# STUDY CODE JPL 20-01-LOP

**TITLE**: Spatiotemporal sources of mortality in juvenile reservoir-reared UWR spring Chinook salmon: implications for successful downstream passage at Willamette Valley Projects with an emphasis on Look- out Point.

**MANAGEMENT PURPOSE**: This study will investigate sources of instantaneous mortality for juvenile UWR spring Chinook salmon. Results will inform effectiveness of strategies to reduce sources of mortality related to Willamette Valley Project reservoirs

**FISH PROGRAM FEATURE**: CRFM

**BIOLOGICAL OPINION ACTION**: 4.10, 4.12

**BACKGROUND**: A two-year study (2017-2018; Kock et al. 2019) using staggered release and recapture of juvenile Chinook salmon at Lookout Point has demonstrated statistically robust survival estimates using an N- mixture model approach (0.17 in 2017 and 0.04 is 2018). However, the framework does not provide information about sources of reservoir mortality rates, nor does it explain why survival in both years of study are low. Several downstream passage feasibility studies and solutions are being considered at Lookout Point reservoir. Many of these strategies (interim and long-term) rely on hypotheses about the factors limiting juvenile survival but mainly focus on the availability of fish to pass given juvenile life stage behavior (ie, sub- and yearling). Given that sources of mortality have not been explicitly identified and quantified, there is uncertainty about the ability to improve reservoir survival enough to achieve replacement even if downstream survival rates are high. Furthermore, quantified estimates of reservoir mortality rates would allow managers to develop strategies to enhance the probability of survival to passage.

At Lookout Point, the Corps is investigating interim operations and structural solutions for downstream passage as part of the NMFS 2008 Biological Opinion. Given uncertainty about sources of reservoir mortality, it is difficult to predict passage strategy value with respect to producing a self-sustaining population. A robust predictive model that estimates disparate sources of reservoir mortality would allow managers to identify factors that may be within their ability to effect such that overall passage strategies are of greater benefit to ESA-listed spring Chinook salmon recovery.

Quantitative stock assessment is commonly used to evaluate the status of valuable fish stocks, usually with the purpose of regulating sustainable harvest or identifying management targets for conservation (Sweka et al. 2018). Assumptions about these models are: the sampling design includes the unit stock (ie, it is a closed system), sampling is distributed randomly over the unit stock, and the abundance index (sampled fish) is proportional to total abundance (catch ∝abundance). These approaches are integral to describing population dynamics and quantifying unobservable processes (e.g., annual recruitment, instantaneous mortality rates, abundance) that would otherwise be logistically difficult, costly, or impossible to capture empirically. For closed systems (ie, no im/emigration), approaches may include a population dynamics process (unobserved) and a population index (based on observable sampling units). These assessments are typically based on some derivation of:

𝑁𝑦+1 = 𝑁𝑦𝑒−𝑍 (Unobservable process)

𝐼𝑦 = 𝑞 ∗ 𝑁𝑦 (Observable process)

Where 𝑁𝑦 is abundance in year, y, and *z* is the total mortality rate from all sources of mortality. In more complex models, z is decomposed into disparate components of mortality, usually fishing, *F,* and natural

mortality, *M*. The underlying assumption is that the observable index (e.g., spawning ground surveys, creel surveys, recaptured fish) is proportional to unobserved abundance, *N,* that is, the observable sample drawn is representative of the total population of interest. This proportional relationship in fisheries science requires assumptions about *q*, the “catchability coefficient,” or the probability of any given fish being captured during the instantaneous sampling event. It is assumed that capture probability is constant and does not change through time. This assumption is convenient because it allows estimation of mortality rates without direct empirical evidence other than capture data and capture efficiency.

Reasonable assumptions about mortality rate can be included in the model and evaluated based on the model prediction reliability (ie, how well can the model accurately reconstruct the observations using existing information on mortality?). This is the fundamental basis of modelling “residual” mortality (Neuenhoff et al. 2019; Hollowed et al. 2000). If assumptions about natural mortality produce model predictions that are consistent with observed catch data, then there is better support for these assumptions.

At Lookout Point, similar methods were used to estimate survival. A known number of juveniles were released at several time intervals, and the researchers used two approaches (staggered release and N- mixture) to reconstruct data based on observed number of fish recaptured and gear capture efficiency. This study was useful in providing quantitative information on total reservoir mortality of juvenile spring Chinook salmon. The preferred approach (N-mixture) yielded survival rates that could be further decomposed into seasonal sources of reservoir mortality (ie, predation, temperature, etc.) such that:

1 − 𝑠 = 𝑚𝑡, and

𝑚𝑡 = 𝑚1 + 𝑚2 + ⋯ 𝑚t

where 𝑚𝑡 is the total estimated mortality rate (inverse of survival) and *i* indexes the mortality source, ie, assumptions about predation, temperature, or other sources of mortality.

Quantifying disparate sources of mortality has implications for management, namely, “what sources of mortality might managers be able to impact/reduce to improve survival to passage” and “what is the expected magnitude of effect on overall survival rate in the reservoir?” For example, Kock et al (2019) speculated that differences in mortality between years could be attributed to water year type/operation, exposure to parasitic copepods, temperature, or a combination thereof. These data are currently available for mortality covariate analysis using the existing model framework. Predictive stock assessment model not only allows managers to quantitatively support or refute assumptions about survival, but more importantly, provides a basis for making management decisions in the face of uncertainty based on weight of evidence (ie, “tuning” assumptions) rather than relying on empirically driven studies (e.g., predator-prey dynamics) that may require many years of study to support an informed management decision.

# OBJECTIVES:

**Obj. 1. Using a quantitative stock assessment approach, model disparate sources of mortality for subyearlings and yearlings in Lookout Point Reservoir by month**

**Task 1: Develop a set of working hypotheses about sources of reservoir mortality to incorporate into the model**

**Task 2: Use the model to evaluate the sensitivity of different parameter assumptions.**

**SCHEDULE:** 2021-2022.

# References:

# Hollowed, A. B., Ianelli, J. N., & Livingston, P. A. (2000). Including predation mortality in stock assessments: a case study for Gulf of Alaska walleye pollock. *ICES Journal of Marine Science*, *57*(2), 279-293.

# Kock, T. J., Perry, R. W., Hansen, G. S., Haner, P. V., Pope, A. C., Plumb, J. M., ... & Hansen, A. C. (2019). *Juvenile Chinook salmon (Oncorhynchus tshawytscha) survival in Lookout Point Reservoir, Oregon, 2018* (No. 2019-1097). US Geological Survey.

# Neuenhoff, R. D., Swain, D. P., Cox, S. P., McAllister, M. K., Trites, A. W., Walters, C. J., & Hammill, M. O. (2019). Continued decline of a collapsed population of Atlantic cod (Gadus morhua) due to predation-driven Allee effects. *Canadian Journal of Fisheries and Aquatic Sciences*, *76*(1), 168-184.

# NMFS (National Marine Fisheries Service). 2008. Biological Opinion on Continued Operations and Maintenance of the Willamette River Basin Flood Control Project. Completed pursuant to the Endangered Species Act 7(a)(2) Consultation Biological Opinion & Magnuson-Stevens Fishery Conservation & Management Act Essential Fish Habitat Consultation. Issued: July 11, 2008. NOAA NMFS Northwest Region.

# Sweka, J.A., Neuenhoff, R., Withers, J. and Davis, L., 2018. Application of a depletion-based stock reduction analysis (DB-SRA) to Lake Sturgeon in Lake Erie. *Journal of Great Lakes Research*, *44*(2), pp.311-318.

# NMFS Comments:

# While this describes as part of the goals resolving "uncertainty about the ability to improve reservoir survival enough to achieve replacement even if downstream survival rates are high" prior studies were unable to contrast survival in reservoir and d/s survival for routes and elevations other than those provided by standard operations. If in addition to a new model, they could look at a range of possible operations, both from existing data and possible alternatives, and suggest how to incorporate future tracking to capture effects of passage timing and routes under alternative operations, this would be more useful.