ERTG 2013-01

Calculating Survival Benefit Units for Subactions Involving Floodplain Lakes

Prepared by the Expert Regional Technical Group of the Columbia Estuary Ecosystem Restoration Program

Prepared for the Bonneville Power Administration, U.S. Army Corps of Engineers, and NOAA Fisheries

September 2013

Preface

The Expert Regional Technical Group (ERTG) was formed by the Action Agencies (Bonneville Power Administration [BPA] and U.S. Army Corps of Engineers [USACE]) in 2009 in response to the National Marine Fisheries Service's (NMFS's) 2008 Biological Opinion on the operation of the Federal Columbia River Power System. The ERTG reviews ecosystem restoration actions in the floodplain of the lower Columbia River and estuary (LCRE) proposed by the Action Agencies under the Columbia Estuary Ecosystem Restoration Program (CEERP). The ERTG's main role is to assign survival benefit units (SBUs)[1] for ocean- and stream-type juvenile salmon from the restoration actions. The ERTG's work is directed by a steering committee composed of representatives from BPA, NMFS, and USACE.

The purpose of *Calculating Survival Benefit Units for Subactions Involving Floodplain Lakes* (ERTG 2013-01) is to offer an approach for calculating SBUs for subactions in floodplain lakes in the LCRE, and identify important uncertainties that affect the calculation of SBUs for such projects. Because of their large size, shallow-water habitats, and locations relative to the main stem of the river, the restoration of large floodplain lakes (FPLs) of the LCRE may provide important rearing habitat for juvenile salmon. However, the definition of FPLs is vague, their function and importance to juvenile salmon has not been widely studied, and the attributes used to estimate survival benefits for other habitat types may not directly apply. The intent is to provide an approach based on the best available science that the ERTG can apply to calculate SBUs for proposed FPL restoration projects. The results of this process will help inform and guide restoration practitioners and CEERP managers as they develop restoration projects.

This document was prepared by the ERTG: Dan Bottom Greg Hood, Kim Jones, Kirk Krueger, and Ron Thom. It was reviewed by the ERTG Steering Committee, led by Blaine Ebberts, Lynne Krasnow, and Ben Zelinsky.

Suggested citation: ERTG (Expert Regional Technical Group). 2013. *Calculating Survival Benefit Units for Subactions Involving Floodplain Lakes*. ERTG 2013-01, prepared for the Bonneville Power Administration, U.S. Army Corps of Engineers, and NOAA Fisheries. Portland, Oregon. Available from http://cbfish.org/ERTG.

[1] A survival benefit unit (SBU) is an index intended to represent the effect of LCRE habitat restoration on juvenile salmon survival. The SBU method uses an ecosystem-based approach to assess improvements to habitats supporting juvenile salmon and other species. SBUs are assigned on a restoration project-specific basis.

Contents

Introduction

The Expert Regional Technical Group (ERTG) scores potential restoration projects to calculate survival benefit 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 (BiOp) on operation of the Federal Columbia River Power System (FCRPS). As stated in the BiOp, SBUs are calculated using, "the approach originally applied in the FCRPS Biological Assessment…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 the ERTG describes an approach to calculate SBUs for subactions in floodplain lakes in the lower Columbia River and estuary (LCRE), and identifies important uncertainties that affect the calculation of SBUs for such projects.

Problem

Because of their large size, shallow-water habitats, and locations relative to the main stem, restoration of large floodplain lakes (FPLs) of the LCRE may provide important rearing habitat for juvenile salmon. However, the definition of FPLs is vague, their function and importance to juvenile salmon has not been widely studied, and the attributes used to estimate survival benefits for other habitat types may not directly apply. Because many FPLs are very large, the estimated SBUs of a FPL restoration project could be substantially over- or under-valued because the area of habitat affected by a project is used to calculate SBUs.

The ERTG reviewed information describing FPLs in the LCRE and other estuaries to address the following questions which are relevant to its SBU scoring:

- What are the defining attributes of FPLs?
- What locations within FPLs constitute high-quality salmon habitat?
- What fish densities should be expected in restored FPLs and used to calculate SBUs for FPL restoration actions?
- What is the likelihood that a restoration action will succeed if the natural flooding processes that create and maintain FPLs are impeded by flow regulation?
- How do currently modified river hydroperiods affect fish access to FPLs?
- How do seasonal water temperatures affect salmon access to and rearing capacities of FPLs?
- What effect will invasive species likely have on juvenile salmon survival in FPLs?
- How productive are FPLs relative to other habitats and how will this productivity likely directly and indirectly affect juvenile salmon survival?

Background

The ERTG uses a spreadsheet "SBU Calculator" to calculate SBUs by subaction based on the 2010 Estuary Module values for total possible SBUs, total subaction goal (acres/miles), a weighting factor for 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 prescribed in the 2010 Estuary Module 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 calculation process starts with an optimal fish density that is derived from the literature, and then discounted by expert scoring of site- and project-specific attributes.

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 contribute differently to salmon survival. For example, Subaction CRE-10.2[2] can provide access to a variety of habitat types, such as saltwater marsh, freshwater wetlands, and FPLs. Each habitat type likely affects survival differently and therefore requires a different weighting factor. Here the ERTG reviews the status of knowledge of floodplain lakes and describe the basis for the weighting factor for floodplain lakes.

Floodplain Lake Workshop

At a regional workshop held in Portland, Oregon on June 18, 2013, scientists and restoration practitioners reviewed the status of knowledge about the "Role of Floodplain Lakes for Juvenile Salmonids in the Lower Columbia River and Estuary." Workshop participants discussed the development and geomorphology of FPLs, the diversity of FPL types and features, and the status of knowledge about their use by salmon and other fish species. They described considerable uncertainty about FPL functions for juvenile salmon, reinforcing the questions listed above. For example, no new data were presented to quantify the salmon-rearing capacity of large FPLs or to devise a method for partitioning salmon densities by habitat type within a large lake (e.g., littoral fringe vs open water). Overall the workshop discussion reinforced the approach and uncertainties for estimating relative SBUs for FPL restoration projects described by the ERTG herein. Some key points from the workshop relevant to the ERTG scoring process are as follows (workshop presenters are identified in parentheses):

- Floodplain lakes are difficult to distinguish from some other water bodies. The National Wetland Inventory (NWI) and the Columbia River Estuary Ecosystem Classification (CREEC) provide indications of what may be classified as a lake or wetland. In both classification systems, a lake generally means the site is dominated by open water relative to emergent vegetation. Some lakes are artificially created and maintained through management, roads, etc. (Evans).
- Because of local and inter-annual variations in hydrology, which can affect the area dominated by emergent marsh versus open water, a continuum of habitats is represented from emergent-marsh-

[2] 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).

dominated through open-water-dominated floodplain, making it difficult to partition FPLs into particular habitat types.

- Appropriate juvenile salmon density for calculating SBUs remains uncertain. Although there were very limited data on salmonid presence in lakes, data from channels leading to and from lakes did contain young salmon. There are no published data on juvenile salmonid densities in Columbia River FPLs (Johnson, Baker, Bottom). However, data taken at the interface between a fringing marsh and an associated channel leading to a FPL showed salmonid densities to be ≈0.01 m^{-2} (Johnson). Further, the composition and diversity of the fish assemblages and fish growth rate were similar between FPL-associated channels and floodplain wetlands (Johnson).
- Flow regulation and land use likely constrain the restoration of FPLs. Large back swamp lakes were present historically, along with smaller lakes formed in swales and low spots in the floodplain. The back swamp lakes had extended periods of connection with the main-stem river. Some of these water bodies are relics because of altered hydrology and levee construction, and are generally filling in (O'Conner). Groundwater can be a major contributor to the hydrology of FPLs (Kolp).
- Flow regulation can affect juvenile salmon access to FPLs. Salmon access to Columbia River floodplains and FPLs is dependent on episodic pulses of high river flow that inundate low-lying areas and may facilitate fish dispersal from the main river channel. Stock-specific use of FPLs thus depends on the timing of flood events relative to the seasonal migrations of particular stocks and life histories of juvenile salmon (Baker, Bottom).
- Predation on juvenile salmonids by exotic species appeared to not be a major factor in the few locations that had been surveyed (Baker, Johnson).
- Export of organic matter and prey produced in FPLs probably can occur, and could be substantial if hydrological connections are available (Diefenderfer). However, salmonids were found to be selectively feeding on prey (e.g., dipterans) likely produced in wetlands associated with lakes and other floodplain habitats (MacNeale, Peterson).

Identification of Floodplain Lakes

Accurate and consistent identification of FPLs is necessary for the appropriate and consistent calculation of SBUs among projects. Unfortunately, FPLs are difficult to define, making some identification difficult. Based on a review of the scientific literature and discussions with scientists and restoration practitioners, and given consideration of the use of the concept of FPLs in the restoration process, the ERTG suggests the following:

1. The concept of a floodplain lake is used to define (or classify) water bodies with similar attributes, especially surface area, depth, flow, flood frequency, and amount of emergent aquatic vegetation, that distinguish them from other water bodies and likely affect the growth and survival of juvenile salmon that access them.
2. Within the LCRE, FPLs have a variety of forms and origins and can be distinguished from other water bodies, but their identification can be difficult because defining attributes occur along several, often interacting, continua or gradients. For example, surface area and depth are useful attributes, but

criteria to define a FPL based on them do not exist and their measurements are often positively correlated because of the origin of the FPLs.

3. The ERTG operationally defines FPLs as water bodies within the current and historic floodplain of the LCRE that have low water velocities relative to the river main stem, have large surface areas, are relatively deep, and have relatively little emergent aquatic vegetation. These attributes are expected to vary seasonally and as succession occurs.
4. In FPLs, more primary production and organic matter is likely from upland sources and seasonal inundation rather than from within the FPL (although planktonic production is higher than in lotic riverine environments), compared to that in other water bodies present in the LCRE, such as wetlands. Furthermore, water-quality parameters, such as temperature, dissolved oxygen concentration, and water clarity, are at least seasonally different from those of the river main stem and the FPL tributaries and they are usually different from wetlands and other water bodies.

Given their familiarity with project site conditions, project proponents are encouraged to identify the habitat type(s) that their project will affect and to provide a concise description of the aforementioned attributes to support water body identification. Project proponents are also encouraged to describe their expectation for the effect of their project on the attributes of the site and the survival and growth of juvenile salmon. Review of the FPL conceptual model (below) can prove useful in this endeavor. Consistent with previous work, the ERTG will review the identification of habitat types and request clarifying information or reclassify the habitat type, as needed, to maintain consistency within the process of calculating SBUs.

Conceptual Model

The ERTG developed a conceptual model to portray an FPL system and provide guidance for an approach to calculate SBUs for restoration subactions in FPLs (Figure 1). The ERTG used the model to highlight system features and processes that are most relevant for scoring proposed FPL projects. The model identifies the major elements considered in the ERTG scoring in terms of juvenile salmon access/opportunity via hydrological reconnections; 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.

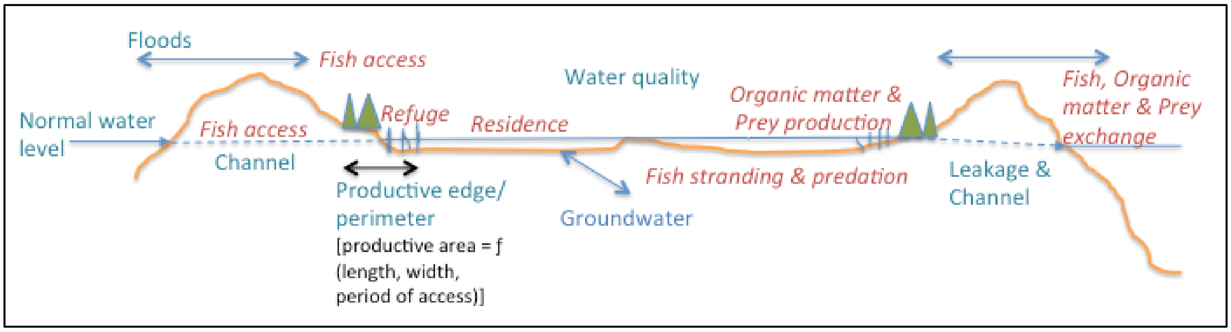

Figure 1. Floodplain lake conceptual model highlighting the major habitat features and ecological processes.

The degree and type of connection between a river and a FPL varies with river flow. Connection has been characterized as having three hydrological phases (Trockner et al. 1999):

- Phase I, Disconnection -- occurs during low-water conditions when the floodplain is hydrologically decoupled from the river.
- Phase II, Downstream Surface Water Connection and Seepage Flow -- occurs when the river level rises causing seepage flow into the floodplain, but discharge from the floodplain remains low because water is retained in the floodplain channels.
- Phase III, Upstream Surface Connection -- occurs 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 than for Phase II. The frequency of Phase III is very low. Water retention time is also much greater in Phase I compared with the other two phases. Whether the hydrology of FPLs in the LCRE follows the patterns described by Trockner et al. (1999) remains to be substantiated.

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 FPLs 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 a FPL, 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 some 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. In addition, 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). The ERTG suspects that organic matter (i.e., detritus) and prey are exported at times from the lakes into the main stem of the Columbia 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 exported from, FPLs in the LCRE are not well studied but could be very high based on the size of these systems.

Scoring Criteria

Scoring criteria for the three factors are described below.

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 used, 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 detail for some elements. Hampering evaluation of FPL benefits to salmon is the lack of well-documented (i.e., monitored) examples of FPL restoration in the LCRE. There is significant uncertainty regarding the degree to which the natural hydrology can be restored to FPLs. If hydrological reconnections between the river and FPLs can be restored through natural geomorphic features (e.g., natural channels), the ERTG 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 high. Uncertainties also exist regarding water-quality conditions, rate of habitat development, ability to maintain natural habitats, invasive exotic introductions, predation pressure (although data suggest that this may be a minor factor), 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 2010a). 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 levees 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, and distance from salmon source populations migrating downstream. 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 floodwaters 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 LCRE, 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 is required to quantitatively evaluate the conditions that mediate this risk. The much greater catch of warm-water non-natives versus juvenile salmonids in the historical record also suggests potential for predation of or competition with juvenile salmon by non-native fish; the extent of these interactions and their effects on juvenile salmon are uncertain.

Potential Benefit for Habitat Capacity/Quality

The ERTG scoring criteria also include an evaluation of habitat capacity/quality (ERTG 2010a). For 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 about the amount of organic matter and prey produced in FPLs, the lakes are assumed to 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 (40.5-ha) restored site, can export 178 T 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 than in 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 ensure that salmon benefit from FPL restoration.

Applications of the SBU Approach for Floodplain Lakes

Floodplain lakes occur in a continuum of environments distinguished by water depth, the extent of vegetative cover and open water, the persistence of connections to the main river, and other attributes. A primary task when calculating SBUs is to understand clearly where a proposed project is located along this continuum—historically, currently, and after restoration. This interpretation, in turn, directly influences each component of the ERTG scoring process. Two main components of the SBU Calculator—Subaction Selection and Weighting Factor—are explained below.

Subaction Selection

It is important to select the most appropriate subaction for each project activity. For FPL projects the primary engineering activity is limited breaching of existing natural or anthropogenic levees and construction of channels to increase the flow of water, juvenile salmon, and nutrients to and from the lakes. Management of sites for several species can mean that the levee breach invert elevation is constrained to prevent complete drainage so that ponding would be maintained, but salmonid ingress and egress would be constrained. In other cases, a historically re-routed channel that has accumulated debris, rather than the historical channel, can be proposed to reconnect the FPL to the river. The Module Subaction description provided by ERTG (2011) and the scoring criteria described by ERTG (2010a) suggest that for these projects the Subaction CRE-10.X is the most appropriate subaction series for calculating SBUs. Subaction 9.4 would also be applied when the channel between the FPL and river is improved. The ERTG selects among the subactions in the 10.X series for FPLs using the same reasoning applied to other habitat types, i.e., considering the relative degree of reconnection of the habitat.

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 2010a). 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 FCRPS, the ERTG suggests 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, some projects will likely improve the flow of water, sediment, nutrients, and fish through these systems and thus might provide large areas of useful salmon habitat. Further, projects that do not include using engineered structures (e.g., tide gates or culverts) might enhance natural processes.

Weighting Factor (Fish Density)

Because the actual survival benefit of various habitats to juvenile salmon are unknown, the ERTG uses habitat capacity (optimal fish density) as a surrogate measure. The ERTG SBU Calculator involves a weighting factor to relate optimal fish densities characteristic of different habitats to the idealized Estuary Model Density for various subactions (ERTG 2010b). Consequently, a new weighting factor is recommended to adapt the potential density of fish used in the Subaction 10.X series to accommodate the restoration of FPLs.

The densities of juvenile salmon in FPLs relative to other types of estuarine water bodies are poorly understood. While data exist for a few floodplain areas (PCTA 2012; Vigg et al. 2011), the ERTG found no quantitative estimates of juvenile salmon densities for permanently or seasonally flooded lakes. Salmonids using FPLs likely reside in them 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 them. Each of these floodplain habitats likely has unique hydrological and biological characteristics that influence species composition, residence time, and performance.

The sites of 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 salmon m^{-2} and 0.0002 to 0.098 chum salmon m^{-2}.

The ERTG has no data describing which locations within FPLs 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. Surveys in the narrow, vegetated outlet channel of one Columbia River FPL (Franz Lake) estimated seasonal salmon densities of ≈0.01 fish m^{-2} (L. Johnson, unpublished data). However, these results may not depict average densities for the open-water habitats of the lake itself. To extrapolate fish densities from smaller high-quality habitats to large FPLs with heterogeneous habitats, the ERTG proposes a conservative estimate of potential fish-carrying capacity. The ERTG recommends an optimal density of salmonids in FPLs to be 0.01, 0.005, and 0.0025 salmonids m^{-2} averaged over the surface area of the lake for Subactions 10.1, 10.2, and 10.3, respectively. These FPL-wide densities recognize that smaller and more complex edge habitats will support higher densities of fish, while the extensive central portion of a lake will support few fish. Ideally, the ERTG would use detailed information about fish densities in FPL microhabitats and how those microhabitats are distributed to calculate SBUs, but that information is not available at this time.

Summary of Approach

Using the existing SBU Calculator as a basis, the ERTG suggests the following approach to assign SBUs for FPL reconnection actions:

1. Module Subactions – Use Subaction 9.4 (channel improvements) and the Subaction 10.X series (levee breach or improved hydrology) (ERTG 2011).
2. Area – Apply wetted area based on the 2-year riverine flood elevation or extreme high water for delineating the area of sites (ERTG 2012); no restriction to a buffer or edge zone.
3. FPL Determination – Consider that lakes have a large amount of open water relative to vegetated edge habitat. The National Wetland Inventory Classification (Level 1) decision tree provides a general guide for distinguishing open-water lakes from other floodplain wetlands (NWI defines wetlands as >30% vegetation and <2 m depth). However, sponsors should consider all information available (NWI, CREEC). Sponsors should provide evidence for their FPL or wetland determination for ERTG to review.
4. Scoring – Downgrade scores where 1) uncertainty in outcomes is high; 2) partial access to the floodplain lake already exists; 3) natural, historical processes will not be restored (ERTG 2010a).
5. Weighting Factor – Use the 10.X series with weighting factors as listed below. Subaction 9.4 does *not* need a weighting factor specific to FPLs.

Module CRE	SBU Goals Ocean	SBU Goals Stream	Module Goal (acres or miles)	Module Fish Production (#/acre)	Computed Module Fish Density (#/m^2)	ERTG Optimal Fish Density (#/m^2)	Weighting Factor
10.1 FPL	13	4	5,000	65	0.016	0.01	0.625
10.2 FPL	3	1	2,000	35	0.009	0.005	0.556
10.3 FPL	2	1	1,000	50	0.0125	0.0025	0.200

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 River, or 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 LCRE 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 levees, culverts, floodgates, water-control structures, and re-routed streams. Nevertheless, what little is known about these systems suggests they could be beneficial habitat for juvenile salmon if risks associated with predation by non-native fish, stranding of juvenile salmon as floodwaters recede, and seasonal development of stressful water-quality conditions can be managed. Given the large size of many FPLs in the LCRE, the potential benefit of their restoration to salmon could be huge. However, given the significant uncertainties in this disturbed system, the ERTG must proceed by adhering to the precautionary principle: conservatively estimating restoration benefits to juvenile salmon, while scientific investigations systematically reduce uncertainty regarding FPL restoration through monitoring of FPL restoration projects, as well as basic research on the ecology of LCRE 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 canary grass 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 ensure 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 it becomes better informed by monitoring results.

References Cited

Baker C. 2008. *Seasonal Floodplain Wetlands as Fish Habitat in Oregon and Washington*. PhD. Dissertation. Oregon State University, Corvallis, Oregon.

Bottom DL, CA Simenstad, AM Baptista, DA Jay, J Burke, KK Jones, E Casillas, MH Schiewe. 2005. *Salmon at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon*. NOAA Technical Memorandum NMFS-NWFSC-68, Seattle, Washington.

Cordell JR, JD Toft, A Gray, GT Ruggerone, M Cookseyl. 2011. "Functions of restored wetlands for juvenile salmon in an industrialized estuary." *Ecological Engineering* 37:343−353.

ERTG (Expert Regional Technical Group). 2010a. *ERTG Scoring Criteria*. ERTG Doc# 2010-02, available from Bonneville Power Administration or the U.S. Army Corps of Engineers, Portland, Oregon.

ERTG (Expert Regional Technical Group). 2010b. *History and Development of the SBU Calculator*. ERTG Doc# 2010-03, available from Bonneville Power Administration or the U.S. Army Corps of Engineers, Portland, Oregon.

ERTG (Expert Regional Technical Group). 2011. *Guidance on Estuary Module Actions and Subactions Relevant to the ERTG Process*. ERTG Doc#2011-02, available from Bonneville Power Administration or the U.S. Army Corps of Engineers, Portland, Oregon.

ERTG (Expert Regional Technical Group). 2012. *ERTG Analysis of Water levels for Site Delineation in Tidal Dominated Regions*. ERTG Doc# 2012-01, available from Bonneville Power Administration or the U.S. Army Corps of Engineers, Portland, Oregon.

Kukulka T and DA Jay. 2003. "Impacts of Columbia River discharge on salmonid habitat: 2. Changes in shallow-water habitat." *Journal of Geophysical Research* 108 (C9):3294, doi:10.1029/2003JC001829.

Lampman BH. 1946. The Coming of the Pond Fishes. Binfords and Mort, Portland, Oregon.

Moyle PB, PK Crain, and K Whitener. 2007. "Patterns in the use of a restored California floodplain by native and alien fishes." *San Francisco Estuary and Water Science* 5(3):1-27. Available at http://escholarship.org/uc/item/6fq2f838

Naik PK and DA Jay. 2011. "Human and climate impacts on Columbia River hydrology and salmonids." *River Research and Applications* 27:1270−1276.

PCTA (PC Trask and Associates). 2012. *Juvenile Salmonid Use of Very Large, Shallow, and Tidally Influenced Lakes in the Floodplain of the Lower Columbia River: A Literature Review*. Review draft available from the Bonneville Power Administration, Portland, Oregon.

Sommer TR, WC Harrell, and ML Nobriga. 2005. "Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain." *North American Journal of Fisheries Management* 25:1493−1504.

Thom R, H Diefenderfer, A Coleman, A Borde, C Roegner, J Tagestad, G Johnson. 2012. "Ecology and Hydrology of Restoring Wetlands in the Lower Columbia River and Estuary." Chapter 2, in G Johnson + 18 co-authors. 2012. *Evaluation of Cumulative Ecosystem Response to Restoration Projects in the Lower Columbia River and Estuary, 2010 FINAL REPORT*. PNNL-20296, prepared for U.S. Army Corps of Engineers, Portland District under a Government Order with the U.S. Department of Energy Contract DE-AC05-76RL01830, by Pacific Northwest National Laboratory, Richland, Washington.

Trockner K, D Pennetzdorfer, N Reiner, F Schiemer, JV Ward. 1999. "Hydrological connectivity, and the exchange of organic matter and nutrients in a dynamic river-floodplain system Danube, Austria." *Freshwater Biology* 41:521−535.

Vigg S, D Phelps, A Uber, and D Bighouse. 2011. *Literature Review on Floodplain Lakes and Associated Wetlands*. Literature Review Document. Prepared by Washington Department of Fish & Wildlife, Vancouver, Washington.

Woodruff D, R Thom, C Roegner, S Breithaupt. 2012. "Material and Nutrient Flux from Restoring Wetlands in Tidal Freshwater of the Lower Columbia River and Estuary." Appendix E in G Johnson + 18 co-authors. 2012. *Evaluation of Cumulative Ecosystem Response to Restoration Projects in the Lower Columbia River and Estuary, 2010 FINAL REPORT*. PNNL-20296, prepared for U.S. Army Corps of Engineers, Portland District under a Government Order with the U.S. Department of Energy Contract DE-AC05-76RL01830, by Pacific Northwest National Laboratory, Richland, Washington.