Estimating Survival Benefit Units for Subactions Involving Floodplain Lakes

Prepared by the RPA 37 Expert Regional Technical Group on Estuary Habitat Actions

Purpose

The Expert Regional Technical Group (ERTG) scores potential restoration projects to estimate survival benefits units (SBUs) for ocean- and stream-type juvenile salmon from estuary habitat actions implemented by the Action Agencies (AA) as called for in the 2008 Biological Opinion of Federal Columbia River Power System Operations (BiOp). Survival benefit units are assigned using, "the approach originally applied in the FCRPS Biological Assessment (Attachment B.2.2; Estimated Benefits of Federal Agency Habitat Projects in the Lower Columbia River Estuary) and all subsequent information on the relationship between actions, habitat and salmon productivity models developed through the FCRPS RM&E to estimate the change in overall estuary habitat and resultant change in population survival...". Here we describe how the ERTG applies this guidance to develop an approach to assign SBUs for subactions in floodplain lakes in the lower Columbia River and estuary, and we identify important uncertainties that affect the assignment of SBUs for such projects.

Problem

Because of their large size, shallow water habitats and location relative to the mainstem, restoration of large floodplain lakes (FPLs) of the lower Columbia River and estuary (LCRE) may provide significant areas of rearing habitat for juvenile salmon. However, juvenile salmon use of FPLs has not been widely studied, and the parameters used to estimate survival benefits for other types of wetland habitat may or may not directly apply. Because many FPLs are very large, salmon survival benefits could be substantially overvalued if the area of high quality habitat resulting from restoration is overestimated.

The ERTG reviewed the status of information for FPLs in the LCRE and other estuaries to address the following questions:

- What fish densities should be expected in well-functioning FPLs to estimate potential survival benefits of FPL restoration actions?
- What proportion of a FPL constitutes high-quality salmon habitat, and how can this area be estimated?
- What is the likelihood a restoration action will succeed if the natural flooding processes that create and maintain FPLs are impeded by flow regulation?
- How do seasonal water temperatures and invasive species affect salmon access to or the rearing capacities of FPLs?
- How do currently modified river hydroperiods affect fish ingress to and egress from FPLs?
- How productive are FPLs relative to river channels, including direct and indirect effects on fish production?

Background

The ERTG uses a spreadsheet "Calculator" to assign SBUs by subaction based on values in the 2010 Estuary Module for total possible SBUs, total subaction goal (acres/miles), total juvenile salmon produced and scores for three factors: Certainty of Success, Habitat Access/Opportunity, and Habitat Capacity/Quality (ERTG 2010a). Inconsistencies in the relationships between the potential number of juvenile salmon produced and the total possible SBUs as outlined as goals in the Module/BA are addressed by using existing literature to ascribe an "Optimal Fish Density" value for each subaction and a weighting factor derived by dividing the Optimal Density by the Module Density. In brief, the SBU estimation process starts with an optimal fish density, derived from the available literature, that is then discounted by expert scoring of site- and project-specific characteristics.

Two challenges to applying this approach are that 1) subactions are, essentially, engineering activities each of which can be conducted in different habitat types, and 2) different habitat types support different densities of fish and have different contributions to salmon survival. For example, Subaction CRE-10.2[1] can provide access to a variety of habitat types, such as saltwater marsh, freshwater wetlands, and floodplain lakes. Each habitat type likely effects survival differently and therefore requires a different weighting factor. The weighting factor for FPL situations is explained below.

Conceptual Model

The ERTG developed a conceptual model to portray FPL systems and provide guidance for an approach to estimate SBUs for restoration subactions in FPLs (Fig. 1). We utilized the model to highlight system features and processes that are most relevant for scoring proposed FPL projects. Our discussions revealed many uncertainties that are also included in our conceptual model.

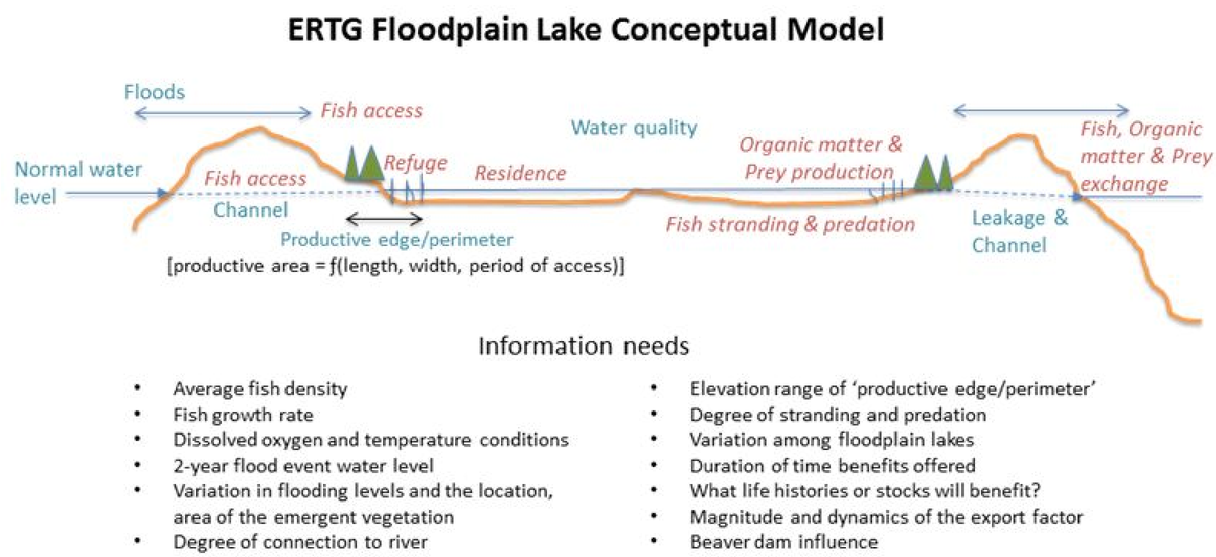

Figure 1. Floodplain lake conceptual model highlighting the major habitat features, ecological processes, and information needs (i.e., uncertainties in our understanding of these ecosystems relevant to juvenile salmon habitat). The model identifies the major elements considered in the ERTG scoring in terms of juvenile salmon access/opportunity via hydrological connections, the capacity of the system to support the fish including habitat refuge and prey production, and the pathways by which organic matter and prey might be exported from the FPL to the broader ecosystem thereby potentially contributing to an expanded number of fish.

[1] Module Subaction 10.2: "Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat…" The ERTG interpreted this to mean actions that result in no or ***moderate*** impediment to natural processes (ERTG 2011).

The degree and type of connection between a river and a floodplain lake varies with river flow. This has been characterized as having three hydrological phases (Trockner et al. 1999): Phase I Disconnection – occurs during low water conditions where the floodplain is hydrologically decoupled from the river; Phase II Downstream Surface Water Connection and Seepage Flow – as the river level rises, seepage flow enters the floodplain, however discharge from the floodplain remains low because water is retained in the floodplain channels; and, Phase III Upstream Surface Connection – the period when discharge into the floodplain increases dramatically, corresponding to massive surface inflow from the river. Typically the frequency of occurrence is much greater for phase I as compared with Phase II. Frequency of Phase III is very low. Water retention time is also much greater in Phase I as compared with the other two phases. Whether the hydrology of floodplain lakes in the LCRE follow the patterns described by Trockner et al. (1999) remains to be studied.

Man-made levees are typically constructed high enough to exclude floodwaters, except for extreme events (e.g., Columbia River during spring 1996). Juvenile salmon are normally able to access floodplain lakes via channels and overtopping hydrological connections. Egress from the lakes may be through open channels, culverts (some affixed with tide gates), or overtopping. While residing in the lake, juvenile salmon presumably would have access to prey resources (i.e., produced by vegetated and un-vegetated habitats) and refuge habitats. Predators may be abundant in lakes, and thus small fish may be subjected to high rates of predation. However, some data suggest predatory fish may not consume many juvenile salmonids (Baker 2008). Small fish may be stranded when water levels decline, eliminating routes of egress. Water quality in the lakes may be impaired, especially temperature and oxygen conditions. Based on the maps available for some lakes, a large proportion of lakes contain vegetation assemblages that are highly productive in terms of organic matter and prey resources (e.g., insects). We suspect that organic matter (i.e., detritus) and prey are exported at times from the lakes into the river where the organic matter supports further prey production, and the prey are available for consumption by fish in the river. The rates and amounts of organic matter and prey production in, and export from, floodplain lakes in the LCRE are unstudied but could be very high based on the size of these systems.

Certainty of Success for Floodplain Lake Restoration

The chances that a habitat restoration project will fully meet its goals for structure, function, and support for salmonids is evaluated by the ERTG within the Certainty of Success criterion (ERTG 2010b). The elements considered in scoring Certainty of Success include the degree to which natural processes or landforms are restored, whether a proven restoration method is utilized, whether the system will be self-maintained, the risk of detrimental effects from the actions, the degree to which project complexity is manageable, the degree of uncertainties regarding benefit to fish, and whether exotic/invasive species are expected (ERTG 2010b). The ERTG found that the literature addressing these elements in FPLs is not extensive and lacks details for some elements. Hampering evaluation of FPL benefits to salmon is that there are no well-documented examples of FPL restoration in the LCRE. There is significant uncertainty regarding the degree to which natural hydrology can be restored to FPLs. If hydrologic reconnections between the river and FPLs can be restored through natural geomorphic features (e.g., natural channels), we would expect significant recovery of natural processes and landforms, such that the system would eventually develop into a self-maintained natural shallow water/vegetated ecosystem that produces and exports prey and organic matter. Several factors may constrain restoration of natural hydrological connectivity such as land ownership, flood protection, multi-species management of sites, and an altered natural hydrograph. Because FPLs are generally very large systems, the cost to fully restore the hydrology could be excessive. Uncertainties also exist regarding water quality conditions, rate of habitat development, ability to maintain natural habitats, invasive exotic introductions, predation pressure, and the amount of time lake systems are occupied by juvenile salmon.

Potential Benefit for Habitat Access/Opportunity

The ERTG scoring criteria include an evaluation of habitat access and opportunity for juvenile salmon (ERTG 2010b). Numerous factors in the LCRE have reduced the period of floodplain inundation and diminished hydrological connectivity between floodplains and the main river. Flow regulation and climatic changes have altered the seasonal hydrograph and decreased flow amplitudes, while dikes and tide gates have increased the magnitude of extreme events necessary to inundate floodplains (Kukulka and Jay 2003; Bottom et al. 2005; Naik and Jay 2011). Restoration, or even partial restoration, of floodplain wetlands, including FPLs, requires reestablishing satisfactory connections to the river to allow fish movement, sediment delivery, organic matter and prey export, and other ecological functions. However, little is known about the use of Columbia River FPLs by juvenile salmon. Access to these habitats may differ for each site, depending for example, on its location along the estuary tidal gradient, local elevations and topography, the extent of previous diking or other modifications, distance from salmon source populations migrating downstream, etc. In some FPLs periods of high temperature, low dissolved oxygen, or other unfavorable conditions may limit salmon access even when water depths and velocities are otherwise satisfactory for fish. Given these uncertainties, considerable site-specific information is required to evaluate accessibility of a particular FPL to juvenile salmon before and after restoration.

As flood waters recede, channel connections to the main river must drain effectively for fish to freely exit the floodplain. Studies of well-drained floodplain habitats of the Yolo Bypass (Sacramento River) concluded that most young salmon were able to successfully emigrate, although stranding rates were relatively high for some areas engineered with water control structures (Sommer et al. 2005). In a restored floodplain of the Cosumnes River (central California) alien fish species were the most often stranded species after large flood events, and stranding most often occurred in pits or behind structures that ponded water (Moyle et al. 2007). Moyle et al. (2007) recommend that restoration projects create a floodplain topography that promotes rapid draining to reduce stranding of native fish and prevent permanent establishment of non-native fish communities.

From the 1920s to 1940s, the state of Oregon maintained a vigorous fish “salvage” program at Sauvie Island and other areas of the lower Columbia River. Biologists actively seined potholes and other depressions in late spring and early summer to prevent fish stranding as peak river flows receded and the floodplains dried (Lampman 1946). Biennial reports of the Oregon State Game Commission tallied the collection and redistribution of thousands to millions of warm-water game fish from floodplain habitats of the Columbia River estuary, although occasionally smaller numbers of salmon, sturgeon, or other native species also were collected. This historical record indicates juvenile salmon stranding is a potential risk in FPLs, but further research effort is required to quantitatively evaluate the conditions which mediate this risk. The much greater catch of warm-water non-natives versus juvenile salmonids in the historical record also suggests potential for significant predation on or competition with juvenile salmon by non-native fish.

Potential Benefit for Habitat Capacity/Quality

The ERTG scoring criteria also include an evaluation of habitat capacity (ERTG 2010b). Within this criterion, the ERTG considers direct habitat use by juvenile salmon (e.g., prey production and consumption, refuge from predation, and refuge from physical stresses) as well as indirect use (e.g., the production and export of organic matter and prey from a particular site to other parts of the estuarine landscape). Although the ERTG is uncertain regarding the amount of organic matter and prey produced in floodplain lakes, we assume that the lakes generally behave like other floodplain habitats. Data from floodplain habitats show that the production of wetland plant organic matter is highly variable among sites, ranging from 400 to 1,200 g dry wt m^{-2} (Thom et al. 2012). The spatial distribution for FPL production is unclear; is it particularly associated with a littoral fringe or not? Are juvenile salmon primarily associated with the littoral zone, where water depths are likely optimal and shoreline edges may provide maximum prey production and refuge from predators? This question is further complicated by the dynamic nature of FPLs, whose boundaries can migrate spatially and seasonally depending on their degree of inundation. This dynamism frustrates precise determination and quantification of the littoral zone or its contribution to salmon production.

The export of organic matter and associated salmonid prey from the site to the broader estuarine ecosystem is also considered an important function of the floodplain wetlands, directly contributing to the capacity of the broader ecosystem for juvenile salmonids. Based on studies at a number of wetland sites in the estuary, approximately 400 g dry wt m^{-2} of wetland macro-detritus is exported from the point of production to other parts of the ecosystem (Woodruff et al. 2012). The cumulative mass of export can be great. For example, a 100 acre (40.5ha) restored site, can export 178 tons dry wt of organic matter annually. Modeling studies have shown that material produced as far as 15 km upstream in a tributary can reach the estuary proper (Thom et al. 2012). Production and export processes in FPLs are affected by the hydrological characteristics of the lakes, including water flow in and out of the system, and retention time in the system. Hence, restoration of natural hydrological processes is critical to restoration of the ecological functions of FPLs. However, significant uncertainties remain regarding the actual mass exported and temporal patterns of export.

The presence of increased numbers of alien fish species toward the upper reaches of the LCRE raises additional uncertainties about the risks or benefits of FPLs and their overall capacity to support juvenile salmon. The hydrology of floodplain habitats will likely be a principal factor determining the degree of competition or predation that salmon may experience at a particular site (Baker 2008). In the Sacramento River system, native fishes are well adapted to the annual cycle of floodplain inundation, while permanently flooded ponds and oxbow lakes often favor alien species (Moyle et al. 2007). In seasonally-flooded habitats in Oregon, small-bodied fish dominate assemblages, while larger individuals (>200 mm) that could directly consume salmon are rare. Risks of salmon predation or competition appear less likely in well-drained, seasonally pulsed floodplain habitats compared with deep, permanently flooded lakes or stagnant pools. Regardless, the presence of numerous alien and piscivorous species in the upper Columbia River estuary suggests that intensive monitoring and management may be required to insure that salmon benefit from FPL restoration.

Trial Applications of the SBU Approach for Floodplain Lake Reconnections

The ERTG performed trial applications of an approach to assign SBUs for floodplain lake reconnections for two proposed actions: Dairy Creek/Sturgeon Lake and Wapato Lake. Two main components of the SBU "Calculator" are explained, Subaction Selection and Weighting Factor.

Subaction Selection

It is important that the most appropriate subaction be selected for each project activity. For the two floodplain lake projects under consideration (Sturgeon Lake and Wapato Lake) the primary engineering activity is limited breaching of existing natural or anthropogenic levees and construction of channels to increase the flow of water and salmon access to the lakes. In the case of Wapato Lake, the dike breach invert elevation was constrained to prevent complete drainage so that ponding would benefit turtles of special concern. In the case of Sturgeon Lake, a historically re-routed channel that has accumulated debris, rather than the original channel, was going to be reconnected to the lake. The Module Subaction description provided by ERTG (2011) and the scoring criteria described in ERTG (2010b) suggest that for these projects the subaction CRE-10.2 is the most appropriate subaction for calculating SBUs. Subaction 9.4 would also be applied when the channel between the FPL and river is improved. For other potential FPL restoration projects that would employ more extensive levee removal and restoration of FPL-mainstem connections, the CRE-10.1 subaction may be appropriate.

An important consideration for the ERTG for most projects is whether natural processes that create and maintain natural habitat (pre-existing conditions) are restored. In lieu of better information, the ERTG assumes that restoration of natural processes, such as the flow of water, sediment and nutrients, has the highest likelihood of re-creating suitable habitats to which salmon have adapted via natural selection, and that restoration of natural processes will reduce the need for additional restoration actions or project maintenance (see especially Certainty of Success and Potential Benefit for Habitat Capacity/Quality in ERTG 2010b). Because FPLs, including those in the LCRE, appear to be formed and maintained by large flood events that are now muted by the operation of the Federal Columbia River Power System, we suggest that restoration actions for these habitat types are limited in their ability to restore the dominant natural process that created and maintains these systems. However, the proposed projects will likely improve the flow of water, sediment, nutrients and fish through these systems and thus might provide useful salmon habitat. Further, these two trial projects do not include using engineered structures (e.g., tide gates or culverts) that might further constrain natural processes. It should be noted that the ERTG considers the use of CRE-10.2 rather than CRE-10.3 for these projects liberal with regard to the calculation of SBUs, because modest local dike breaches or channel improvements alone cannot compensate for the overall effects of the hydropower system on natural floodplain-lake processes (i.e., large flood events).

Weighting Factor (Fish Density)

Because we are unable to ascertain the actual survival benefit of various habitats to juvenile salmon, we use habitat capacity (potential fish density) as a surrogate measure. The ERTG SBU Calculator uses a weighting factor to relate optimal fish densities characteristic of different habitats to the idealized Estuary Model Density for various subactions (ERTG 2010a). Consequently, a new weighting factor is recommended to adapt the potential density of fish used in subaction 10.2 to accommodate the restoration of FPLs.

The relative densities of juvenile salmon in FPLs are poorly understood relative to other types of estuarine wetland. While data exist for a few floodplain areas (PCTA 2012), we found no quantitative estimates of juvenile salmon densities for permanently or seasonally flooded lakes. Salmonids using FPLs likely reside for periods of time ranging from days to months, primarily during the winter and spring. Chinook salmon use these habitats extensively, and coho and chum salmon may also use these habitats. Each of these floodplain habitats likely has unique hydrologic and biological characteristics that influence species composition, residence time, and performance.

The few studies that have estimated abundance or density in these large and dynamic habitats are located in a riverine reach of the Sacramento River in the Yolo bypass (Sommer et al. 2005, Moyle et al. 2007). Fish were observed across the floodplain but were concentrated in the low velocity ponds. Densities of Chinook ranged from 0.0027 fish m^{-2} in the floodplain to 0.19 fish m^{-2} in low velocity pond habitats. Cordell et al. (2011) sampled intensively through the spring in tidally influenced small off-channel areas of the Duwamish River in Puget Sound. Hydrologic access and site velocities influenced fish use. Densities of fish in these restored and natural habitats ranged from 0.00029 to 0.0016 Chinook m^{-2} and 0.0002 to 0.098 chum m^{-2}.

We have no data describing what area or volume of a FPL might constitute high quality rearing habitat for juvenile salmon. For example, studies in small wetland channels suggest that juveniles prefer nearshore habitats along the vegetated fringe over open water areas in the middle of channels. This might similarly apply to FPLs. To extrapolate fish densities from smaller high quality habitats to large FPLs with heterogeneous habitats, we are proposing a conservative estimate of potential fish carrying capacity. We recommend a maximum potential density of salmonids in floodplain lakes to be 0.005 salmonids m^{-2} averaged over the surface area of the lake. This recognizes that smaller and more complex edge habitats will support higher numbers of fish while the extensive central portion of a lake will support few fish. Ideally, we would have detailed information on fish densities in FPL microhabitats and how those microhabitats are distributed, but that information does not currently exist.

Summary

Using the existing SBU calculator as a basis, the ERTG is suggests the following approach to assign SBUs for floodplain lake reconnection actions:

a) Module Subactions = 9.4 (channel improvements) and 10.2 (hydraulic control is returned to a partially normative state; it is unmanaged but not normative) (ERTG Doc#2011-02).
b) Area = Wetted area based the two-year riverine flood elevation or extreme high water for delineating the area of sites (ERTG Doc#2012-01); no restriction to a buffer or edge zone.
c) Scoring = Downgrade scores in response to 1) high level of uncertainty in outcomes; 2) situations with existing access to the floodplain lake; 3) natural, historic processes not being restored.
d) Weighting factor = 0.556 corresponds to an optimal fish density of 0.005 fish/m2 for a Subaction 10.2 (0.005/0.009 = 0.556) (ERTG 2010)

Conclusions and Recommendations

Few FPLs remain in unregulated rivers and undeveloped floodplains on the West Coast, or even globally. Most of our understanding of near-pristine FPLs comes from tropical systems such as the Amazon and its tributaries, the Mekong, or other rivers in tropical Africa—none of which includes studies of systems with tidal influence. Translating this understanding to juvenile salmon use of temperate FPLs in the lower Columbia River and estuary is clearly problematic, particularly given the degree of disturbance present such as regulated flow by up-river dams, introduction of non-native piscivorous fish, introduction of non-native invasive plants, and extensive engineering of the floodplain with dikes, culverts, floodgates, water-control structures, and re-routed streams. Nevertheless, what little we know about these systems suggests they could be beneficial habitat for juvenile salmon if we can manage risks associated with predation by non-native fish, stranding of juvenile salmon as floodwater recede, and seasonal development of stressful water quality conditions. Given the large size of many FPLs in the lower Columbia River and estuary, the potential benefit of their restoration to salmon could be huge. Given the significant uncertainties we face in this disturbed system we must proceed by adhering to the precautionary principle, conservatively estimating restoration benefits to juvenile salmon and systematically reducing our ignorance and uncertainty regarding FPL restoration through thorough monitoring of FPL restoration projects as well as basic research on the ecology of lower Columbia River and estuary FPLs.

The ecological uncertainties about FPL processes not only impede restoration planning but may contribute to contradictory management and restoration approaches. For example, wildlife managers continue to install and operate water control structures as a means to prevent the spread of reed canarygrass and to stabilize water levels for seasonal use by migratory waterfowl. On the other hand, aquatic ecologists and fishery managers often prescribe removal of water control structures to insure unimpeded fish access to and from productive floodplain habitats and to allow naturally pulsing flows that deliver nutrients and organic matter to the estuary. A more comprehensive assessment of the processes and ecological interactions influencing FPLs is clearly needed. At a minimum, selected FPL restoration projects should be designed and evaluated as scientific experiments so that resource managers can learn from and adapt to the results, and so that the ERTG scoring process for FPL projects can be refined as informed by the results.

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