 2010; Li et al. 2015) of juvenile fish passage characteristics confirm earlier studies. Fish that approach hydroelectric projects during the day will delay in the forebay if there is not adequate spill provided as an alternative route. At dark, fish sound to pass through powerhouse. Lower spill during daylight hours could delay fish in forebays and cause more fish to pass through the powerhouse at night.
Similar to historic studies, Beeman et al. (2010) found that their study fish arrived in the forebay of the dam randomly, throughout a 24 hour period. Once in the forebay, fish that approached and passed the powerhouse showed a longer time to pass than fish that passed via the spillway. The greatest differences in passage timing were found in the latter half of the timing distributions. Li et al. (2015) broke powerhouse passage into day and night passage time. They found large differences in powerhouse passage when they compared daytime to night-time passage (Table 1). Generally, juvenile salmon passed without delay when passing the powerhouse at night, while fish that approached during the daytime showed considerable delay; for yearling Chinook only 30% of the fish approaching the powerhouse during the daytime passed within the first hour; for steelhead about 50% passed in the first hour; while for subyearling Chinook only about 25% passed within the first hour. Li et al. 2015 did not separate spillway delay by diel periods.

\textit{Table 1: Hourly passage rates for each major route derived from Beeman et al. (2010) and Li et al. (2015).}

<table>
<thead>
<tr>
<th>Powerhouse</th>
<th>Yearling Chinook</th>
<th>Juv. Steelhead</th>
<th>Subyearling Chinook</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day</td>
<td>Night</td>
<td>Day</td>
</tr>
<tr>
<td>Yearling Chinook</td>
<td>0.3</td>
<td>&gt; 0.99</td>
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</tr>
<tr>
<td>Juv. Steelhead</td>
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<tr>
<td>Subyearling Chinook</td>
<td>0.25</td>
<td>&gt; 0.99</td>
<td></td>
</tr>
</tbody>
</table>
References


Li, Xinya et al. Migration depth and residence time of juvenile salmonids in the forebays of hydropower dams prior to passage through turbines or juvenile bypass systems: implications for turbine-passage survival. Conservation Physiology, Volume 3, Issue 1,Published: 03 February 2015


