Monitoring Recovery Trends in Key Spring Chinook Habitat Variables and Validation of Population Viability Indicators

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Narrative

Table 1. Proposal Metadata -*(You may provide a link to this information in Pisces, if available, rather than filling out this table.)*

Project Number	2009-004-00
Proposer	CRITFC
Short Description	Monitoring recovery trends in key spring Chinook habitat
Province(s)	Blue Mountain
Subbasin(s)	Grande Ronde
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Information transfer:

A. Abstract

The framework for recovery trend monitoring under the Accords follows the following logic pathway:

1. The Accords and BiOp constitute a set of hypotheses concerning restoration trends.
    a. The aggregate sets of restoration actions will improve habitat conditions in freshwater subbasins and watersheds, the mainstem, and estuary;
    b. The viability of listed populations (assessed by VSP metrics) will improve as a result of these aggregate actions;
    c. Gains in habitat condition from aggregate restoration actions by watershed or subwatershed will outpace cumulative degradational actions from land management and climate change;
2. Monitoring metrics, protocols, and statistical underpinnings need to be more rigorously planned and framed to gain the greatest understanding of trends in habitat condition and fish species viability.
    a. Baselines established on professional opinion are not repeatable and must be replaced by quantitative habitat monitoring.
    b. Monitoring metrics must be carefully evaluated to ensure a sound compromise between broad spatial accuracy and precision and providing a

limited set of variables that captures essential aspects of the freshwater environment controlling fish viability;
    c. A monitoring protocol must be statistically rigorous.
3. The monitoring effort can be incorporated into a cost-effective means of incorporating learning into a management decision-making tool that makes use of habitat and population viability models.
    a. We need to learn how fish respond to changes in habitat conditions at the reach and watershed scales and how that translates to fish abundance, distribution, and survival;
    b. That learning needs to be viewed in a life-cycle context to assess population persistence over time;
    c. To the extent possible, we need to evaluate variation and directed change in habitat conditions in all portions of the salmon life cycle: freshwater as well as ocean, as influenced by climate change.

This project is described in three phases (a) the first year, to develop and test sampling procedures, develop a long-term coordination plan and design successive phases, (b) a 5-year period to implement full sampling in two damaged watersheds supporting key TRT Chinook populations; continue development of sampling procedures and protocols; develop a set of models representing the relationship between watershed conditions and fish responses at the individual and population scales; and plan for the second 5-year phase, and (c) the second 5-year phase: continuation of lower intensity monitoring of trends in the two initial study areas and implementation of monitoring in a second set of streams to represent contrasting intensities of disturbance and development of additional models representing habitat/fish interactions for all life stages. This 10-year framework will, presumably, include two major workshops and planning of the next 10-year Accords monitoring plan.

The current proposal is focused on the first year's work which is preparatory to the first five-year phase of work. The scope of the first five-year module is abstracted below:

1. Refine sampling methods for sediment, temperature and stream flow. The new procedures will include a description of the statistical properties of each method, including accuracy, precision, and bias. Field manuals and training procedures to increase comparability of results and reduce variation among sampling teams will also be developed.
2. Monitor changes in habitat conditions resulting from restoration and other development in two damaged watersheds in the Grande Ronde subbasin
3. Develop models of the relationships between habitat conditions and Chinook salmon responses:
    a. At the reach and watershed scale in detail;
    b. For the entire life cycle
4. Implement the coordination plan developed during the first year
    a. Hold pre- and post-field season workshops for CRITFC member tribes to 1) train teams and standardize sampling methods and 2) coordinate

sampling plans and locations to provide cost effective and statistically sound results across tribal ceded areas.
   b. Coordinate sampling protocols, procedures and sampling locations with other agencies;
   c. Regularly report the results of tribal restoration efforts for the Columbia River Accord projects in coordination with the Data Network Project.
5. Habitat degradation is attributed as a significant cause for the decline of numerous salmonid populations in the Columbia basin. Watersheds that support depressed populations within a sub-basin of the Columbia basin will be selected to act as study watersheds for determining whether habitat conditions are improving or declining with time. In these study watersheds (expected to be the upper Grande Ronde River and Catherine Creek) habitat conditions for their spring Chinook populations will be assessed at various spatial scales. Year 1 work will emphasize gathering all available environmental data pertaining to study areas, evaluating methods for monitoring key variables, reviewing regionally used monitoring protocols, comparing monitoring methods for adequacy against scientific literature, developing monitoring manuals for individual elements, developing overall monitoring protocols, and coordinating with tribal habitat staff, agencies, and landowners concerning plans. After locating sample sites needed, habitat condition data will be collected as a preliminary test of methods and logistics. Sample sites will be identified according to various criteria. Sites for streamflow and water temperature measurement will be determined according to a criterion of a tributary providing more than 5% of streamflow to a mainstem. Nodes upstream and downstream of these tributaries are needed for water temperature modeling purposes. Sediment analysis will be focused in spawning areas, which will be classified according to channel gradient class. LiDAR data will be collected for the entire riparian system bordering the historic spawning and rearing area used by the study populations.
6. TIR (thermal infrared) data will be collected on the stream systems supporting spring Chinook and used with LiDAR data to develop a deterministic water temperature physical model.
7. The effectiveness of habitat restoration actions on specific stream reaches and as aggregate actions applied to entire watersheds will be evaluated preferentially using Before-After Control Impact (BACI) designs, or treatment-control designs depending upon physical limitations. These statistical designs will be applied to both habitat conditions and population attributes (abundance and productivity) on these sub-basins.
8. A theoretical biological model will be developed that will express spring Chinook abundance and survival as a function of a set of sub-models based on (a) known relationships between fine sediment in spawning gravel and survival to emergence, (b) summer water temperature and juvenile summer rearing survival, (c) streamflow (d) spawning gravel availability for adults, (e) riparian vegetation canopy structure and height; topographic shading; streamflow vs. water temperature.
9. Within the 5-year framework of this project, life cycle-based habitat models for spring Chinook salmon will be developed from empirical monitoring of

populations and habitat conditions to address life history complexities and capture inter-annual variation in recruitment as a function of freshwater and early ocean/estuary environmental variation. Based on habitat data collected from the status and trend monitoring, overlain with life-history parameters, we will develop a quantitative modeling approach to estimate the annual variation in recruitment (and survival). This empirical, life cycle model will be used to validate the application of the set of individual models relating survival and abundance to specific habitat factor quantity and quality.

10. Projections of future changes in streamflow, runoff patterns, and water temperature stemming from associated CRITFC projects on climate change will be incorporated in future years into Chinook abundance and productivity model predictions.
11. This study and its specific methodologies, metrics, and design will be developed and improved with time based on a collaborative effort with other agencies in the region. For example, ODFW, NMFS, and the Tribes have similar sets of interests, objectives, and ongoing monitoring in surrounding basins. Collaboration and cooperation will be important in increasing the value of data collected.

B. Technical and/or scientific background

The Columbia Basin Fish Accords (2008) (hereafter, Accords) developed between the Action Agencies (Bonneville Power Administration, Army Corps of Engineers, and the US Bureau of Reclamation) and the CRITFC member Tribes (Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and the Confederated Tribes of the Warm Springs Reservation of Oregon) hold the expectation that significant gains can be made in population, major population group (MPG), and ESU (evolutionarily significant unit) viability by joint habitat restoration actions taken by all federal, state, and tribal groups. Quantitative estimates of the anticipated 10-year increase in survival were laid out in NOAA (2007, 2008) and the Accords (2008) for each listed Chinook and steelhead population. The percentage increases were calculated from estimated current and expected future habitat function of all key limiting factors. An expected, integrated percentage habitat improvement was also described in NOAA (2007, 2008), which was essentially the average of percentage improvements from individual limiting factors.

The Interior Columbia Basin TRT (Technical Recovery Team) identified all Chinook populations for each ESU that was specified as threatened or endangered under the ESA. These populations were assembled into major population groups (MPG) depending upon genetic and life history similarity and geographic proximity. The TRT suggested that certain populations must achieve a status as viable in order for the MPG and the ESU to be viable. The Columbia River Treaty Tribes are placing great reliance on the hydropower and estuary provisions to improve survival of salmon during the mainstem phase of the freshwater life cycle. They have agreed in the Accords to test the ability of increased habitat restoration actions to provide a sufficient increase in freshwater survival so that life cycle productivity is positive.

A critical uncertainty in the 2007 Bi-Op Remand and Accords (2008) involves determining whether the improvements in overall habitat quality anticipated from aggregate habitat actions on a basin scale will yield a net improvement in basin-wide habitat quality or whether ongoing degradation will negate or outweigh these improvements.

It is not possible to conduct intensive monitoring of habitat status on all salmon-bearing basins within the Columbia Basin, so a representative sample of basins has already been selected for monitoring progress in habitat restoration by other agencies. For example, model watersheds such as the Wenatchee, Entiat, Salmon River (South Fork Salmon, Lemhi), and John Day (South Fork John Day, Bridge Creek) are being studied intensively (ISEMP, see http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/index.cfm).

The current proposal suggests that useful information would be provided by the upper Grande Ronde River and Catherine Creek. These basins are among those often cited as being extremely damaged (NOAA 2007). They support listed spring Chinook and steelhead populations that are very weak. The importance of restoring these basins is very high in the interest of restoring key populations essential to the major population group. With habitats and populations that are so damaged, the potential of being able to demonstrate improvement should be high.

Problems posed by past modeling concepts

During the 2007 Bi-Op Remand Collaborative Process, the Habitat Subcommittee explored options for estimating the potential productivity of spring Chinook and steelhead habitat. Productivity in the freshwater, tributary rearing phase of the life cycle can be measured empirically as survival from egg-to-smolt stages, or even include the pre-spawning adult survival leading up to the egg deposition stage. However, estimation of the potential survival in the tributary freshwater phase involves understanding (1) the current or future spatial distribution of habitat condition in historically used habitat, (2) the life stage specific influence of current or future habitat condition of key habitat limiting factors on survival, and (3) how to integrate the combined influence of all habitat limiting factors through all freshwater life stages and life history types.

The Habitat Subcommittee adopted a methodology for estimating the expected change in population survival that could result from habitat improvement that has the following elements: (1) identify the key habitat limiting factors, (2) identify the current condition of each limiting factor, (3) estimate the current survival by life stage under the influence of specific limiting factor habitat conditions, expressed as a habitat factor percentage function, (4) estimate the maximum egg-to-smolt survival expected under natural potential habitat conditions (i.e., fully restored), and (5) estimate the overall (i.e., egg-to-smolt) tributary freshwater phase survival as an average of the percentage functions for the individual key limiting factors times the maximum potential survival.

The methodology above was used by the Action Agencies to estimate for each listed population in the Columbia River the expected current survival and the future survival, given the anticipated level of restoration accomplished in 10 and 25 years. This procedure leads to the expressed need of this proposal to monitor the actual level of improvement in survival that occurs. This will be pursued indirectly as an increase in in-channel habitat condition (expressed at either a reach scale or a stream system scale) and directly as a measured improvement in biological response (e.g., increase in survival, abundance, growth rate).

Despite the apparent simplicity of this concept, there are difficulties inherent in this method for monitoring restoration effectiveness that lead to various proposed field measures. For example, (1) The method of averaging percentage habitat function from individual limiting factor percentage functions based on professional judgment is most likely unreliable and irreproducible, (2) The ability to derive an average habitat condition for a long reach and especially an entire stream system is problematic as a rapid assessment and does not lend itself to integrating habitat condition qualitatively as a mental process on a large special scale, (3) Potential survival varies by stream reach in conjunction with current and potential habitat condition and should be evaluated spatially, (4) Overall survival is a multiplicative function of life stage survivals (Walters 1997) rather than related to an average overall habitat function as assumed by the BiOp using the so-called "hybrid method", (5) Current fish survival rates from a watershed reflect only the present habitat conditions experienced in its series of life stages from adult holding to smolt emigration and do not necessarily integrate habitat conditions throughout all historical habitat, whose 10-year improvement is the object of concern.

More detailed explanation of these problems that serve as a basis for developing a comprehensive monitoring and evaluation plan

Habitat quality in the Upper Grande Ronde, the Mid Grande Ronde, and Catherine Creek is significantly impaired. NOAA (2008) identified in its BiOp that the primary limiting factors in the Upper Grande Ronde were in-channel characteristics, riparian/floodplain condition, sediment, and water temperature. Water temperature was estimated to have a current percentage function of 20%. This is expected to increase to 30% function in 10 years. Temperature impacts on survival can be experienced primarily either during the winter incubation period or during the summer rearing period. At the same time, sediment is currently estimated to operate at a percentage function of 30%, increasing to 40% in 10 years. The estimated percentage function is translated roughly as a current egg survival to emergence of 30% of potential survival caused by fine sediment levels that is expected to improve to 40% of potential survival after a 10-year restoration program. Other primary limiting factors (in-channel characteristics and riparian/floodplain function) each were assigned a function of 40%, with a potential of increasing to 50% of historic function. The BiOp (NOAA 2007) and Accords (2008) estimated that the average current percentage function for these four limiting factors was 34%. However, given the fact that water temperature impairment to survival would affect salmon independently of the more favorable level of function in other habitat characteristics, it is more likely that the governing functionality of habitat is closer to 20%, assuming this "professional opinion" about water temperature percentage function is meaningful at the outset. This proposal for monitoring habitat and fish (population) response (to habitat restoration actions) in the Upper Grande Ronde and Catherine Creek is expected to be a test case in years 1 to 5 for how to predict the combined effects of habitat condition operating on a population throughout its freshwater life phase and integrated at a spatial scale encompassing the entire watershed supporting the population. These methods can then be expended to other streams in either the Grande Ronde basin or John Day basin in years 6-10, to explore habitat-fish relationships, habitat restoration, and improvements in fish population viability over a 10-year period.

It was noted by this Habitat Subcommittee that the approximate maximum egg-to-smolt survival observed in the field in the Pacific Northwest for spring Chinook is 18% and that for steelhead is 4%, with the differences related to the difference in time spent in freshwater rearing (NOAA 2007, Accords 2008). These survival rates are apt to be those found under relatively optimal conditions, such as in a pristine or minimally developed basin. However, even pristine basins may not all provide spatially distributed conditions that would permit these maximum observed egg-to-smolt survival rates. This implies that it would be necessary to be able to estimate potential conditions by stream reach throughout a stream system. In a developed basin a high survival percentage of a fish population might be empirically measured in a small portion of the basin that remains pristine, but this would not be a relevant indicator of the quality of the overall habitat for the population. Empirical estimates of survival for all eggs deposited in a given year would reflect the habitat quality primarily of a limited portion of a large watershed or subwatershed that is actually used. In order to understand potential freshwater survival rates in tributary habitat, it is important to understand also the quality of the habitats used in all historically occupied stream reaches.

If certain smaller watersheds within the large watershed supporting a TRT population (e.g., Meadow Creek in the Upper Grande Ronde) that were historically used are heavily damaged and then not used by salmon for spawning or rearing, the overall survival observed for the large watershed does not integrate the quality of those unused habitats. If supplementation of a watershed occurs by stocking of adults, high quality habitat may become limited and adults would need to seek out more marginal spawning and rearing areas or adults would spawn in limited-capacity habitat (superimposition), resulting in an overall reduction in productivity from that found at low density. Also, as a natural population increases in abundance to fully seed its available habitat, the spawners and rearing juveniles would expand into the areas of marginal habitat quality, resulting in a similar overall reduction in productivity. This could be interpreted as a density dependent effect expressed at maximum population abundance. This is a limitation defined by the carrying capacity, which is related to the abundance of habitat (percentage of the full historical range) and the distribution of habitat quality over this range.

As habitat is gradually improved, more extensive habitat area will be used in production of the population. These newly used, improving habitats may have a lower quality than the limited high quality areas used prior to habitat restoration work. This could result in an overall, integrated habitat quality for the expanding population distribution that is somewhat lower on average, but can have a total quantity that can support a larger total abundance. This illustrates that restoration must be assessed by both a change in productivity and abundance, reflecting both quality and quantity of habitat.

How this project addresses the problems described

The project objectives expressed for **Year 1** are essentially involved with planning, development of prototypes, and coordination. In more detail, the key objectives of Year 1 in this proposal include:

1. Develop and test (prototype) sampling methods and locations
    a. Develop monitoring manuals for field work on water temperature, streamflow, and fine sediment;
    b. Develop a field monitoring instrument for measuring surface fine sediment;
    c. Develop field monitoring protocols, including schedules, crew plans;
    d. Collect preliminary data on water temperature, streamflow, and cross sections; collect GIS data on watershed characteristics; collect available climatic data;
    e. Develop probabilistic sampling designs and assess statistical properties of sampling schemes;
    f. Establish a laboratory at CRITFC for processing sediment samples;
    g. Acquire all necessary equipment for the first five years of work;
    h. Collect LiDAR data on riparian and floodplain surface topography, create usable DEMs (digital elevation models) from these data, map riparian vegetation height by stream reach;
2. Develop a coordination plan for a) CRITFC member tribal activities under the Columbia Basin Accords and b) with other agencies doing related work in the interior Columbia Basin.
    a. Participate in a workshop convened by CBFWA to coordinate an interagency framework, share knowledge, and develop a coordinated interagency action plan to fill in framework elements;
    b. Coordinate with tribes, agencies, and landowners in gaining permission for the work, accessing sites, gathering available information, and coordinating work;
    c. Identify key metrics and formats for reporting progress under the CRITFC tribal Accord projects.
3. Plan activities for the first five-year period of activity
    a. Conduct literature reviews on monitoring methodologies, equipment, fish-habitat relationships, regional monitoring protocols, carrying capacity;
    b. Evaluate existing biological data collected by agencies or tribes on the study watersheds;
    c. Develop a database structure for assembling and interpreting all data collected;
    d. Describe fish/habitat model structures and validation procedures;

e. Establish milestones, peer-review process, and Adaptive Management process for the next 10 years.

Figure 1 illustrates the overall scheme for monitoring habitat and fish variables and linking these in a habitat-fish model. In Figure 1 water temperature is controlled by solar radiation and its alteration by riparian condition. Intrinsic watershed characteristics such as topographic roughness and channel morphology affect the potential to accumulate solar loads. Current condition (anthropogenic effects), such as riparian road density, can modify the riparian shading effects. Variations in the spatial distribution of water temperature affect the spatial distribution of potential survival of summer-rearing juveniles. The intrinsic characteristics of the hydrograph are a function of intrinsic watershed topography, climatic class, and potential vegetation but are modified by human effects such as road density, irrigation withdrawal, and vegetation alteration. The modifications to the natural hydrograph determine streamflow, which affects water temperature patterns. Lower streamflows reduce the thermal buffering capacity of the stream. The watershed class, classified by intrinsic features such as topography, soils, and potential vegetation may be modified by human disturbances, such as grazing, road construction, and vegetation removal, which lead to changes in the sediment delivery regime. Increased fine sediments can reduce pool volume, which can alter the thermal buffering capacity of a reach. Increased fine sediment deposition in spawning gravel also reduces salmon and trout egg survival to emergence (Chapman and McLeod 1987, Chapman 1989, Rhodes et al. 1994).

The cumulative environmental improvements resulting from quantitative changes in water temperature, streamflow, fine sediment, and riparian condition set the framework for modeling the adult to smolt survival. This can be modeled as a single step from adult to smolt or as a series of life stages, as shown in Figure 1.

The habitat and fish population monitoring intent of the **5-year module** includes:

(1) Assess current status and trends in fish habitat characteristics considered to be key limiting factors (especially water temperature, fine sediment, and streamflow) to salmon viability for selected important populations.
(2) Assess the overall fish habitat functionality for watersheds supporting selected TRT populations as well as for individual assessment units within each study watershed. These watersheds were among those evaluated in the 2007 BiOp (NOAA 2007) and Accords (2008) for current percentage function and expected future function.
(3) Assess current status and trends in other selected fish habitat characteristics known to be essential in defining population abundance or productivity that might vary with climatic trends. See Appendix A.
(4) Evaluate the linked biotic responses of salmonids, other fish populations, and macroinvertebrates to changes in key fish habitat variables.
(5) Biotic response will be assessed as population level smolt output relative to adult input to the watershed; life stage survival at the stream reach level where survival can be indexed to key habitat quality indices; fish community indices by stream

reach (position within the stream network for the spring Chinook population watershed); macroinvertebrate community indices by stream reach (position within the stream network for the spring Chinook population watershed);

(6) Evaluate habitat status and trends at both the watershed (stream system and watershed condition trends) and the stream reach scales; evaluate effectiveness of specific restoration actions to improve specific limiting factors by selection of treatment and control sites (e.g., reaches of similar class within the mainstem of the upper Grande Ronde where restoration has significant local effects on a treatment reach and where control reaches may be both upstream and downstream of the treatment or may be in a separate stream reach of the same class; in this design, the intent is for control reaches to have similar watershed influences as the treatment). Given enough lead time prior to the treatment, pre-project monitoring can be contrasted with post-treatment monitoring. Pre-project monitoring is likely critical for supporting final conclusions.

(7) Collaborate with the CRITFC Climate Change mpact database development and decision support tools for habitat management (BPA project number 200900800) and Influence of Environment and Landscape on Salmonid Genetics projects (BPA project number 200900500) to estimate the potential effect of habitat conditions and future climate change on Chinook genetics and spring Chinook abundance and productivity and limits of habitat restoration to counteract the negative impacts of climate change.

Item 4 above describes development of a habitat-fish relationship, which is illustrated in Figure 1.

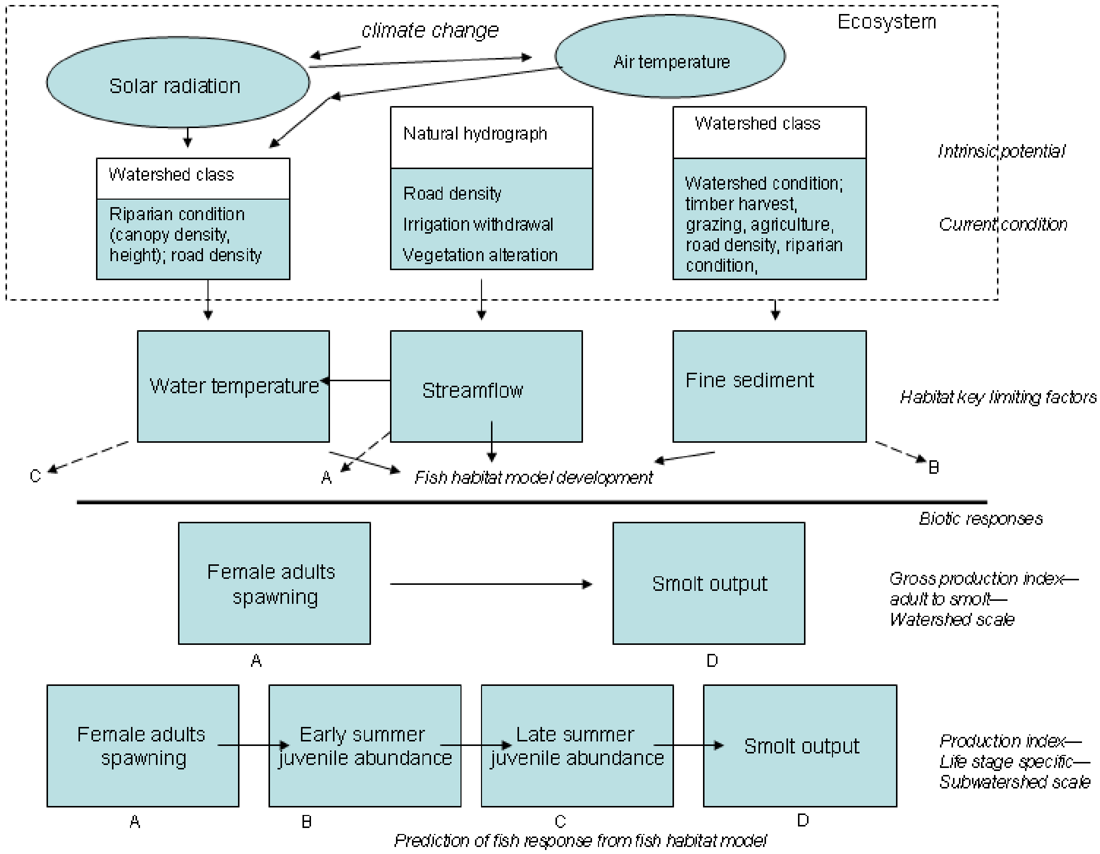

Figure 1. Illustration of the key components of the modeled habitat system (water temperature, streamflow, and fine sediment in spawning gravel), with linkage upward of these components to their environmental system (intrinsic and extrinsic factors) and downward to the biological responses (gross fish productivity described from adult to smolt stage, and finer scale life stage specific productivity).

Modeling for Habitat-Fish Relationships

There are several existing models of biological response as a function of habitat quality/quantity. In the Columbia basin, the EDT (Ecosystem Diagnosis and Treatment) model has been widely used to assess potential changes in population abundance and productivity based on restoration scenarios. However, this model has been criticized for having an excessive number of parameters, many of which are not known and can only be guessed (McHugh et al. 2004). This model also has not had its habitat-biological response relationships especially well documented. Because most listed populations have had between 3 and 6 limiting factors identified as controlling their potential recovery (NOAA 2007), it appears to be excessively burdensome to attempt to model production based on all 45 variables, and more reasonable to focus on a limited number of significant limiting factors. instead.

Recently, Cramer Fish Sciences (2008) developed an extensive model for abundance and productivity of coho from input by noted experts on various elements of the freshwater life cycle. This framework is exemplary, but is specific for coho.

The overall objective of this proposal is to develop a spatially-based system for modeling abundance, productivity, and growth rate for spring Chinook. The initial model will be a simple one based on water temperature, fine sediment (surface and depth), streamflow, and riparian condition in an attempt to create a robust alternative to EDT. This model will be compared against empirical measurements of productivity (see Appendix B) to further the understanding of the linkages between habitat quality/quantity and fish abundance, productivity, and growth rate. It will also link watershed and riparian condition to predictions of the status and trend in in-channel physical condition. For example, riparian vegetation, height, orientation, and canopy density will be used in conjunction with streamflow and stream depth and width to model longitudinal water temperature distribution. This creates a template for modeling summer rearing potential and summer survival for holding adult spring Chinook. Availability of pools providing thermal refuge will be identified in future work. These localities can provide holding areas for adults that increase pre-spawning survival and offer discontinuities in the longitudinal thermal continuum expressed along the mainstem.

Development of this model will allow us to contrast fish abundance and productivity among basins of varying levels of degradation in comparable ecoregions. It would also permit a pre- and post-restoration assessment based on comparison of baseline vs. restoration state abundance and productivity.

Our model of production and abundance of spring Chinook will be linked to physical models of survival by life stage based on spatial and temporal patterns of water temperature, fine sediment, and streamflow in particular. Additional control of survival from effects of other important habitat characteristics (e.g., pool availability, food availability) will be incorporated into the model as feasible in subsequent phases of habitat monitoring.

Key benefits of producing a production model of this sort for Grande Ronde spring Chinook include the following:

1. Because habitat quality varies from reach to reach longitudinally in a stream system and among tributaries, it is not possible to predict overall survival from limited point estimates of habitat quality in only index reaches. For example, McHugh et al. (2004) extrapolated summer water temperature measurements from only three monitoring locations to the entire Upper Grande Ronde basin for estimating mortality impacts to the whole population. Water temperature tends to be a habitat quality variable that increases generally from headwaters to basin mouth, with an irregular pattern of variation occurring at tributary junctions, entry points for seeps, and zones of groundwater-surface water exchange (Ebersole et al. 2003). Spatially explicit information on water temperature, sediment, and streamflow patterns allow modeling of survival that integrates impacts throughout the portion of the stream system utilized as spawning or rearing habitat. More

biologically adequate and reproducible estimates of overall habitat functionality are anticipated to result from this work than what has been constructed from expert opinion using the Habitat Workgroup method (or “hybrid method”) (NOAA 2007) or EDT.

2. Inclusion of information on the ability of juveniles to move during the summer to relocate to more favorable water temperature conditions in conjunction with information on food availability and fish densities by thermal habitat unit permit more accurate use of spatially-based water temperature data to infer impacts to survival and growth rate.
3. Juvenile growth rate will act as a biological integrator of habitat quality that relates directly to potential survival. Juveniles with higher growth rates are more likely to be able to smolt in the first year, thereby avoiding an extra juvenile overwintering period in freshwater. High growth rates indicate a relatively abundant food supply and absence of disease. Passage survival is generally associated positively with smolt size.
4. This model will permit integration of the effects of multiple limiting factors in calculation of freshwater egg-to-smolt survival.
5. This model will permit clarification of the role of individual limiting factors in controlling survival and highlight the importance of restoring certain functional elements of the habitat system. For example, because excessive summer water temperatures are considered to limit salmonid productivity, the extent of the importance of riparian vegetation and channel width in controlling water temperature will be revealed. Site-specific habitat restoration or degradation actions can be mathematically examined based on the Heat Source temperature model, assumptions of channel width, streamflow, or riparian canopy recovery, and the modeled linkages between water temperature and survival. The effect of riparian thinning or catastrophic loss by fire or disease can also be modeled in terms of the level of impact to the function provided by shading or streambank stability. Water flows that are altered by irrigation withdrawal have a significant impact on water temperature. The reach specific impacts of alterations to natural flow patterns on survival can be modeled by use of the water temperature model to in turn model the survival impact. Restoration or degradation caused by further alterations to the streamflow can be modeled in terms of change in rearing or spawning area and as a change in water temperature.
6. This model can be coupled with a life cycle population model detailing mainstem passage and ocean rearing survival in order to infer the ability of freshwater habitat improvement to increase population abundance and life cycle survival.

C. Rationale and significance to regional programs

There are several notable regional studies that have been conducted on habitat-fish relationships that have similarities to the studies proposed here. There are intensive habitat/fish studies being conducted by NOAA and collaborators under the ISEMP (Integrated Status and Effectiveness Monitoring Program). These studies are ongoing in the Wenatchee/Entiat, Lemhi/Pahsimeroi, and John Day basins. The John Day studies are focused on steelhead; the Wenatchee/Entiat studies are focused on steelhead and spring Chinook; and the Lemhi/Pahsimeroi studies include multiple species in their evaluations. The John Day study utilizes LiDAR and TIR analysis as in this proposal although the details of intended analysis are sketchy considering research reports currently available to the public. However, the various species studied with their different life history characteristics (spring vs. fall spawning, or steelhead vs. spring Chinook, respectively) and different sensitivities to temperature and fine sediment make these investigations different in scope. Also, there are substantial differences in methods used and proposed among all ISEMP studies for habitat quality analysis whose implications to survival need to be more thoroughly evaluated. The Wenatchee ISEMP study plan states that the intent of the ISEMP studies is to address critical uncertainties on multiple spatial and temporal scales (NOAA 2005). This document admits that the work may require several years for "elucidation of key scientific uncertainties." This caution is important to consider when evaluating realistically obtainable results from basin scale monitoring.

> Due to the large scope of this RME program and the environmental complexities and differences among subbasins, it may be important to gain experience exploring salmonid-habitat relationships in different regions and using somewhat different methods and protocols than those used by other intensive monitoring projects despite the conventional wisdom of adopting a universal monitoring protocol. An advantage of having multiple study areas in aggregate in the Columbia River basin includes gaining greater representation of recovery trends for the entire set of populations within an ESU. It cannot be assumed that validation of recovery in the watershed of one population ensures recovery in other similar populations. In addition, differences in ecoregions and the environmental conditions provided, species, life history adaptations, and regional susceptibility of biotic parameters to climatic variation can all result in different responses or consequences of recovery rates. Also, there is value in exploring different monitoring methods considered to be adequate among experts. Years of monitoring work spent using a single monitoring method for a habitat parameter, later demonstrated to be inadequate, will not be productive if the intent is to be able to inform the region about better methods of monitoring and analysis. However, in order to compare habitat recovery, for example, in terms of fine sediment reduction, it must be assured that methods are equally sensitive to trends in the "truth" measures. Also, it must be assured that methods are applied to similar habitats (e.g., spawning zones of specific physical characteristics, rather than simply riffle areas or the entire reach). This illustrates that even a common method for monitoring surface fine sediment can produce results dependent upon classification of the exact locations monitored. An objective of inter-tribal coordination on monitoring will be sharing the knowledge gained in reviewing and applying field methods.

The Grande Ronde Subbasin Plan (NPCC 2004a) reported an Ecosystem Diagnosis and Treatment (EDT) analysis to identify limiting factors to production (Mobrand and Lestelle 1997). The Upper Grande Ronde (UGR) and Catherine Creek (CC) are priority areas for protection of multiple populations (spring Chinook, steelhead, and bull trout). In the UGR, the priority life stages include prespawning holding, age 1 rearing, and egg incubation. The habitat factors that are limiting these life stage activities include sediment, temperature and flow. In CC, the life stages cited as priorities include age 0 active rearing and prespawning holding. The key habitat factors include temperature, flow, sediment, and various biotic threats (competition with hatchery fish, food, pathogens, and predation). The conclusions for the UGR are that temperature and sediment are widespread impacts requiring that sediment delivery be reduced and riparian function increased to decrease water temperature and increase LWD. In CC, the factors needing to be addressed are sediment, water withdrawal, and riparian condition. These three factors form the central basis for habitat quality monitoring in these two basins. NOAA (2008) identified many of the same major limiting factors for Snake River spring-summer Chinook (physical passage barriers, such as culverts and push-up dams; reduced flows from water withdrawals; altered channel morphology caused by bank hardening or streambank impacts from livestock; excess sediment from roads, mining, agriculture, livestock impact, and recreation; and high summer water temperatures.

The Grande Ronde/Imnaha MPG (a major population group of the Snake River spring Chinook) (NOAA 2008) is comprised of six extant populations, the Imnaha, Lostine/Wallowa, Catherine Creek, Upper Grande Ronde, Minam, and Wenaha. The Interior Columbia TRT (ICTRT) suggested that either the UGR or CC become viable or highly viable to ensure MPG viability. These two populations represent “large” populations with significant spatial structure and diversity. Recovery level population abundances for these large populations were set at 1000 adults each. The 1997-2006 10-year geomean population abundances were 36 and 107, respectively, for the UGR and CC (NOAA 2008). The low abundances, low productivity, and limited use of historic habitat offer the possibility of assessing habitat quality on a large spatial scale to assess the freshwater limitations. Major tributary habitat factors limiting productivity in critical habitat for spring/summer Chinook include altered channel morphology, excess sediment in spawning gravel, and high summer temperatures in spawning and rearing areas (NOAA 2008).

The UGR had 45 stream segments listed on Oregon’s 1998 303(d) list of water quality limited streams. In the ODEQ 2005 303(d) evaluation there were 73 listed stream segments based on 1998 and 2002 water quality reviews. This list covers the entire Upper and Middle portions of the Grande Ronde, including the Catherine Creek system. Some of these reaches were delisted in 2002 upon adoption of the Oregon DEQ temperature TMDL (i.e., the calculation of thermal loading from all point and nonpoint sources for addressing the temperature standards for the basin) and the basin management plan linked to the TMDL. However, even though a stream is officially delisted by the State does not mean that there is not still an actual water temperature problem. It is merely removed from the books as an unaddressed issue but must continue to be solved by implementation of the basin management plan. One purpose of a habitat status and trend monitoring program will be to follow the rate of improvement in the water quality parameter.

Under the Pacific Coastal Salmon Recovery Fund (CTUIR 2004) the Confederated Tribes of the Umatilla Reservation of Oregon (CTUIR) conducted a Grande Ronde fish habitat enhancement project in 2005 (CRITFC 2008). This project was conducted in End Creek watershed, 1 mile upstream from Willow Creek. It also included 2 miles of McDonald Creek, and 1 mile of the SF Willow Creek, and 5 miles of secondary channels.

Restoration has been conducted via the Grande Ronde Model Watershed Program since 1994 under BPA Fish and Wildlife Program funding. The history of projects and funding conducted under the model watershed program in the Grande Ronde basin are detailed in Proposal 199202601: Grande Ronde Model Watershed program Habitat Restoration-Planning, Coordination and Implementation. A catalog of major categories of projects needed to address limiting factors and projects proposed and conducted in the Upper Grande Ronde and Catherine Creek are provided in Appendix A2 Tables 1-5.

NPCC (undated) provides an extensive listing of all habitat projects conducted by all governmental, tribal, and private entities. This offers a good foundation for establishing baseline habitat conditions that can be translated to potential for salmonid abundance, productivity, and diversity. One can also expect that with the delayed response of many projects (i.e., lag times in recovery for various habitat components), there will be a degree of continuing improvement based on past project implementation.

Relative to the NOAA BiOp framework, the NOAA theory of population viability (McElhany et al. 2000), and the work of the Interior Columbia TRT in identifying populations, major population groups, and ESUs, there are a few characteristics of the work proposed here that can be highlighted to demonstrate significance to these regional underpinnings:

1) The Upper Grande Ronde and Catherine Creek were identified by the ICTRT as "large" populations. One of these two must achieve the status of "viable" for the MPG to be viable, according to the ICTRT. Because the poor habitat quality in these two basins has been identified as the factor placing the recovery and future viability of these populations in doubt, improvements in habitat quality (key limiting factors) will be followed through time (trend monitoring).
2) Habitat quality and quantity will be denoted using a limited set of habitat factors. These will be key limiting factors and will greatly simplify the EDT approach to analysis of overall habitat status.
3) Habitat quality and quantity will be incorporated into a spatial model for interpreting current status and trend in spring Chinook population viability (productivity, abundance, spatial structure, and diversity).
4) Among the benefits of this project will be to develop a quantitative, spatially aggregated assessment tool for calculating the percentage function (i.e., percentage of the natural potential survival for these streams) from water temperature modeling and to integrate this with a quantitative, spatially aggregated analysis of fine sediment impacts, as well as a limited set of other key habitat factors. The impact of altered (limited summer flow; shifted runoff timing) streamflow will be estimated via its linkage to seasonal water temperature

patterns, availability of spawning gravels during spawning season, rearing area, and availability of holding pools.

5) The use of remote sensing information (LiDAR and TIR) will provide high quality data for the baseline riparian and channel condition. It will also set the foundation for water temperature modeling using the Heat Source model. A water temperature model that can be run in real-time or as a hypothesis generation tool will allow continuing validation of the model as more years of temperature data are collected and estimation of the potential for recovery of this essential habitat quality component at a watershed, as well as site-specific scale, given proposed aggregate riparian or channel restoration measures, site-specific restoration, and restoration of natural streamflow in certain locations.
6) The baseline conditions and the specific habitat conditions (e.g., streamflow, air temperatures, and riparian condition) that lead to a certain potential population viability can be linked with a baseline climatic condition. Changes in regional climate may lead to changes in streamflow distribution and percentage runoff, air temperatures, humidity, etc. NOAA (2007), in its BiOp, made similar assumptions by stating that "this recovery plan module takes a conservative approach of assuming reduced snowpacks, groundwater recharge, and stream flows, with associated rises in stream temperature and demand for water supplies." The associated CRITFC Accord project on climate change impacts may provide more realistic or updated estimates of these climatic/hydrologic changes that will influence our modeled predictions of impacts to Chinook viability. These can then be linked to potential changes in water temperature regime at numerous sites throughout the stream network. This produces an important linkage between climate change and potential spring Chinook viability and provides a means to understand key mechanisms for maintaining fish spawning and rearing habitat. CRITFC climate change studies will provide important input data for use in water temperature modeling to represent future climate scenarios.

Although it is sometimes argued that it is more important to be doing restoration actions than it is to put great effort into monitoring and model building, this project will have value in terms of evaluating, testing, and improving monitoring methods and protocols; providing a quantitative framework for monitoring habitat condition and relating this to biotic response; highlighting the level of control of key habitat limiting factors on population survival and abundance; incorporating existing habitat and fish data into analysis frameworks that extract useful information; and increasing the ability to learn about the interaction of human-caused environmental conditions and natural climatic variation. Specifically, this project has the following important benefits:

1) It will make use of existing information collected on adult input, juvenile seasonal migration habits, and smolt output and survival available from ODFW and the tribes. This information will be interpreted within a framework of spatial habitat quantity and quality derived from a combination of remote sensing, pre-existing studies, and new field evaluations.
2) There is considerable uncertainty about the existing overall functional quality of habitat and its ability to produce fish (e.g., contrast the subjective methods of the

BiOp with the more quantitative methods of McHugh and Budy (2002)). In some watersheds supporting TRT spring Chinook populations, habitat quality was estimated using EDT analysis This model was based on spatially specific estimates of habitat quality and quantity. However, in many cases this analysis was a matter of professional opinion rather than reliance on empirical data applied to known habitat quality-fish survival relationships. In other cases, the evaluation for a basin was constructed as a stream-wide average purely from professional judgment. Given the uncertainty involved in deriving a professional opinion at one point in time to establish an average, watershed-wide or assessment unit (subwatershed) baseline condition, the uncertainty inherent in producing a new opinion after 10 years and comparing it with the first is even greater due to the likelihood that a different observer or changed perspectives of the same observer will be involved. This argues for development of a more quantitative system for evaluating habitat function based on single- and multi-factor models.

3) There has been considerable effort in the region in contrasting various habitat and fish population monitoring protocols (e.g., Roper and Homel, in draft). These have been compared on the basis of coefficient of variation (indicator of precision) and signal to noise ratios, but possibly not enough effort has been applied in ascertaining whether the methods are apt to provide accurate, biologically and physically meaningful answers. In terms of habitat monitoring, water temperature monitoring via use of a few selected locations in the rearing area may not be spatially adequate. Average water temperatures from a few selected gages do not apply in a meaningful way to spatially diverse spawning or rearing areas (e.g., McHugh and Budy 2002, McHugh et al. 2004). A limited number of McNeil core samples taken only in prime spawning habitat does not indicate anything about the quality of spawning habitat that had been degraded or the potential for improvement in survival to emergence at a stream system level. The use of a spherical densiometer (a tool commonly cited based on past use, e.g., Peck et al. 2001, Hillman 2006) to measure shading has an unclear relationship to solar radiation interception in the stream (Ringold et al. 2007, Teti and Pike 2005). Other methods that have a physically based relationship with insolation that have been shown to provide more accurate data will be evaluated, compared, and tested. Data from these methods will also be compared with estimates made using LiDAR data with physical canopy modeling in . Streambank stability has been quantitatively estimated as a key habitat variable for decades (Bauer and Ralph 1999, 2001) but there is growing concern that the visually based estimates have little relationship with potential sediment delivery to the channel (McCullough 1999b, Rosgen 1996, Simon et al. 2007). While Bauer and Burton (1993) recommend use of a fine mesh wire grid for estimation of surface fine sediment, it has been demonstrated that the grid spacing must be adjusted to match the size of the largest substrate particles (Bunte and Abt 2001a, b). Also, the use of the Wolman pebble count method (Wolman 1954) has been traditionally recommended for characterizing streambed substrate (Kauffman et al. 1999, Peck et al. 2001). However, it has been justifiably criticized as being biased against small sized particles (Bunte and Abt 2001a, b) due to the difficulty of selecting a small particle at the tip of a boot. There is also a related bias against

large particles in the conventional Wolman method of heel-to-toe pacing in the stream and selecting a large particle at the toe of a boot when it is not practical to stand on large boulders (Bunte and Abt 2001a, b). Consequently, rather than simply comparing the variance in data collected using these methods or protocols among crews with differing levels of experience as a means of identifying a "best" method (e.g., Roper and Homel, draft), it should be evaluated whether the methods used are at all related to the stream processes intended and each field method should be contrasted against a "truth" method (i.e., highest resolution feasible) using skilled practitioners of both the high intensity (truth) method and the rapid method. If it is practical to always use the truth method, it would seem that that is preferred. If there is to be a significant connection between habitat quality and fish abundance or productivity, the surrogates for habitat quality must have a direct association with the processes establishing the habitat template. For example, in relation to streambank stability, if bank angle is not actually related to amount of fine or coarse sediment input to the stream reach, a change in bank angle with time should not be linked to a change in bed fine sediment or substrate composition. With respect to fine sediment monitoring, differentiation of surface particle composition from subsurface (i.e., at egg pocket depth) is important as a means of relating the more easily observable surface fines concentrations to the fines in spawning gravels that have well-studied relationships to egg survival to emergence.

4) If we devise more spatially adequate monitoring systems with biologically and physically meaningful methods, we will have a greater ability to identify a baseline condition that has a strong linkage to fish viability (abundance, productivity, spatial structure, and diversity, or A, P, SS, and D) and also an increased ability to recognize the means to control actions that lead to negative habitat changes that affect fish.
5) If we develop a logical and validated means of linking habitat quality and change to potential fish viability, it becomes clearer how to communicate the need for restoring a stream system either holistically or in certain selected parts.
6) Better understanding of the linkages between fish habitat quality, quantity, and spatial distribution and fish population abundance, productivity, spatial structure, and diversity will assist land managers in (a) prioritization of restoration actions, (b) communicating to the public the importance of addressing habitat concerns at a systemic level, (c) increasing our ability to meaningfully assess limiting factors and rate of recovery in quantitative terms of population viability, and (d) providing a mathematical means to integrate the impacts of multiple key habitat factors while reducing the complexity of modeling.
7) This project will help managers understand how populations respond to environmental conditions;
8) The Landscape Genetics project (an associated CRITFC Accord project) will provide information about how habitat characteristics affect fish genetics. The genetic information obtained from that project will complement the biological information gained from this project to give managers a deeper understanding of the inter-relationships between fish populations and habitat conditions.

9) The Climate Change Impacts project (an associated CRITFC Accord project) will evaluate how key habitat metrics and conditions are likely to change under the pressures of climate change and population growth. It is anticipated that these physical projections can be entered in the habitat-fish model to predict impacts to the modeled sensitive fish population.
10) These anticipated habitat changes, plus the knowledge of habitat-fish interactions gained from the first two projects, can be used to help managers:
    a. Identify potential future salmon strongholds and areas at high risk;
    b. Effectively incorporate the impacts of climate change, population growth and hatchery programs in natural resource plans and objectives. This was not adequately done in the 2004 subbasin plans;
    c. Identify ecological conditions in a watershed and stream system in a manner that can allow, for example;
        i. determining appropriate hatchery broodstock and stocking/outplanting locations,
        ii. determining appropriate stocks for recolonization following habitat restoration
        iii. identifying watershed areas and land use practices most likely to preserve and restore temperature, sediment, and flow levels necessary to maintain and rebuild populations.

D. Relationships to other projects

There are several ongoing and proposed new projects that have high relevance to our proposed project in the Upper Grande Ronde and Catherine Creek. These include studies by ODFW, the Grande Ronde Model Watershed group, the CTUIR, and NOAA working in the Grande Ronde and the nearby John Day basins. Several proposed studies by CRITFC relate future climate change to change in environmental conditions that will affect salmon long-term viability.

Table 2. Relationship to existing projects

Funding Source	Project #	Project Title	Relationship (brief)
BPA	198402500	ODFW Blue Mountain Oregon Fish Habitat Improvement	GRMW & ODFW staff coordinates restoration project planning, landowner involvement, funding acquisition, ESA compliance, permitting and implementation. ODFW staff provides technical assistance to GRMWP Project.

Funding Source	Project #	Project Title	Relationship (brief)
BPA	199202604	Investigate Life History of Spring Chinook Salmon and Summer Steelhead in the Grande Ronde River Subbasin	Project 199202604 helps identify critical habitat needs of juvenile Chinook to assist GRMW staff in targeting restoration opportunities.
BPA	1996608300	CTUIR Grande Ronde Subbasin Restoration Project A Columbia River Basin Fish Habitat Project. 2007	This is the 2007 annual report on monitoring of restoration in McCoy Creek and End Creek in the Grande Ronde basin.
BPA	199608300	Grande Ronde Watershed Restoration	GRMW and CTUIR staff coordinates restoration project planning, landowner involvement, funding acquisition, ESA compliance, permitting and implementation. CTUIR staff provides technical assistance to GRMWP Project.
BPA	DOE/BP-00004338-2	Grande Ronde Basin Fish Habitat Enhancement Project", 2004-2005 Annual Report	Annual report provides monitoring results on Salmon, Beaver, McCoy, Meadow, and Camas creeks, as well as methodologies.
BPA	200002100	Securing Wildlife Mitigation Sites-Oregon Ladd Marsh WMA	GRMW staff assists ODFW staff with landowner contacts and coordinate projects developed under this project with GRMWP Project activities.
BPA	199202601	Grande Ronde Model Watershed Program Habitat Restoration	Coordinates BPA funded restoration activities in the Grande Ronde and Imnaha Subbasins working with tribes, agencies, and landowners. Annually implements 10-20 restoration projects.
BPA	199801600	Oregon Plan Monitoring of Steelhead Status, Trend, and Habitat in the Grande Ronde River Subbasin	Coordinated M&E design to evaluate habitat status and trend of anadromous and resident fish populations to evaluate project compliance and provide real-time data to guide restoration and adaptive management.

Funding Source	Project #	Project Title	Relationship (brief)
BPA	200708300	Grande Ronde Cooperative Salmonid Monitoring and Evaluation Project	Collaborate with ODFW and NPT to describe salmonid abundance, productivity, spatial structure, diversity, and habitat status and trend
BPA	199202604	Investigate Life History of Spring Chinook Salmon and Summer Steelhead in the Grande Ronde Subbasin. FY 2007-2009 F&W Program Project Solicitation.	ODFW studied the adult spawning in the Grande Ronde, smolt output from key branches of the basin, juvenile distribution, and migratory behavior.
BPA/Upper Salmon Basin Watershed Project		STREAM HABITAT INVENTORY REPORT Lemhi, Pahsimeroi, and the East Fork Salmon River, Idaho. Trapani. 2002.	This stream inventory was conducted solely on private lands in these two upper Salmon River basins under the Model Watershed Program.
BPA	2003-017-00	Monitoring strategy for the upper Columbia basin. Appendix A: An implementation strategy for Wenatchee Subbasin monitoring. Terraqua. 2005.	The ISEMP program integrates existing status and trend information available and new monitoring and evaluation studies to ensure that 2000 BiOp expectations are being realized. Monitoring in the Wenatchee basin follows protocols specified by Hillman (2004).
BPA	2003-017-00	First quarter of 2005 Progress report on the John Day RME pilot project.	This RME program is an ISEMP program. It is an Intensively Monitored Watershed Study (IMW) that was initiated under the 2000 FCRPS BiOp. This work is a status and trend monitoring project for salmonids and habitat focused on population level salmonid productivity effects of habitat restoration.

Funding Source	Project #	Project Title	Relationship (brief)
BPA	200352100	Landscape genetics	Shawn Narum. A CRITFC MOA project designed to determine the correlation between landscape features and genetic structure of populations.
BPA	200851600	Impacts of Climate Change on Tribal Natural Resources	Phil Roger. A CRITFC MOA project to integrate the results of climate change models with databases of habitat conditions.
BPA		Tribal data network project	Phil Roger. A CRITFC MOA project to coordinate data capture, database structure development, data dissemination, and standard reporting.

The ability to link trends in habitat quality and quantity with spring Chinook abundance and productivity depends upon having an ongoing infrastructure for measuring smolt output. The upper Grande Ronde River and Catherine Creek have smolt traps installed at the downstream ends of the spawning habitats in each stream system. These smolt traps (Appendix Figure 1) have been run by ODFW and provide multiple years of smolt output data and migration timing data.

E. Project history (for ongoing projects)

N/A

F. Proposal biological/physical objectives, work elements, methods, and metrics

Work elements are given below. These work elements reflect those that are part of the BPA SOW. Metrics and methods will be reviewed, analyzed, and evaluated in Year 1 of this project as discussed under “Technical and/or scientific background: How this project addresses the problems described.” Metrics suggested for Year 1 work and Years 2-5 are summarized in Appendix A-1, along with presumptive methods.

1. Objective. Perform all necessary planning, coordination, literature review, laboratory set-up, field installations, and equipment testing to be prepared to collect data

Task 1.1 Watershed Coordination
Title: Coordinate with regional agencies, tribes, and landowners
Description: Coordination with other entities involved in M&E and data collection in the Grande Ronde and Upper Columbia such as in ISEMP and PNAMP work. Agencies involved will be NMFS, ODFW, Umatilla, Yakima and Nez Perce.

Deliverable Specification: Coordination with the specified agencies in the Columbia needed to initiate and sustain work. Provide peer review of monitoring plans of other agencies and tribes and seek peer review of CRITFC plans and progress. Participate in appropriate regional forums (e.g. PNAMP), and individually with other agencies, to improve the comparability of results from tribal projects with similar efforts within the interior Columbia Basin.

Task 1.2 Tribal Coordination
Title: Coordinate with CRITFC member tribes on RM&E plans
Description: Coordination with CRITFC member tribes that are seeking to develop sound RM&E plans.
Deliverable Specification: Share information, data, scientific literature, expertise in developing monitoring plans that have highly reliable methods and a spatially stratified and statistically sound sampling design. Host pre- and post-field-season workshops with habitat monitoring teams from member tribes. These workshops will be used to standardize sampling protocols, training material and methods, and sampling designs among our member tribes

Task 1.3 Develop RM&E Methods and Designs
Title: Review and develop monitoring protocols and statistical designs
Description: Review scientific literature on water temperature, fine sediment, streamflow, and climate data collection with a focus on standardly used monitoring protocols. Use this information in development of a final monitoring plan to be available by 2010.
Deliverable Specification: A preliminary plan for field data collection and monitoring protocols for temperature, sediment and flow that will be uploaded to PISCES.

Task 1.4. Other
Title: Lab Set Up
Description: Modification and set up of laboratory workspace at CRITFC for sample processing.
Deliverable Specification: Install a venting fan to move moisture in air from a dryer oven to the outside. This will require installing a small metal hood; cutting a hole in the building wall; installing the fan. Install other lab equipment and organize lab space for processing samples and storing equipment.

Task 1.5 Install Flow Measuring Device

Title: Install flow depth gages at two channel cross-sections
Description: Install a small pressure transducer and data logging system in one location in the Upper Grande Ronde River and one location in Catherine Creek. A small, secure instrument housing anchored at streamside will be needed to protect the equipment from weather and disturbance. The sensor will need to be secured to the stream bottom at a cross-section where it can accurately reflect stream stage heights for estimation of flow-stage height relationships.
Deliverable Specification: Two streamflow gaging stations in the Upper Grande Ronde and Catherine Creek for continuous recording of flow heights that will be related to manual streamflow measurements.

2. Objective. Collect all essential habitat data in the field.

Task 2.1 Collect/Generate/Validate Field and Lab Data
Title: Collect preliminary water temperature, streamflow data, and LiDAR data
Description: Collect preliminary field data on water temperature and streamflow at selected stream sites. LiDAR data collection will be collected by aerial remote sensing.

Deliverable Specification: Preliminary monitoring data on water temperature and streamflow taken at strategic representative locations in the Upper Grande Ronde River and Catherine Creek. Compile and summarize these data using a combination of Excel, database, and GIS applications. A summary will be uploaded to Pisces in Word or Excel. LiDAR data will be collected in a subcontract on the entire perennial stream/riparian system for the Grande Ronde and Catherine creeks.

3. Objective. Manage data, create metadata, interpret, and disseminate data.

Task 3.1 Create/Manage/Maintain Database
Title: Develop and manage fish habitat condition database
Description: A database will be designed and maintained for the habitat variables collected under this project
Deliverable Specification: Database designed and collated with field data.

Task 3.2 Analyze/Interpret Data
Title: Summarize preliminary findings
Description: Preliminary analysis on existing GIS data and collected stream flow and temperature will be conducted
Deliverable Specification: Maps and habitat attributes using GIS information will be generated.

Task 3.3 Disseminate Raw/Summary Data and Results
Title: Present findings and procedures in professional meetings
Description: Disseminate data in Public forums and scientific meetings, as well as at agency/tribal meetings on RM&E.
Deliverable Specification: AFS paper will be submitted on aspects of this project.

Task 3.4 Share data electronically
Title: Post data to the Internet
Description: Work with the Tribal Data Network project to make data available to regional trading partners by publishing metadata to the Internet and posting appropriate raw and summary data elements on the CRITFC web site.
Deliverable Specification: metadata and databases available through the Internet and World Wide Web.

4. Objective. Produce journal articles summarizing and interpreting the fish/habitat relationships discovered; trends in habitat conditions; and effectiveness of habitat restoration actions in increasing spring Chinook survival.

Task 4.1 Produce Journal Articles
Title: Produce journal publications on fish/habitat relationships
Description: Completion of a journal article in which water temperature criteria are applied to evaluation of the effectiveness of current state water quality standards in protecting coldwater fish. This work is linked to the development of quantitative means of estimating fish survival at a basin scale. Other proposed publications include recent studies of ocean climatic and marine conditions that affect marine survival of salmon stocks. These studies assist in completing the evaluation of effects of climate change on the entire salmon life cycle.
Deliverable Specification: A peer-reviewed review article evaluating the ability of common indices of fish population viability to protect salmonids in all 50 states.

5. Objective. Produce all necessary reports for administering this MOA contract.

Task 5.1 Produce (Annual) Progress Report
Title: Submit Progress Report for the period (April 1, 2009) to (March 31, 2010)
Description: The progress report summarizes the project goal, objectives, hypotheses, completed and uncompleted deliverables, problems encountered, lessons learned, and long-term planning. Examples of long-term planning include future improvements, new directions, or level of effort for contract implementation, including any ramping up or ramping down of contract components or of the project as a whole. Apr 2009 to Mar 2010 will be agreed upon by the COTR and the contractor. This may or may not coincide with the contract period. For an ongoing project, a progress report covering a contract period may be submitted under the subsequent contract, if approved by the COTR.

Task 5.2 Produce Pisces Status Report
Title: Periodic Status Reports for BPA
Description: The Contractor shall report on the status of milestones and deliverables in Pisces. Reports shall be completed either monthly or quarterly as determined by the BPA COTR. Additionally, when indicating a deliverable milestone as COMPLETE, the contractor shall provide metrics and the final location (latitude and longitude) prior to submitting the report to the BPA COTR.

Task 5.3 Manage and Administer Projects
Title: Produce workplan for second phase of project. Submit phase 2 SOW.
Description: Manage and Administer Project on Monitoring and Evaluation for CRITFC

1. **Deliverable Specification:** Submit next year's SOW, Budget, and Property Inventory to the BPA COTR. The SOW should include location information (latitude and longitude) for those work elements that require it. If contractor or contractor's organization takes longer than 30 days to sign the contract, the contractor will need to send this funding package to BPA more than 90 days before the end of the current contract.

G. Monitoring and evaluation

Experimental design

The framework used will be that as shown in Sharma et al. (2005) and Scheurrell et al. (2006). The intent of this project is to use a management framework to address issues of fish-habitat relationships. In general, the design will work on two aspects of this project: i) habitat data and monitoring in the Grande Ronde, and ii) collecting data on adult and juvenile Chinook abundance. Further details on each of these aspects can be obtained on habitat (Appendix C) and fish (Appendix B) respectively.

In order to measure sites with variation and extrapolate to the entire regions the following equations could be used to estimate the mean attribute by the unit (reach scale) and extrapolate for the entire sub-basin based on the stratification chosen:

(1) $$\overline{M}_{i,s} = \frac{1}{n}\sum_{l=1}^{n} M_{j,s_l}$$

where M is the average habitat attribute measured (e.g., fine sediment) in stream, (s) in for a reach within a strata of segment (i) measured in time (t).

(2) $$\operatorname{var}(M_{i,s}) = \left(\frac{\left(1-\frac{n}{N}\right)}{n-1}\right)\sum_{l=1}^{n}\left(M_{i,s_l} - \overline{M}_{i,s}\right)^2$$

where n is the number of samples observed out of the entire sample-space (N).

To extrapolate to the entire basin for that attribute, we would multiply the average estimate by the entire sample-space estimate (N).

Sampling will be targeted on a desired level of precision for a measured attribute that will be determined using equations 1 and 2. In most cases the CV targeted will be low (<0.25) or the signal-to-noise ratio target will be greater than 2.5. For further details on habitat data that will be collected refer to Appendix A and Appendix C.

Methods for Monitoring and Evaluating Results

We will use the modeling framework with empirical data to evaluate change in habitat functionality and to link habitat-fish production relationships. Details about the approach and techniques can be found in Appendix B. More details on how this might be done for habitat data separately can also be found in Appendix C.

Justification of Sample Size

Sampling will be targeted on a desired level of precision for a measured attribute that will be determined using equations 1 and 2. In most cases the CV targeted will be low (<0.25) or the signal-to-noise ratio target will be greater than 2.5. In most cases a Stratified Random Survey design will be applied with a sample rate targeted to meet the desired objectives (namely CV<0.25 or Signal-to-noise ratio> 2.5). Further details on the specifics of what will be collected at what scale can be obtained for the habitat component (Appendix C) or fish component (Appendix B).

Compatibility of Data Collection with Historical and Regional Data

Regional data and approved monitoring protocols are available for habitat and environmental parameters such as water temperature (ODEQ), streamflow (USGS), analysis of streamflow statistics (OWRD), riparian vegetation (ODEQ LIDAR data), and climate (NWS air temperature, humidity, and wind speed).

Evaluations of monitoring methodologies for each habitat variable, which will be work elements prior to field monitoring of each variable, will be completed to ensure that methods used will be as good or better than the methods commonly regarded as standards throughout the region. Coordination and consultation with PNAMP staff and cooperators will be conducted to achieve support, advice, or concurrence in methods selection and development. Among the key variables linked to principle limiting factors (water temperature, fine sediment, and streamflow), methods are relatively standard for water temperature and streamflow:

- Water temperature methodology will be developed from evaluation of available protocols from the literature (e.g., Dunham et al. 2005, IDEQ 2000, ODEQ 2004a). For streamflow, the methods employed by USGS will be considered standard methods as a foundation.
- Fine sediment monitoring will rely on basic McNeil core sampling (Schuett-Hames et al. 1999) with modifications that will facilitate collection of very fine material. Surface and subsurface fines methods will likely be based on Bunte and Abt (2001b). However, the standard Wolman pebble count method for monitoring surface particle distribution has been shown to be heavily biased against fine particles, the key to estimating fines in surface substrate, and by correlation, subsurface layers. Consequently, new modifications to surface fines estimates will be explored using simulation with a GIS and variable grid spacing to provide guidance on number of samples required for statistical accuracy.
- Use of a spherical densiometer has remained as a standard field technique for shade measurements in many monitoring protocols despite the fact that at least some applications of this device produce results that are either biased or do not accurately represent solar radiation interception at the stream level. Other methods that have been shown to be more relevant in water temperature modeling (e.g., application of fish-eye lens digital photography of canopy cover and analysis by use of image analysis software; use of the Solmetric canopy analysis tool; use of a net radiometer to measure solar loading on the stream) will be reviewed and considered in this context.
- Remote sensing to collect FLIR and LiDAR data will follow standard regional protocols. Coordination with the Oregon LiDAR Consortium (Ian Madin, DOGAMI) will be done to ensure application of regional standards for data collection. The Consortium will also be relied on to seek cost sharing in funding needed data collection. Quality Assurance/Quality Control methods will be developed from evaluation of available methods from the literature (e.g., ODEQ 2004 b, c).

Data are available on channel substrate (particle size distribution) in the Upper Grande Ronde and Catherine Creek for limited stream zones (McCullough and Greene 2006). Data summaries are available for a limited number of habitat parameters in the Upper Grande Ronde and Catherine Creek by channel type: channel gradient, width, W/D, pools/mile, bank stability (%), total wood/mile, embeddedness (%), percentage fines, and percentage shade (Huntington 1994). Other details can be obtained on Habitat data from Appendix C.

Methods by which Data will be Analyzed

Data will be linked via a database to GIS mapping of the stream network. This will facilitate developing summaries of habitat condition by channel unit (habitat type), reach, segment, or entire stream networks (Frissell et al. 1986, Hawkins et al. 1993). Also, the ability to identify field sampling points will facilitate repeated measurement of habitat conditions in the future to track changes.

Population survival will be estimated by construction of a biological model with life stage components represented by the key limiting factors. The specifics of this approach can be obtained from Appendix B (Modeling section). In the study, the most significant habitat limiting factors in streams are summer water temperature in rearing areas, fine sediment in spawning areas, and summer streamflow, which affects adult holding, available rearing area, available spawning area, and summer water temperature. The combination of spatially-explicit water temperature distribution (based on FLIR mapping and intensive ground-based monitoring) and streamflows (current and estimated historical) will be used in a state-of-the-art water temperature model to predict temperatures under control of solar input, air temperature, and streamflows, and their consequential effect on survival of juvenile Chinook (see Appendix B, evaluating changes in fish or habitat condition in a pre- versus post-evaluation framework).

The effect of fine sediment on egg-to-emergence survival rates will be estimated from current levels of subsurface fine sediment measured in key spawning areas. Subsurface fine sediment levels from these key spawning areas will be extrapolated to other spawning areas where only surface fine sediment levels are estimated based on empirical relationships between surface and subsurface fines concentrations. It is likely that this extrapolation will be based on stream gradient as a co-variate. The survival estimates will be derived from literature review of the impact of fine sediment in spawning gravels, or from direct observations at the second stage of this proposal (when we collect fish data). Egg-to-emergence survival percentage will be compared with available data on redd counts by stream reach, predicted egg deposition count, and early juvenile fish densities and abundance estimates, either empirically (Appendix B) or using a model based approach (Appendix B).

Communication of Results

Results will be made available on the BPA PISCES system for regional dissemination. Data will be available in the form of written annual reports, databases, and GIS files.

Results will also be communicated to the public in scientific meetings and will be published in the peer-reviewed literature.

H. Facilities and equipment

CRITFC lab in the basement at 729 NE Oregon Street, Portland, Oregon will be used for processing (drying, sieving, and weighing) all sediment samples. It will also be used for equipment storage.

Vehicle needs include a pickup truck with a canopy.

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Appendix A1

Habitat

Habitat monitoring has often been burdened by monitoring of an extensive list of variables so that it becomes infeasible to monitor all possible variables controlling salmon productivity and abundance. However, because many of these variables tend to be tightly coupled so that one variable may act as a proxy for others, it may not be necessary to monitor all variables considered to be important. This monitoring and evaluation proposal is based on the concept that it is feasible to construct a habitat database using fewer variables than typically used in EDT analyses to estimate the effect of current and future habitat condition on salmon productivity.

Basic quantitative modeling proposed

This proposal is presented with work elements for Year 1 and a broader description of work elements for Years 2-5 in a 10-year MOA framework. Unless the 5-year scope of work for a study watershed is given, it would not make sense interpreting the work elements proposed for Year 1. We anticipate that a full physical and biological evaluation for a study watershed can be completed in 5 years. At that point, a second cycle of monitoring could be conducted on a different set of watersheds in the same general subbasin—e.g., the Lostine, Wallowa, Wenaha, or Minam rivers. In Year 1, the field habitat work we propose conducting involves preliminary data collection on water temperature, flows, selected channel cross sections related to flow measurements. Subsequent work in Year 2 will follow with full scale monitoring of **water temperature** and **flow**, TIR, and substrate analysis (surface and subsurface substrate particle size composition, emphasizing **fine sediment** concentration). Solar radiation and riparian vegetation condition will be critical to prediction of solar radiation load to the stream surface and modeling of water temperatures. Current and historic climatic conditions (especially air temperature and humidity) will be important data to enter into the water temperature model (Heat Source) to predict water temperatures during the summer rearing period. These key habitat components will comprise the basic model used to predict spring Chinook survival and abundance. Empirical monitoring of biological performance (survival, abundance, growth rates by life stage) will be used as a validation of predictions based on habitat variables. The influence of watershed and riparian condition on controlling the condition and trend of in-channel habitat condition will also be estimated based on GIS analysis.

Fine sediment levels in spawning gravels constitute a key limiting factor to spring Chinook survival. Literature available concerning the linkage between fine sediment and spring Chinook egg survival to emergence (Chapman and McLeod 1986) can be used with instream monitoring data on fine sediment concentrations in spawning gravels to estimate survival to emergence as a biotic response to substrate composition recovery. Fine sediment concentration at egg pocket depth is most directly linked to survival. However, the relationship between percentage surface fine sediment and depth fines will be evaluated as a means of providing a more rapid and repeatable monitoring methodology for following recovery trends.

Fine sediment concentrations can be applied to the egg-to-fry stage during intragravel incubation to predict survival (Chapman and McLeod 1987). Fine sediment may also be a useful index to intragravel dissolved oxygen concentration in intragravel flow, both habitat measures related to survival. Percentage fines can also act as an index to survival via the control on egg-alevin entombment. The spatial distribution of substrate sediment conditions (indexed via percentage fines in surface or subsurface sediment or IGDO) will be used to calculated proportional contribution to overall population productivity and abundance in relation to the degree that the reach is used. Level of use of spawning gravels can be indexed with data on redd density. The Interior Columbia TRT inferred potential spawning use of stream reaches based on reach gradient, valley width, and channel width (bankfull or summer wetted width), variables specifying intrinsic potential. The relationship between channel intrinsic potential and substrate fine sediment conditions will be evaluated.

In terms of water temperature distribution, the site-specific thermal regimes found throughout the spawning and rearing areas create a template for assessing summertime or winter survival. Elevated mortalities in disturbed stream channels can arise from either elevated summertime temperature regimes or depressed wintertime regimes, or both. Taking spatially limited samples of temperatures and averaging these values for an entire stream network (e.g., McHugh et al. 2004) can provide erroneous or imprecise estimates of survival at the watershed scale. This proposal emphasizes applying more spatially and temporally extensive analysis of water temperature distribution to predict potential survival. By application of the water temperature model (Heat Source , see Boyd and Kasper 2003) it will be feasible to estimate future restored water temperature conditions, and thereby the related potential improvement in survival.

Water temperature regime is one of the key habitat limiting factors controlling population viability in the Grande Ronde basin. The relationships between spring Chinook survival and water temperature are well detailed in the literature (McCullough 1999a, McCullough et al. 2001). The linkages between water temperature, riparian and stream channel condition, and climate condition can be explained using a state-of-the-art water temperature model such as Heat Source (Boyd and Kasper 2003). This model will be calibrated using surface water temperature data collected using TIR technology (Boyd and Kasper (2003), a spatially distributed network of thermistors sampling temperature at hourly intervals, LIDAR data on near-stream topography and riparian canopy density and height, and local climatic data (e.g., see ODEQ 2004d).

A third key limiting factor in the Grand Ronde basin is water availability. Water availability is linked to the ability of the stream to control water temperature maxima (i.e., thermal inertia). In addition, water availability during the summer holding period and primary pool depth influences the holding capacity and survival of pre-spawning adults. Water availability during the October period will influence the available spawning area.

Altered summer streamflows (e.g., reduced summer streamflows due to irrigation withdrawals) can produce increased summertime temperatures (ODEQ 2000). By estimating historic streamflows, the potential for summer water temperature regimes to be moderated can be calculated using a water temperature model (e.g., Heat Source). A reduction in wetted water surface width in rearing areas can also increase predation rates by lowering water depth in rearing areas and can also increase competition for food by increasing fish density artificially via reduction in available rearing area. Although the impact of reducing rearing area available may be difficult to model, a reduction in summer streamflow is more tractable via its application in a water temperature model. The effects of both fine sediment in spawning gravel and water temperature in spawning and summer rearing areas can be directly applied in a simple production model. Effects of fine sediments will be applied to the incubation life phase while water temperature effects will be primarily applied in the summer rearing phase. Sediment dynamics during the incubation phase (see McCullough and Greene 2006) will need to be considered due to temporal cycles of fine sediment infiltration. Temporal dynamics of temperature will be incorporated into estimates of survival, using indices such as time spent above various critical thresholds, number of consecutive days above critical thresholds. Thermal effects on growth rates will be estimated based on cumulative thermal exposure, mean temperatures, exceedance of growth or feeding limits, and diel thermal cycles in relation to growth optima. Models such as those used by Sullivan et al. (2000) for modeling growth of coho and steelhead may be adapted to express the effect of temporal and spatial patterns of temperature on the Chinook population. Linkage of these three limiting factors will allow prediction of habitat carrying capacity and potential survival. The biotic response from water availability can be partially expressed via its direct effect on water temperature regulation and its indirect effect on oxygen saturation levels and metabolic demand and growth rates and food consumption rates by the fish. Water availability can also express its effect in terms of carrying capacity control (i.e., spawning or rearing area available). Water temperature and fine sediment effects on survival will be modeled as independent, multiplicative, life stage dependent effects.

With these basic data available, a computer model will be developed to project survival from various distributions of spawning and subsequent rearing. Initially it will be assumed that of a total spawning population (escapement), spawners will be distributed according to intrinsic spawning habitat quality estimated according to channel gradient and stream width as done by the TRT. Simulated survival of fish distributed throughout intrinsic potential spawning habitat can be contrasted with predictions based on current spawners distributed only in currently used habitat (as reflected by current redd distribution). Survivals will be predicted for current and intrinsic potential condition based on current and restored fine sediment conditions. Additional simulations will be performed by assuming a distribution of spawners linked to holding pool location; spawning habitat quality (judged by intrinsic potential and fine sediment condition indexed by IGDO); relative juvenile rearing densities by month and stream reach.

Integrating survivals by tributary and reach per tributary would be a matter of assessing the site-specific multiplicative survivals for each reach and tributary (i.e., deriving the individual effects of each independent limiting factor per reach) and then integrating the survivals on a proportional basis for all reaches relative to their percentage of total habitat area. Survival by reach would be multiplicative in the sense that survival from life stage to life stage during the freshwater phase, assessed from key habitat quality factors limiting each life stage, would be multiplied together to derive total freshwater survival. Stages that will be considered include adult holding (pre-spawning), spawning, incubation, summer juvenile rearing, overwinter juvenile rearing, and smolt migration. High quality rearing areas with inadequate spawning areas may present a complication in modeling of survival and abundance and may require evaluation of the spatial arrangement of habitat units. As an example, if all high quality winter rearing areas in a stream system are found in a single tributary, the ability of fish from other locations in the stream system to locate this overwintering area may require assessment by modeling potential overwinter survival of parr from throughout the stream system. These considerations in modeling survival require evaluation of overall carrying capacity (Marshall and Britton 1980, Levy and Slaney 1993, McCullough 1996, Rosenfeld 2005).

Estimates of the current productivity of a population determined empirically by a process of counting redds, estimating total egg deposition, and measuring total smolt output would reflect the habitat quality of probably the best portions of the subbasin studied. As such, this measure, even though biologically relevant, is not a comprehensive integrator of the habitat quality needed to provide the future population abundances that would allow delisting a population and creating a highly viable population. Consequently, by making use of habitat condition assessed at the scale of the historic spawning/rearing range of the population within the natal subbasin, we can model the current and potential improved survivals and abundance. If a spatially extensive stream monitoring program is initiated such as proposed, aimed at key limiting factors, we can model the current and potential future integrated survival and abundance of the population.

Fish Habitat Condition

A. Water temperature

Water temperature has been linked to productive capacity of streams (Slaney 1974). We plan to establish an extensive network of water temperature monitoring stations on the mainstem and major tributaries in basins being monitored. We will: collect hourly temperature data for all sample points; retrieve air temperature data from nearby weather stations for use in the water temperature model and to develop regressions between air and water temperatures. In addition, we plan to establish air temperature monitoring stations in selected riparian areas to represent the near-stream air temperatures creating the stream environment for various riparian conditions.

We plan to capture the extensive spatial distribution of water temperature on the mainstem and major tributaries of monitored watersheds using TIR (thermal infrared imagery). The correlation between summertime hourly water temperature records and the point-in-time but spatially extensive TIR record will allow estimation of hourly and spatially extensive water temperatures for the entire study stream systems. Then, after stratifying the stream network from TIR monitoring, we will establish refined water temperature monitoring points. This repositioning of thermographs will make use of TIR to provide more representative monitoring of temperature to capture local thermal anomalies. We will survey the stream system for thermal refugia or thermal hot spots to assess the current holding capacity, potential thermal migration blockages, and refuge size and distribution.

B. Substrate composition

Substrate composition has been one of the most commonly used habitat factors for defining the physical template within stream reaches (Chapman 1989, Larkin and Slaney 1996). Substrate composition is typically linked with the channel gradient for each stream reach. Steep gradient streams tend to have median particle sizes that are larger than for those stream reaches with lower gradients. Macroinvertebrate and algal communities are tightly linked to the substrate composition, water temperature, riparian condition, solar input, and channel gradients found in a stream reach (Tait et al. 1994). Substrates that have predominantly very fine sediment particles do not have the abundant interstitial spaces and stable surfaces found in coarser substrates that provide important cover and surface rearing or attachment areas for macroinvertebrates and algae. When stream substrate median or dominant particle sizes exceed certain thresholds, the utility of the substrate for spawning becomes negligible. Spring Chinook require at least 5 m^2 of contiguous substrate of a quality that facilitates redd excavation and provides good intragravel flow and dissolved oxygen (Cuenco and McCullough 1995).

Characterization of stream reaches by substrate composition will demonstrate the linkage to channel gradient and reveal anomalies that may indicate local inputs of either fine sediment or coarser alluvial particles. It can be used to identify spawning capacity of a reach and also would be instrumental in stratifying microhabitats within a reach so that more efficient surface and depth fine sediment, embeddedness, or IGDO analyses can be conducted.

a. Surface substrate fine sediment

Surface fines are expected to be correlated with subsurface (depth) fines (McCullough and Greene 2005) but will likely respond to watershed restoration faster than depth fines. Surface fines will reflect ongoing delivery and release of fines from watershed and stream channel storage sites. As such, it is a sensitive indicator of current fine sediment supplies and transport and is easier to monitor than depth fines. The abundance of surface fines in summer is an index to the tendency of spawning gravels to become infiltrated with fines during the winter period (McCullough and Greene 2005). Surface fines concentrations are more responsive to variations in streamflow than depth fines. Depth fines are more directly linked to salmonid egg survival to emergence because eggs are directly surrounded by fines at the depth of egg pockets (Chapman 1989). Depth fines concentrations can be reduced by active spawning and redd cleaning as well as streamflows sufficient in magnitude to disturb substrate at egg pocket depth (Everest et al. 1987). However, the linkage between surface and subsurface fines makes surface fines concentration a useful index to longer term conditions at depth.

Although methods will be thoroughly evaluated prior to field work, our initial judgment is that we will sample surface fine sediment in riffles and glides by use of a 2-stage stratified sampling method. Stage 1 is a quantitative classification of the stream channel according to channel slope and a visual classification of surface materials into substrate classes to differentiate potential spawning vs. non-spawning habitats; Stage 2 is a grid-based sampling where particle size is recorded on a grid spacing determined relative to the Stage 1 d_{50} or dominant particle size (Bunte and Abt 2001a). It may also be necessary to stratify a spawning habitat unit by microhabitat type (e.g., stream margin vs. stream center) to differentiate depositional zones from erosional zones.

b. Depth fine sediment

Depth fines would be sampled at the depth of spring Chinook egg pockets (max. 20 cm) in a subsample of sites where surface fines are measured. Sampler design will be a modified McNeil or Plexiglas dome sampler (Schuett-Hames et al. 1999a, 1999b) where large particles will be measured and weighed in the field; fines would be suction dredged and sieved; sand and gravel would be scooped into filtration netting for eventual drying and weighing in the laboratory. Depth fine sediment at egg pocket depth is known to have the potential to kill incubating embryos/alevins by a combination of effects: entombment, restriction of the flow of water past the incubating embryo/alevin, and reduction in dissolved oxygen concentration. Studies of survival to emergence have correlated percentage fines with survival, but this does not distinguish the separate impacts of entombment and oxygen supply. Consequently, these incubation stage impacts will be studied separately.

c. Substrate embeddedness

Substrate embeddedness indicates the degree to which cobbles are surrounded by fine sediment, thereby removing access to interstitial spaces used by either macroinvertebrates or juvenile rearing fishes (Burton and Harvey 1990, Nelson et al. 1996, Nelson and Burns 1999, Devries 2007, Potyondy and Sylte 2008). Embeddedness, by its control on macroinvertebrate biomass and production, exerts an influence on salmonid carrying capacity and productivity. Embeddedness should be measured in stream reaches having consistent or defined depths, water velocity, and channel gradient. The relationship between embeddedness and gradient could allow extrapolation of percentage embeddedness to rearing area on a spatially extensive basis. Trends in embeddedness would theoretically relate to changes in overwinter and summer rearing capacity in streams, although this capacity can also be augmented by LWD and off-channel habitats. Riffle substrate embeddedness is also related to the capacity for salmonid production via its relationships to macroinvertebrate and algal production and usable surface area.

d. IGDO (intra-gravel dissolved oxygen)

IGDO concentration is a key controller of survival to emergence of salmonids (Baxter and Hauer 2000, Jeric et al. 1995). Streams with elevated concentrations of fine organic matter have the potential to reduce dissolved oxygen concentrations (Ringler and Hall 1988, Spence et al. 1995). This can increase embryo/alevin mortality despite a generally low concentration of fine sediments. IGDO methodologies will be reviewed and an appropriate method will be employed. IGDO will be measured at sites where surface and depth fines are also measured. The availability of fines of sizes ranging from the threshold limits of <6.3 mm, <2.0 mm, and <0.85 mm (see McCullough and Greene 2005) within the substrate by weight will be calculated in relation to total weight of particles greater than the threshold size and these indices will be related to IGDO values.

C. Streamflow

Streamflow will be measured at representative cross-sections during summer recession flows to assess the summer variation in flows and recession rates (flow stability) (Anderson and Burt 1980), calculate rearing potential habitat, and to use in water temperature models for calibration of current water temperature distribution. Improvements in water flows during the summer from watershed and habitat restoration work could result from efforts to shade streams, narrow channel widths, restore off-channel wetlands, improve irrigation management, and acquire instream flows for fish. Improvements in late summer flows would need to be related to upstream basin area, integrated riparian and channel condition, irrigation diversion, and antecedent precipitation. Estimate the total volume of irrigation withdrawal.

The Oregon Department of Water Resources (Cooper 2002) has data on the 50th and 80th percentile natural streamflows for the Upper Grande Ronde and Catherine Creek. These flow indices represent the natural long-term performance of the hydrological systems for the two study streams. The current streamflows of some representative streams of the Grande Ronde basin (e.g., Lookingglass Creek, Wenaha River) will be measured and compared with their ODWR rating curves to assess current streamflow against the long-term rating curve. The disparity between the UGR and Catherine Creek current flows and estimated natural flows will then be made. The percentage improvement in summer flows will be evaluated in order to examine the potential improvement in stream temperatures.

Peak streamflows will be measured for selected channel cross-sections using a pressure transducer for accurate depth measurements during peakflow events. A stage height-rating curve will be developed for the gaged sites by periodically measuring flow depth, water surface profile in a uniform reach above the gage site, and current speed for the reach. Peak streamflows will be extrapolated from the measured peakflow water depths. Pressure transducer readings require correction for variation in atmospheric pressure. This is done either by acquiring atmospheric pressure from a climatic station within a 10-mi radius or by deploying another pressure transducer in the air near the channel cross-section. Because no climatic stations are near enough to proposed sample sites, the measurement of local air pressure is the preferred method.

Low flow statistics will be critical to assessing the effects of water temperature, flow availability, and climatic trends on juvenile salmon survival. Ratios of 20-year low flows with 10 and 20-year recurrence intervals or other statistics provide evidence of flow stability, related to the underlying lithology and valley fill (Orsborn 1990).

D. Channel parameters

a. wetted width, bankfull width, water depth

Channel wetted width, bankfull width, and water depth will be measured at each cross-section where surface and depth fine sediment are monitored. These data will be useful for relating to channel gradient determined from GIS mapping as a predictor of spawning habitat potential and streamflow. Potential spawning areas were estimated by the TRT according to a combination of wetted and bankfull width and channel gradient. Water depth will also permit better standardization of sites used to collect fine sediment data.

b. Stream cross-sections

Channel cross-sections will be measured at strategic stream reaches. Cross-sections will be evaluated as part of the measurement of streamflow. Upstream-downstream cross-sections measured by survey equipment (level and stadia rod) in reach segments of uniform bed slope and channel morphology will be used to estimate peakflows. Essential information will be water surface slope and Manning's n estimated from substrate composition data (Barnes 1970).

Stream cross-sections in representative reaches will be used as a measure of channel morphological recovery. Channel bankfull width or wetted width estimated for a peak flow of known magnitude will be a useful index to long-term changes in channel morphology. Channel narrowing may not be accompanied immediately by a reduction in canopy gap. Reduction in channel width is a dynamic adjustment controlled by the combination of peakflow reductions (frequency, magnitude), riparian cover control of streambanks, and sediment delivery reductions. Methods will be surveyed and evaluated within the first 5-year period prior to implementation for using cross-sectional analysis as a tool (e.g., see Grant et al. 1992).

c. Channel volume

Channel volume is the volume available in the stream channel to be filled with water. Normally this is the volume to bankfull stage (Gregory 1976, 1977). However, during the summer period, the channel volume to the summer flow stage would provide a good indicator of the available thermal inertia to warming. A large cumulative pool volume for the channel aids in buffering thermal increases. Streams with low sediment inputs and active pool forming structures provide the framework for a large channel volume.

Channels with high roughness factors created by LWD, boulders, or bedforms increase the water transit rates, which could produce greater rates of stream warming.

d. Primary pool frequency/volume

Recently documented 50-year trends in primary pool available for major tributaries in the Columbia basin by McIntosh et al. (1994a, b) showed up to an 80% loss in pool volumes. This loss in habitat quantity is a key factor in reduction in carrying capacity of key salmon-bearing streams. The recovery of this pool volume and frequency will be a key factor in restoring abundance of salmon.

e. Streambank stability

We plan to evaluate streambank stability as an indication of the lateral delivery of fine sediment to the stream channel within the 5-year timeframe after full evaluation of methodologies. Streambank stability is also a measure of the tendency of the channel to migrate or downcut and the state of riparian (and channel sinuosity) restoration. The level of streambank stability may also be clearly related to the primary pool frequency/volume.

An evaluation done on methods for streambank stability (McCullough 1999b) revealed numerous differences among the most commonly used indices. These differences call into question how certain parameters, such as bank angle or bank height, relate to sediment delivery or resistance of the bank to erosion. Rosgen's (1996) system for streambank stability classification appears to be more logically constructed than that of Bauer and Burton (1993) for streambank stability, but Simon et al. (2007) found there to be a lack of linkage to physical processes.

Soil science or geomorphologic literature will likely approach streambank stability more from a physical process view, so a review of this literature may shed important light on best methods for monitoring streambank stability trends. It may also be that monitoring of riparian condition and streambed fine sediment condition (especially surface fines) will be adequate as a representation of stability.

E. Vegetation

a. Woody debris

During the initial 5-year period, we will review existing protocols for LWD monitoring and evaluate what would constitute appropriate and sufficient measures of LWD status and trend. We anticipate that if LWD appears to be a significant limiting factor, it could be an important link to large pool frequency and depth, channel volume, habitat complexity, distribution of channel gradient longitudinally. LWD can be a significant pool-forming structure as single pieces or multiple pieces in debris jams. It can create important hydraulic mechanisms for substrate sediment particle size sorting, which can produce localized patches of spawning gravel.

Methods would ultimately specify measuring the diameter and number of pieces of LWD associated with pool or riffle features. Pieces greater than 12 inch diameter and greater than 5 m length (for example) will be considered to be a potential pool-forming or fish cover producing material. The ability to form pools by a single key piece depends upon the relative length of the piece to the channel width (Bisson et al. 1987). Either the selection of the size of the LWD piece needs to be adjusted to the channel dimensions or the pieces could be placed in various length-diameter classes to accommodate a gradient of channel size.

b. Riparian vegetation

Riparian vegetation provides numerous critical functions in a streamzone. Riparian vegetation contributes to (1) streambank stability as trees, shrubs and deeply rooted sedges, rushes and grasses bind the soil and coarse substrates in streambanks at the bankfull line, (2) water surface shading in terms of factors such as canopy density, leaf area index, canopy height, canopy gap, and reach compass orientation, (3) leaf quality and quantity inputs that govern the detrital pathways supporting the macroinvertebrate food base, (4) LWD inputs that provide pool forming structure and fish cover, and trap sediments or create local scour zones that can create either spawning habitats, adult holding habitats, or juvenile cover habitats, and (5) retention of sediment and dissolved nutrients on the floodplain or in streamside zones.

Riparian condition can be expressed in terms of streamside vegetation height, gross vegetative type composition (grasses, shrubs, forbs, coniferous tree, deciduous tree), canopy cover and density, vegetation biomass on both sides of the stream, leaf area index, and angular canopy density. The preferred measurement method proposed here to capture a large number of riparian characteristics is LIDAR data collection, which has the advantage of providing comprehensive analysis, particularly of canopy cover, cover density, and tree height. These indices will be validated in future years of monitoring by ground-based methods, emphasizing validation of the ability to predict solar radiation transmission through the canopy based on LiDAR mapping. Future development of potential riparian vegetation cover will be assessed by estimation of historic vegetation by reference to vegetation maps and extrapolation from reference sites based on soils and geomorphology. Riparian condition is expected to be tightly linked to the future supplies of large woody debris, a primary indicator of habitat complexity. LWD supply is tightly coupled to potential development of primary pool structure and frequency as well as potential habitat complexity. Monitoring status and trend of riparian condition is expected to act as a surrogate for future recovery of LWD, pool depth and frequency, streambank stability, and channel complexity, but these linkages will be validated in future recovery monitoring. It is hypothesized that LiDAR data collection will provide robust information on overall habitat quality recovery via riparian condition measures that will render comprehensive monitoring of all associated variables unnecessary, except to understand the rate of recovery of individual habitat quality features.

Riparian vegetation will also be indexed as total volume based on LiDAR measures by regression from tree height and canopy cover (Means et al. 1999). This will be validated by selective monitoring of total standing wood volume in riparian zones. Riparian community composition will be monitored as tree, shrub, forb, grass, and bare earth components. In addition, tree and shrub species composition will be recorded for selected sites to develop a correspondence between geomorphic site and key riparian species (e.g., Kovalchik 1987). Mapping of geomorphic characteristics by riparian site in association with current vegetation and historic potential natural vegetation (USFS-ICBEMP data) will be compared with mapping of potential vegetation compiled by ODEQ in its Grande Ronde TMDL (ODEQ 2000). The Bureau of Reclamation (BOR) has recently (2009) conducted limited LiDAR data collection in the upper Grande Ronde. However, based on consultation with Watershed Sciences, which gathered these data and will also be the subcontractor for our study, this data collection will not represent the mid-summer leaf-out period. Also, its spatial extent is limited enough that is will not be economically feasible to piece this information into a broader LiDAR survey. Watershed Sciences has some older LiDAR surveys available for the two study watersheds that actually will be incorporated into our work.

c. Land surface analysis

Hyperspectral satellite remote imagery may be used during the 10 years of this MOA as a means to evaluate extensive geographic mapping of riparian community types. Hyperspectral analysis provides a means to associate the spectral characteristics of aerial remote sensing data by pixel with known signatures of individual species of trees or shrubs. In the same way that LiDAR will be used as a rapid and cost effective means of monitoring riparian vegetation over a large basin, hyperspectral analysis may provide a reliable means of classifying riparian vegetation.

F. Water chemistry: levels of key indices of aquatic productivity

We anticipate that during the course of the first 5 years of the study, we will evaluate alkalinity, TDS, nitrate, and phosphate from samples taken at various streamflow levels. It is uncertain to what extent these variables will be significant indicators of a disturbed condition in the study watersheds. However, in case there appears to be a strong contrast between the values for these simple water quality variables and those of more undisturbed streams of similar class in the Grande Ronde basin, it would be good to know this and to evaluate continued monitoring of these variables as a reflection of restoration progress. Current or historic data on these variables may be available from ODEQ.

The levels of these water quality variables can be good indicators of overall stream ecosystem productivity. They may be good reflections of food availability in the salmon food webs, salmon growth rates, and carrying capacity (Ryder 1965, Allen 1969, Fausch et al. 1988).

G. Anthropogenic impacts

a. Livestock distribution

Among anthropogenic impacts, livestock grazing is one of the most significant causes of stream channel and habitat quality degradation on public and private lands across the western U.S. (Belsky et al. 1999). For example, grazing in riparian zones reduces ground-based vegetation that would restrain surface erosion. It also interferes with recovery of tree seedlings that could restore riparian vegetation shading. It is also a significant cause of degradation in the Grande Ronde basin (NPCC 2004a).

We plan to map permitted AUMs by stream reach as livestock density per mile by season. Density can be represented as AUMs per mile of the mainstem for livestock use abutting tributaries. Livestock use can also be represented as cumulative AUMs with distance along the mainstem regardless of direct access or proximity to streams. It may also be represented as a cumulative density weighted by distance from points along the mainstem. We will map areas where livestock are permitted in the riparian zone. We will also map the riparian buffer width provided with riparian zone fencing.

b. Roads

Increasing road densities in watersheds providing habitat for salmonids has long been recognized as a significant limiting factor to population recovery (Rhodes et al. 1994, Spence et al. 1995). Roads have a multitude of environmental impacts. The key impacts are related to the key limiting factors identified for the proposed study areas (i.e., water temperature, fine sediment, and streamflow). Also, in terms of simple correlation, it has been found that watersheds having increased road densities have lower salmonid population abundances and diversity (Reeves et al. 2003). Increased road construction and logging in watersheds is related to increases in fine sediment delivery, loss of pools used as holding and resting habitats, increased water temperatures, lower LWD densities in the channel, ~~and~~ more rapid runoff rates and lower summertime flows (Rhodes et al. 1994).

Riparian roads cause the greatest impact on water temperature of all roads within a watershed due to their removal of stream shading. However, roads also intercept shallow groundwater and route it along roadside ditches where it heats up and enters stream channels as the water enters cross-road culverts and is directed into tributaries or the mainstem of stream systems (Rhodes et al. 1994).

Recent direction from the U.S. Fish and Wildlife Service (USFWS) has acknowledged the importance of road densities for bull trout (*Salvelinus confluentus*) conservation, recognizing an average road density of 0.45 mi/mi^2 in bull trout strongholds and the general exclusion of bull trout in watersheds with over 1.7 mi/mi^2 of roads (USDI Fish and Wildlife Service 1998). The USFWS concluded that bull trout “are exceptionally sensitive to the direct, indirect, and cumulative effects of roads” (USDI Fish and Wildlife Service 1998, as cited by Hitt and Frissell 2000). Others have demonstrated the impact of road density on bull trout occurrence (Baxter et al. 1999, Dunham and Rieman 1999).

Basins with more than 25% of their area logged had lower stream habitat diversity, as measured by the number of pools and pieces of wood, than basins with less than 25% of their area logged (Reeves et al. 1993). (From NRDC 2004).

From an analysis of stream-inventory data for the Columbia River basin (Lee and others 1997, as cited by Gucinski et al. 2001), pool abundance was highest in wilderness areas and declined with increasing road density. Gucinski et al. (2001, p. 40).

The amount of fine sediment in a stream reach increased, and the embeddedness of fine sediment (its coverage of large particles) in the substrate increased as the proportion of logged area increased and as the extent to which roads crossed watercourses increased. Eaglin and Hubert (1993). (From NRDC 2004). The majority of studies showed that salmonid embryo survival rates decreased as the percentage of fine sediments in stream substrate increased. With increasing fine sediment levels, dissolved oxygen levels decreased, as did gravel permeability and pore space. Dissolved oxygen levels were found to be critical to the survival of embryos and their later development. Chapman (1988). (From NRDC 2004).

Elevated sedimentation can adversely affect aquatic biota (Young et al. 1991), inhibit pool development (Quigley and Arbelbide 1997, Buffington et al.2002). Elevated sedimentation can widen channels (Dose and Roper 1994). Shallow/wide streams lead to increased water temperature maxima (Bartholow 2000). (From Beschta et al. 2004).

Brook trout populations declined significantly (by 51%) after stream sedimentation levels increased. Populations of stream benthic invertebrates (the major food source of brook trout) declined significantly after stream sediment levels increased. Higher fine sediment levels in a stream resulted in a loss of pool habitat, fish cover, changes in stream velocity, and higher summer water temperatures (Alexander and Hansen 1986, as cited by NRDC 2004).

These road effects suggests that after establishing the role of water temperature, fine sediment, and streamflow in modeling biotic response, it would be potentially useful to monitor recovery in pools and LWD and relate these also to biotic response. As a causative agent, roads should also be monitored in terms of road density within the watershed as a whole and in riparian zones. In year 1 of this project, we will map all roads within the study watersheds and estimate total road densities using GIS mapping.

H. Meteorological data

The historical data will be gathered and analyzed statistically in year 1. Within the first 5-year period, meteorological data collection will include: measurement of air temperature within the basin at two locations differentiated by elevation near the mainstem of a study stream; correlation of local air temperature records with regional air temperature records; monitoring the direct solar radiation levels reaching the stream channel associated with riparian zones of various characteristics. Estimates of canopy density measured via LiDAR will be related to ground-based measurements of canopy density. Ground-based canopy measurements will be made using a fish-eye lens mounted on a tripod in the center of the channel. By use of computer-aided digital image analysis, the direct beam or total direct and diffuse interception at the stream surface will be estimated for various solar paths specified by solar altitude and azimuth. A pyrheliometer (Eppley) mounted on a clock drive may be used to measure the direct beam radiation integrated for an entire cloudless day period. Alternatively, use of a net radiometer (Kipp-Zonen) to measure the net balance of short and long-wave radiation intercepted at the stream level may be the best tool to provide validation of LiDAR-based estimates of solar input. This measurement will also be related to the estimate made from interpretation of the digital image of the canopy from hemispherical photography for the month in question. The use of a LiCor device for measuring leaf area index may also be explored as a method for canopy shading measurement. These overlapping methods will be used for methods validation and also to explore the use of less labor intensive field methods.

I. Biota
   a. Macroinvertebrates and the salmonid food base

Salmonids tend to derive their food intake primarily from terrestrial or aquatic macroinvertebrates in the drift. Sampling food availability in key rearing habitats during the summer rearing period in relation to the temperature regime would provide a means to estimate the growth potential and carrying capacity of streams supporting spring Chinook. Because water temperature regimes vary longitudinally within the study basins under current and restored conditions, a major template for defining food availability (quantity and quality) has a spatial pattern. Survival and growth rates of juvenile salmonids are expected to vary with water temperature patterns as well as the associated food availability.

The availability of food in the field is a complex issue to evaluate, but it has an important influence in concert with water temperature in controlling salmonid growth rate. Salmonid food (prey) availability is a function of the biomass of benthic macroinvertebrates that are prone to drift (Hildebrand 1974), their productivity or turnover ratio (P/B, see Waters et al.1990, Buffagni and Comin 2000), and the drift rate. Drift rate implies the flux of drifting macroinvertebrates passing by the focal feeding stations of salmonids. Drift rate is related to variables such as water temperature, photoperiod or light intensity, and macroinvertebrate density. The density factor may be partially related to behavioral drift. Food availability to any individual size class of juvenile salmonid is a subset of the total drift due to prey size distribution and electivity (Ruginis 2008) Availability to any individual fish is relative to the abundance of other fish of the same or different species competing for the same food in the same location. Juveniles select particles from the total drift composition on the basis of the prey matching their preferred size categories. Prey size preference is dictated by the size of the juvenile salmonid.

Food availability and water temperature are intimately linked to salmonid growth rate (Railsback and Rose 1999), which in turn is a key indicator of overall habitat quality.

Alterations in the water temperature regime at a stream system scale control juvenile growth rates by stream reach and also total useable thermal habitat. Salmonid growth rates and survival distributed by stream reach determine condition factor by reach and potential smolt output for the watershed. The size and condition of smolts entering the mainstem in conjunction with time of entry play a major role in dictating the ability to survive downstream migration in the mainstem.

Juvenile growth rate is maximized at an optimum growth temperature under full satiation feeding. If food availability is reduced, the temperature for maximum growth declines (McCullough 1999). When mean daily field temperatures continue to increase beyond the growth optimum, growth rates decline, even at satiation feeding. If food is limited and the temperatures are high, growth rates would decline even further. Under high temperatures and food limitations, survival rates decline so that at a critical high temperature, loss of production to mortality equals the production of the remainder of the population. At this high temperature, the net production is zero (Hokanson et al. 1977). Because salmonid growth and survival is so dependent upon the combination of water temperature and food availability, it becomes important to monitor both as a confirmation of the potential for salmonids to achieve high survival rates, high condition factor, and high smolt output rates.

Studies of food availability are anticipated within the 5-year framework of this 10-year project. Macroinvertebrates will be sorted into terrestrial and aquatic components and then identified to family. However, in some cases it may be important to identify some taxa further, as total increase in biomass of invertebrates does not necessarily translate into increased salmonid production. For example, Tait et al. (1994) found that canopy loss in streams of the John Day River resulted in increased numbers and density of invertebrates, but mostly due to an overabundance of Dicosmoecus, a grazing caddis. This macroinvertebrate was relatively unpalatable and did not result in increased salmonid production or density. Numbers and biomass (estimated from a length-weight regression or direct weights) will be recorded to allow estimation of energy input available from the food base. Relative importance of terrestrial vs. aquatic sources will be related to riparian condition. One would expect that a high canopy density, high diversity riparian zone would provide high rates of terrestrial macroinvertebrate input to the stream. Instream aquatic macroinvertebrate drift transport may be related to the upstream length of riffle, substrate quality, and riparian characteristics. Drift sampling will be stratified by channel gradient, rearing habitat type for feeding stations and the habitat types upstream within 100m, location in the stream system (watershed area and proximity to major upstream tributaries), and riparian condition. We will assess the life cycle implications of high quality/high abundance food supply by monitoring age at smolting, smolt size, overwinter survival, growth rate of juveniles, and juvenile survival rates. We intend to develop a growth model similar to that used by Sullivan et al. (2003), making use of water temperature, fish density, and food availability (biomass or calories as a flux past specific cross-sections). Growth rates known from laboratory studies at known temperatures and feeding rates will be compared with rates determined in the field (Elliott 1994, Jensen 1990). Comparisons with published field growth rates will also be used as additional confirmation of the joint influence of water temperature, competition, and food availability on growth in study areas. Estimates of consumption needed to support measured field growth rates will be made from laboratory-derived information.

b. Fish populations

Spring Chinook are the central target species for this study. The key fish habitat variables to be monitored are those functionally related to the key limiting factors (water temperature, fine sediment, and streamflow). Survival for the egg to smolt life stages will be integrated from the life stage specific survivals estimated from the spatial and temporal distribution of habitat quality and quantity. Spring Chinook survival will be validated against the data that appear to be available from ODFW on adult spawning (redd counts) and smolt output (ODFW 2007). As an index to the effect of optimal to sublethal summertime temperatures, the growth rates of PIT-tagged fish will be measured in stream reaches in which ambient water temperature regimes are well known from temperature monitoring. Unless it is feasible to block stream reaches to ensure that juveniles are using only habitats of known temperature regime, the upstream-downstream migration of tagged fish will be studied. This can be inferred from identifying the downstream extent of salmonid distribution by week as the summer season progresses and temperature maxima vary. Also, the recapture locations of tagged fish may provide indications of the tendency to migrate upstream or downstream. These fish could be directed toward seines using a light electroshocking application (herding) (Tattam 2006). Tagged fish could be identified and then, measured for length, wet weight, or both. Length estimation from photography against a measurement grid could provide a low fish stress environment. The highest reliability could be given to a NOAA-designed PIT tag antenna placed in strategic channel cross-sections to passively track the migration direction of tagged fish. Growth rate estimates provide a sensitive indicator of the suitability of local environmental conditions to produce healthy fish and the capability of fish to emigrate as smolts in the spring after only one year of summer rearing in tributary habitat. We also have interest in using known biochemical growth rate indicators (e.g., insulin-like growth factor 1, or IFG-1) as a bioindicator of instantaneous field growth rates (Li and Leatherland 2008). Blood levels of these select bioindicators may provide reliable indexes of field growth rates that can be validated from empirical estimates.

In a future phase of fish monitoring, we hope to be able to assess survival by life stage. This monitoring holds the promise of being able to more definitively link habitat quality of a particular assessment unit (e.g., tributary or reach) with the survival of fish from that unit. This more intensive type of fish survival monitoring would then permit application of statistical designs, such as the BACI design. Field instrumentation required would be either the NOAA-designed PIT tag detection arrays or that of Biomark. Due to cost, we are not certain at the outset that these more desirable designs will be feasible to employ. However, with the potential of cost sharing arrangements, it may be feasible to build this approach in the coming years.

Appendix A2

Table 1. Grande Ronde subbasin restoration priorities by watershed and focal fish populations. (Adapted from NPCCc 2004, Table 3-3, page 16)

Watershed	Population(s)	EDT Priority Geographic Area(s) highlighted areas are priorities for multiple pops.	Restoration impacts on population abundance, productivity, diversity (EDT Analysis)	Considerations	Recommendations
Lower Grande Ronde	Lower GR Steelhead Possibly bull trout in tributary headwaters	Lower GR(1-12) – Wenaha Chin Lower Grande Ronde Tribs Wildcat Creek , Mud Creek	Steelhead: Abundance: Moderate; Productivity: Minimal; Diversity: Moderate	No one reach an overwhelming priority. Improving conditions in tributaries will help establish broader life history diversity.	Identify largest tributary sediment sources. Protect riparian & remove roads from riparian.
Joseph Creek	Joseph Creek Steelhead	Lower Chesnimnus Lower Joseph Creek Upper Joseph Swamp Creek, Crow Creek	Steelhead: Abundance: **Large**; Productivity: **Large**; Diversity: Moderate	Tributary reaches are likely the source of the identified sediment impacts. Restoration main Joseph Cr. depends sediment delivery from upstream areas.	Upstream tributaries should be given priority Almost all streams have roads. Protect Riparian & remove roads from riparian.
Wallowa River	Wallowa Steelhead Wallowa-Lostine Chinook Lostine/ Bear Ck Bull Trout	**Steelhead Priorities** Prairie Creek Upper Wallowa River – Wallowa Chin. Hurricane Ck , Whiskey Ck Lower Wallowa (1-3) -Minam Sthd **Chinook Priorities** Lower Lostine – Wallowa Steelhead Mid-Wallowa – Wallowa Steelhead	Chinook: Abundance**: Large**; Productivity: **Large**; Diversity: Minimal Steelhead: Abundance: Moderate; Productivity: Moderate; Diversity: Moderate	No one reach an overwhelming priority (steelhead) Presence of primary pools, hydromodifications, riparian function and wood (Chinook)	Identify largest tributary sediment sources. Protect riparian & remove roads from riparian. Mid-Upper Wallowa address sediment load from decreased flows. Prairie – address sediment from increased flows Lower Lostine – address functions to increase pools, pool quality. Address water withdrawals.
Catherine Creek/ Middle Grande Ronde	Upper GR Steelhead Catherine Ck Chinook Catherine Ck Bull Trout Indian Ck Bull Trout	Mid Catherine Creek (2-9) – UGR Sthd SF, NF Catherine Creek Lower Grande Ronde R. 2	Chinook: Abundance**: Very Large**; Productivity: Minimal; Diversity: Minimal Steelhead: Abundance: **Large**; Productivity: Moderate; Diversity: Minimal	EDT found this area to have a huge Impact on Chinook abundance (5000%). Local ODFW bio's not sure they agree (J. Zakel pers comm.)	Important for Chinook & steelhead. Address sediment & water withdrawal impacts. Improve riparian.
Upper Grande Ronde	Upper GR Steelhead Upper GR Chinook Upper GR Complex Bull Trout	Mid GR 4 (GR 37 - 44) - chin Mid GR Tribs 4 (Whiskey, Spring, Jordan, Bear, Beaver, Hoodoo…) Phillips Creek Upper GR Ronde 1 (45-48) - chin Mid GR 3 (GR – 34-36) Valley Sheep Ck, Fly Ck, Lower Meadow Ck - Chinook	Chinook: Abundance**: Very Large**; Productivity: **Large**; Diversity: Minimal Steelhead: Abundance: **Large**; Productivity: Moderate; Diversity: Moderate	No one reach an overwhelming priority. Sediment & temperature consistent impacts	Find opportunities to restore functions. Reduce sediment delivery, improve riparian (decrease temps, increase wood inputs).

Table 1: taken from:

ODFW. 2007. FY 2007-2009 F&W Program Project Solicitation Section 10. Narrative. Project ID: 198402500. ODFW Blue Mountain Oregon Fish Habitat Improvement. Proposal submitted to Bonneville Power Administration, Portland, Oregon.

Key elements of the table above, which was from ODFW (2007) were also presented in Table 7 from GRMWF (2006). This table (GRMWF 2006, Table 7) indicates that for the Upper Grande Ronde, the targeted fish populations are Chinook, steelhead, and bull trout. The EDT reach priorities are Mid GR 4 (GR 37-44), Mid GR Tribs 4 (Whiskey Spring, Jordan, Bear, Beaver, and Hoodoo), Upper GR 1 (45-48), and Mid GR 3 (GR 34-36), Sheep, Fly, and Lower Meadow Creek for spring Chinook. In Catherine Creek and the Middle Grande Ronde, Catherine Creek Chinook, UGR steelhead, and Catherine Creek and Indian Creek bull trout are targeted fish populations. The EDT priority tributaries are Mid Catherine (2-9), and SF Catherine, NF Catherine.

In the UGR, the priority habitat factors are sediment, flow, temperature, and key habitat quantity (reduced wetted widths). For Catherine Creek, the priority habitat factors are the same as for UGR, with the addition of habitat diversity (reduced LWD and riparian function).

Table 2. Summary of Grande Ronde Model Watershed Program projects currently planned for FY 2007-2009 and to be implemented by ODFW, CTUIR and NRCS. (Source GRMWP)

Project/Project Lead	Watershed	Habitat Limiting Factors	Focal Species	Metrics	Partnerships & Funding
Meadow Creek Restoration (CTUIR)	Lower Meadow	sediment, flow, temperature, and key habitat quantity	Chinook (rearing, historic spawning), steelhead (spawning/rearing), bull trout (migration)	-1 mile restoration/wetland channels. -Restore 200 acres emergent/shrub-scrub wetland	NRCS (WRP) CTUIR, ODFW GRMW
End Creek Restoration (NRCS)	Willow Creek	Lower Willow winter habitat – juvenile Chinook/steelhead	Steelhead/resident trout (spawning/rearing) Chinook (winter rearing)	-8-12 miles restoration channel -Restore 400-600 acres emergent/ shrub-scrub wetland	NRCS (WRP) CTUIR, ODFW GRMW, OWEB, BMRC, NAWCA BPA,
Ladd Creek Restoration (ODFW)	Ladd Creek/Mid Catherine Creek	Habitat quantity, diversity, sediment, temperature,	Steelhead spawning/rearing Chinook rearing	-4 miles restoration channel -Restore 200 acres emergent/shrub-scrub wetland	ODFW GRMW/BPA CTUIR OWEB, BMRC
Upper Mainstem Grande Ronde River Habitat Enhancement (CTUIR)	Upper Grande Ronde	sediment, temperature, key habitat quantity	Chinook, steelhead winter/summer rearing; bull trout migration	-1 mile instream habitat enhancement -0.5 miles dike/railroad grade removal	CTUIR, USFS, ODFW, GRMW
Wallowa River Restoration	Upper Wallowa	key habitat quantity, habitat diversity, sediment, and	Chinook, steelhead spawning/rearing, bull trout	-0.5 miles restoration channel	Wallowa Resources, ODFW, CTUIR,

(ODFW)	River	temperature	rearing/migration	0.25 mile dike removal	GRMW, OWEB

CTUIR – Confederated Tribes Umatilla Indian Reservation
ODFW – Oregon Department Fish and Wildlife
NRCS – Natural Resource Conservation Services
GRMW – Grande Ronde Model Watershed
USFS – U.S. Forest Service, Wallowa-Whitman National Forest
OWEB – Oregon Watershed Enhancement Board
BMRC – Blue Mountain Restoration Council (Union Pacific Railroad Mitigation Trust)
NAWCA – North American Wetland Conservation

Table above taken from:

ODFW. 2007. FY 2007-2009 F&W Program Project Solicitation Section 10. Narrative. Project ID: 198402500. ODFW Blue Mountain Oregon Fish Habitat Improvement. Proposal submitted to Bonneville Power Administration, Portland, Oregon.

TABLE 3. Summary of Projects Completed or in progress by the ODFW/BPA Grande Ronde Basin Fish Habitat Enhancement Project, 1985-2004. (source McGowan 2005)

UPPER GRANDE RONDE:		GRMWP	Year	Stream	Acres	Fence	Spring
Stream	Landowner	Project #	Built	Miles	Protected	Miles	Devel.
Bear Creek	Alta Cunha Ranches	1616	2002-03	1.03	48	CREP	0
Beaver Creek	Clark/Crown Pacific	1095,1120	1993-94	6.0	243.6	11.5	0
Coon Ck. Tributary	Warren*	1440	1998	0.25	2.1	0.5	0
Dobbin Creek	Rynearson*	1508	1999	0.4	4.4	0.4	0
Eaton Creek	Sunderman*	1515	1999	0.5	160.0	0.5	0
End Creek	Rice	1658	In progress			WRP	0
Fir Creek	Wyland*	1528	1997	0.4	3.0	0.8	0
Fly Cr.	Smith	1123	1987	1.2	14.8	1.7	0
Grande Ronde R.	Smidtt*	1516	1999	0.5	6.0	0.2	0
Jordan Cr.	Alta Cunha Ranches	1616	2003	1.26	56.5	2.5	1
Ladd Creek	ODFW/LMWA	1468	2002	3.7	WRP	n/a	0
Little Cr.	Kerr*	1365	1998	0.25	5.0	0.4	0
McCoy McIntyre Cr	Misener/Tipperman	1117	1988	2.8	231.9	3.35	3
Meadow Cr.	Alta Cunha Ranches	1406	1998-99	1.8	149.8	3.5	0
Meadow Cr.	B.M.C.B.A.	1114	1990	0.4	6.6	1.1	0
Meadow Cr.	Habberstad	1550	2000	1.1	48.0	0.0	0
Meadow Cr.	Misener/Tipperman	1115	1988	2.7	256.5	5.3	3
Meadow Cr.	Waite	1116	1989	1.2	19.7	2.6	1
Milk Creek	Hall Ranch*	1579	2000-01	0.24	1.5	0.25	0
N.F. Cabin Cr.	Johnson	NFCR	In progress	0.5			0
Sheep Cr.	BLM	1112	1988/2004	0.7	80.0	1.25	0
Sheep Cr.	Vey	1113	1987-88	4.3	54.7	6.0	4
U.G.R. River	Bowman/Hoeft	1118	1991	1.5	37.8	3.2	1
U.G.R. River	Crown Pacific	1321	1997	5.2	179.7	5.1	2
U.G.R. River	Delve	1119	1991	0.5	7.0	0.9	2
Whiskey Cr.	Courtney	1121	1991-92	3.3	35.0	5.6	3
Whiskey Cr.	Hampton	1122	1990-91	1.5	15.2	3.0	0
			Subtotals:	**42.7**	**1,666.8**	**59.7**	**20**

Table taken from:

ODFW. 2007. FY 2007-2009 F&W Program Project Solicitation Section 10. Narrative. Project ID: 198402500. ODFW Blue Mountain Oregon Fish Habitat Improvement. Proposal submitted to Bonneville Power Administration, Portland, Oregon.

Table 4 The GRMWF (2006) cross references GRMW Project habitat projects with Subbasin Plan Objectives, Strategies, and Geographic Priorities and identifies work elements associated with each project. "Objectives listed in the table are the habitat attributes being addressed. Generic objective statements for each of the attributes are found in the Grande Ronde Subbasin Plan Supplement, pp. 37-43. When developed each project will have more specific objectives related to limiting factors and metrics listed in Table 5. This is not a final list and will likely change as additional opportunities arise." (GRMWF 2006).

Table 5. GRMW Subbasin Restoration Projects Fiscal Year 2007-2009

Project/Project Lead	**Habitat Limiting Factors**	**Geographic Priority** (Sec B.Table 2)	**Subbasin Plan Objectives** (Supplement pp. 37-43)	**Subbasin Plan Strategies** (Supplement pp. 37-43, 46-48)	**Work Elements** (BPA Pisces)
Meadow Creek Restoration (CTUIR) private	sediment, flow, temperature, and key habitat quantity	**#2** Upper Grande Ronde	-channel condition -riparian function	-reconstruct channelized reaches -reconnect channels with floodplains -improve vegetation density, condition and species -re-establish historic wet meadow complexes -improve riparian function and water storage	#29 Increase instream habitat complexity #30 Realign, connect and/or create channel #47 Plant vegetation #181 Create, restore, and/or enhance wetland
End Creek Restoration (NRCS) Private	Lower Willow winter habitat – juvenile Chinook/steelhead	**#2** Upper Grande Ronde	-channel condition -riparian function	-reconstruct channelized reaches -reconnect channels with floodplains -improve vegetation density, condition and species -re-establish historic wet meadow complexes -improve riparian function and water storage	#29 Increase instream habitat complexity #30 Realign, connect and/or create channel #47 Plant vegetation #181 Create, restore, and/or enhance wetland
Ladd Creek Restoration (ODFW) Public (ODFW)	Habitat quantity, diversity, sediment, temperature,	**#3** Catherine Creek/Middle Grande Ronde	-channel condition -riparian function	-reconstruct channelized reaches -reconnect channels with floodplains -improve vegetation density, condition and species -re-establish historic wet meadow complexes	#29 Increase instream habitat complexity #30 Realign, connect and/or create channel #47 Plant vegetation #180 Enhance floodplain

Project/Project Lead	Habitat Limiting Factors	Geographic Priority (Sec B.Table 2)	Subbasin Plan Objectives (Supplement pp. 37-43)	Subbasin Plan Strategies (Supplement pp. 37-43, 46-48)	Work Elements (BPA Pisces)
				-improve riparian function and water storage	
Ladd Creek Flow Enhancement (channel consolidation) (GRMWP) Private/public	Flow, temperature	**#3** Catherine Creek/Middle Grande Ronde	-low flows/irrigation diversions	-reduce irrigation withdrawals….	#84 Remove/install diversion
Upper Mainstem Grande Ronde River Habitat Enhancement (CTUIR) private	sediment, temperature, key habitat quantity	**#3** Upper Grande Ronde	-channel condition -riparian function -sediment conditions	-manage grazing in riparian areas -stabilize active erosion sites -remove/relocate channel confinement structures -implement integrated noxious weed management program -improve vegetation density, condition and species -improve riparian function and water storage	#29 Increase instream habitat complexity #40 Install fence #47 Plant vegetation #180 Enhance floodplain
Wallowa River Restoration (ODFW) private	key habitat quantity, habitat diversity, sediment, and temperature	**#1** Wallowa River	-channel condition -riparian function	-reconstruct channelized reaches -reconnect channels with floodplains -improve vegetation density, condition and species -remove/relocate channel confinement structures	#29 Increase instream habitat complexity #30 Realign, connect and/or create channel #40 Install fence #47 Plant vegetation #180 Enhance floodplain
Prairie Creek Riparian (GRMWP) private	temperature, sediment, riparian function	**#1** Wallowa River	-riparian function -sediment conditions	-manage grazing in riparian areas(off-site water development) -reestablish riparian vegetation -stabilize active erosion sites -encourage landowner participation in riparian management incentive programs -promote/implement grazing plans	#40 Install fence #47 Plant vegetation #34 Develop alternative water source

Project/Project Lead	Habitat Limiting Factors	Geographic Priority (Sec B.Table 2)	Subbasin Plan Objectives (Supplement pp. 37-43)	Subbasin Plan Strategies (Supplement pp. 37-43, 46-48)	Work Elements (BPA Pisces)
L. Chesnimnus Riparian Restoration (GRMWP) private	Temperature, channel complexity, riparian function	**#4** Joseph Creek	-riparian function -sediment conditions	-manage grazing in riparian areas(off-site water development) -reestablish riparian vegetation -stabilize active erosion sites -encourage landowner participation in riparian management incentive programs -promote/implement grazing plans	#40 Install fence #47 Plant vegetation #34 Develop alternative water source
L. Hurricane Cr. Restoration (GRMW) private	Channel morphology (width:depth), riparian vegetation	**#1** Wallowa River	-channel condition -riparian function	-manage grazing in riparian areas(off-site water development) -reestablish riparian vegetation -stabilize active erosion sites -encourage landowner participation in riparian management incentive programs -promote/implement grazing plans -install in-channel structures	#29 Increase instream habitat complexity #34 Develop alternative water source #40 Install fence #47 Plant vegetation #181 Create, restore, and/or enhance wetland
Foster Ditch Diversion (GRMWP) private	Passage, sediment, flow reduction	**#1** Wallowa River	-restore watershed connectivity (Supplement, Table - 6, p46)	-restore fish passage to good habitats	#84 Remove/install diversion
Sage Creek Culvert-Big Canyon (USFS) public	Passage, sediment	**# 1** Wallowa River	-restore watershed connectivity (Supplement, Table - 6, p46) -sediment conditions	-restore fish passage to good habitats	#184 Install fish passage structure
Bear Creek Hi Flow Channel reconnect-RY Timber (GRMWP) private	habitat complexity, temperature	**#1** Wallowa River	-channel condition -riparian function	-reconnect channels with floodplains or historic channels -promote interaction of stream channels and floodplains -improve vegetation density, condition and species	#30 Realign, connect and/or create channel #181 Create, restore, and/or enhance wetland
Wallowa River/Stone Dike Setback (GRMWP) private	habitat complexity, riparian function	**#1** Wallowa River	-channel condition -riparian function	-promote interaction of stream channels and floodplains -improve vegetation density, condition and species	#180 Enhance floodplain #47 Plant vegetation

Project/Project Lead	Habitat Limiting Factors	Geographic Priority (Sec B.Table 2)	Subbasin Plan Objectives (Supplement pp. 37-43)	Subbasin Plan Strategies (Supplement pp. 37-43, 46-48)	Work Elements (BPA Pisces)
				-Remove or relocate channel confinement structures such as …dikes	
Mud Creek meadow restoration (GRMWP) private	meadow riparian area degraded, temp., habitat complexity	**#5** Lower Grande Ronde River	-channel condition -riparian function	-manage grazing in riparian areas(off-site water development) -reestablish riparian vegetation -stabilize active erosion sites -encourage landowner participation in riparian management incentive programs -promote/implement grazing plans 10 acres meadow stream habitat restored	#34 Develop alternative water source #40 Install fence #47 Plant vegetation
Tope, Courtney, Wildcat Creeks (GRMWP) private	meadow riparian areas degraded., temp., channel and habitat complexity	**#5** Lower Grande Ronde River	-channel condition -riparian function	-manage grazing in riparian areas(off-site water development) -reestablish riparian vegetation -stabilize active erosion sites -encourage landowner participation in riparian management incentive programs -promote/implement grazing plans 10 acres meadow stream habitat restored	#34 Develop alternative water source #40 Install fence #47 Plant vegetation
Davis Dams (2) (GRMWP) private	passage	**#3** Catherine Creek/Middle Grande Ronde Creek	-restore watershed connectivity (Supplement, Table 5-6, p46)	-restore fish passage to good habitats	#184 Install fish passage structure
Catherine Creek diversions (4) (GRMWP) private	passage	**#3** Catherine Creek/Middle Grande Ronde	-restore watershed connectivity (Supplement, Table 5-6, p46)	-restore fish passage to good habitats	#184 Install fish passage structure
Catherine Creek/State Ditch Diversion (GRMWP) private	Passage	**#3** Catherine Creek/Middle Grande Ronde	-restore watershed connectivity (Supplement, Table 5-6, p46)	-restore fish passage to good habitats	#184 Install fish passage structure

Project/Project Lead	Habitat Limiting Factors	Geographic Priority (Sec B.Table 2)	Subbasin Plan Objectives (Supplement pp. 37-43)	Subbasin Plan Strategies (Supplement pp. 37-43, 46-48)	Work Elements (BPA Pisces)
Willow Creek Diversion(s) (GRMWP) private/public	passage	**#3** Catherine Creek/Middle Grande Ronde	-restore watershed connectivity (Supplement, Table 5-6, p46)	-restore fish passage to good habitats	#184 Install fish passage structure
Cabin/Gordon Cr Culverts (3) (GRMWP) private	passage	**#3** Catherine Creek/Middle Grande Ronde	-restore watershed connectivity (Supplement, Table 5-6, p46)	-restore fish passage to good habitats	#184 Install fish passage structure
Wildcat Creek Passage 1 bridge (GRMWP) public	passage	**#5** Lower Grande Ronde River	-restore watershed connectivity (Supplement, Table 5-6, p46)	-restore fish passage to good habitats	#184 Install fish passage structure
Wallupa Creek Passage 1 bridge (GRMWP) public	passage	**#5** Lower Grande Ronde River	-restore watershed connectivity (Supplement, Table 5-6, p46)	-restore fish passage to good habitats	#184 Install fish passage structure
Wallowa River-Lostine River Water Transfer (GRMWP) private	In-stream flow	**#1** Wallowa River	-Address ESA Recovery Goals, Improve in-stream flows, (Supplement, Table 5-6, p48	-restore fish passage to good habitats -Restore natural stream flows in dewatered streams	#115 Produce Inventory or Assessment

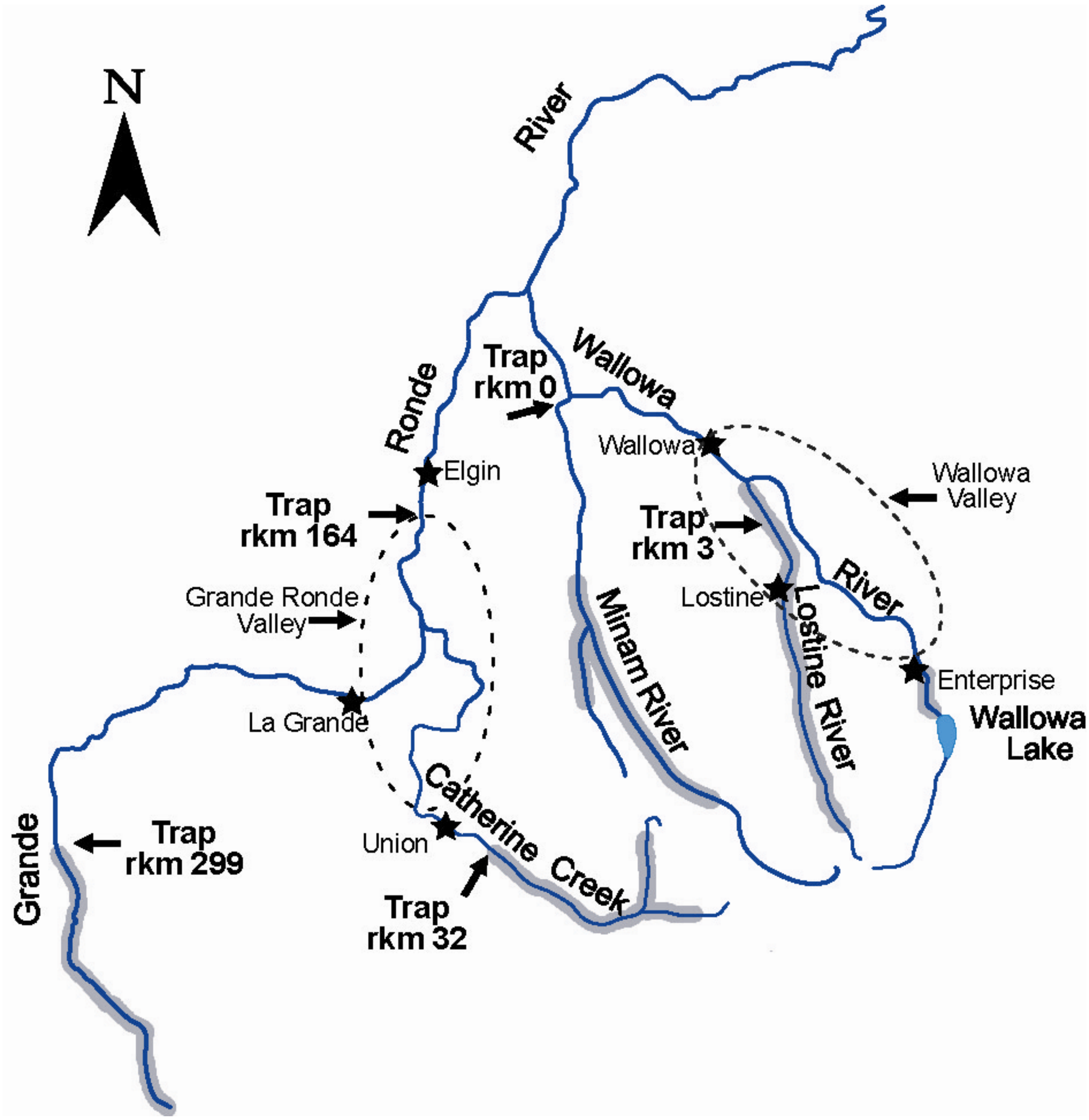

Figure 1. Locations of fish traps in the Grande Ronde River subbasin operated for the Salmonid Life History project. Shaded areas delineate spring Chinook salmon spawning and upper rearing areas in each study stream. Dashed lines indicate the Grande Ronde River and Wallowa River valleys.

Figure reproduced from ODFW. 2007. Investigate Life History of Spring Chinook Salmon and Summer Steelhead in the Grande Ronde Subbasin. FY 2007-2009 F&W Program Project Solicitation. Project ID 199202604.

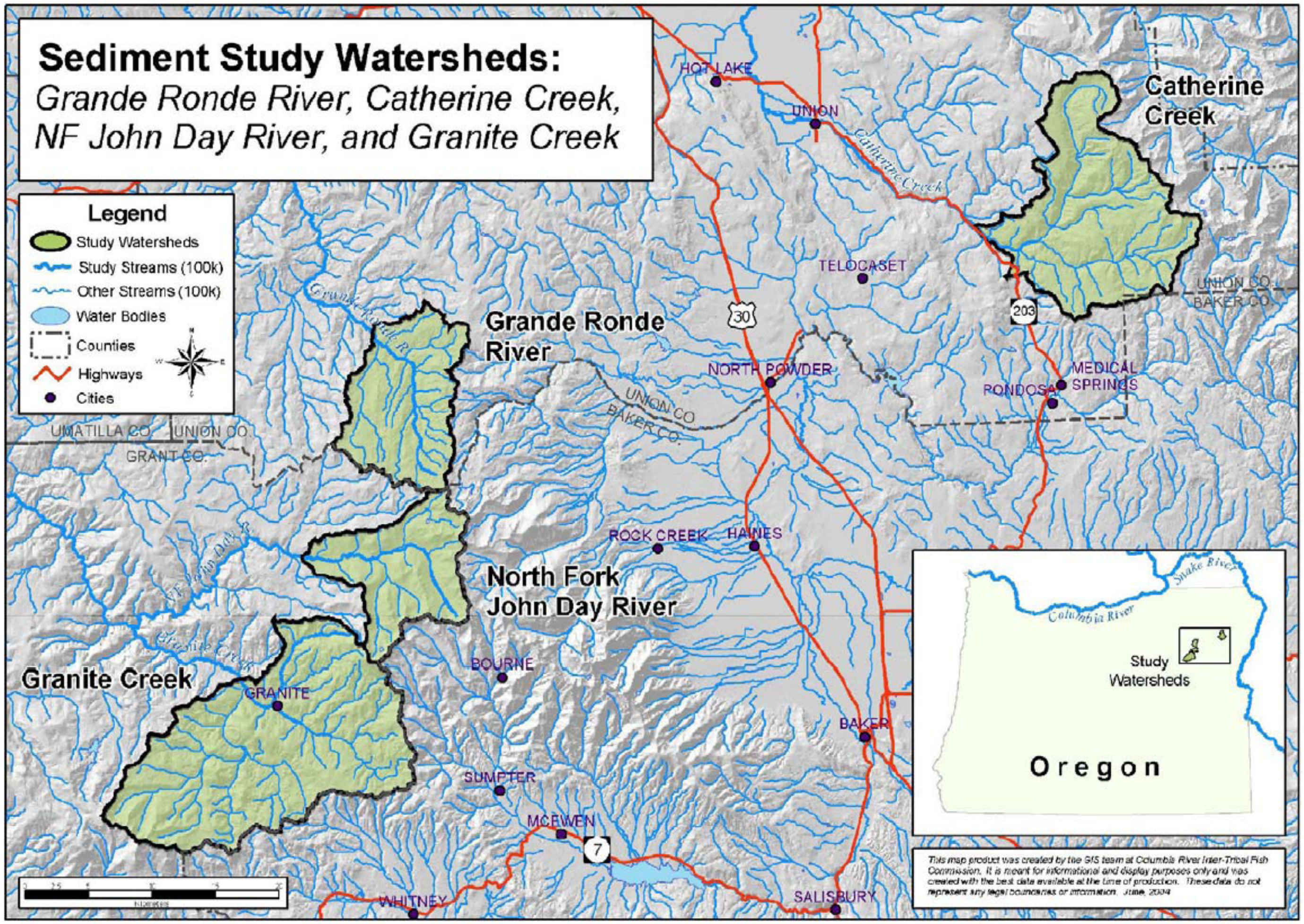

Figure 2. The Upper Grande Ronde River and Catherine Creek study watersheds.

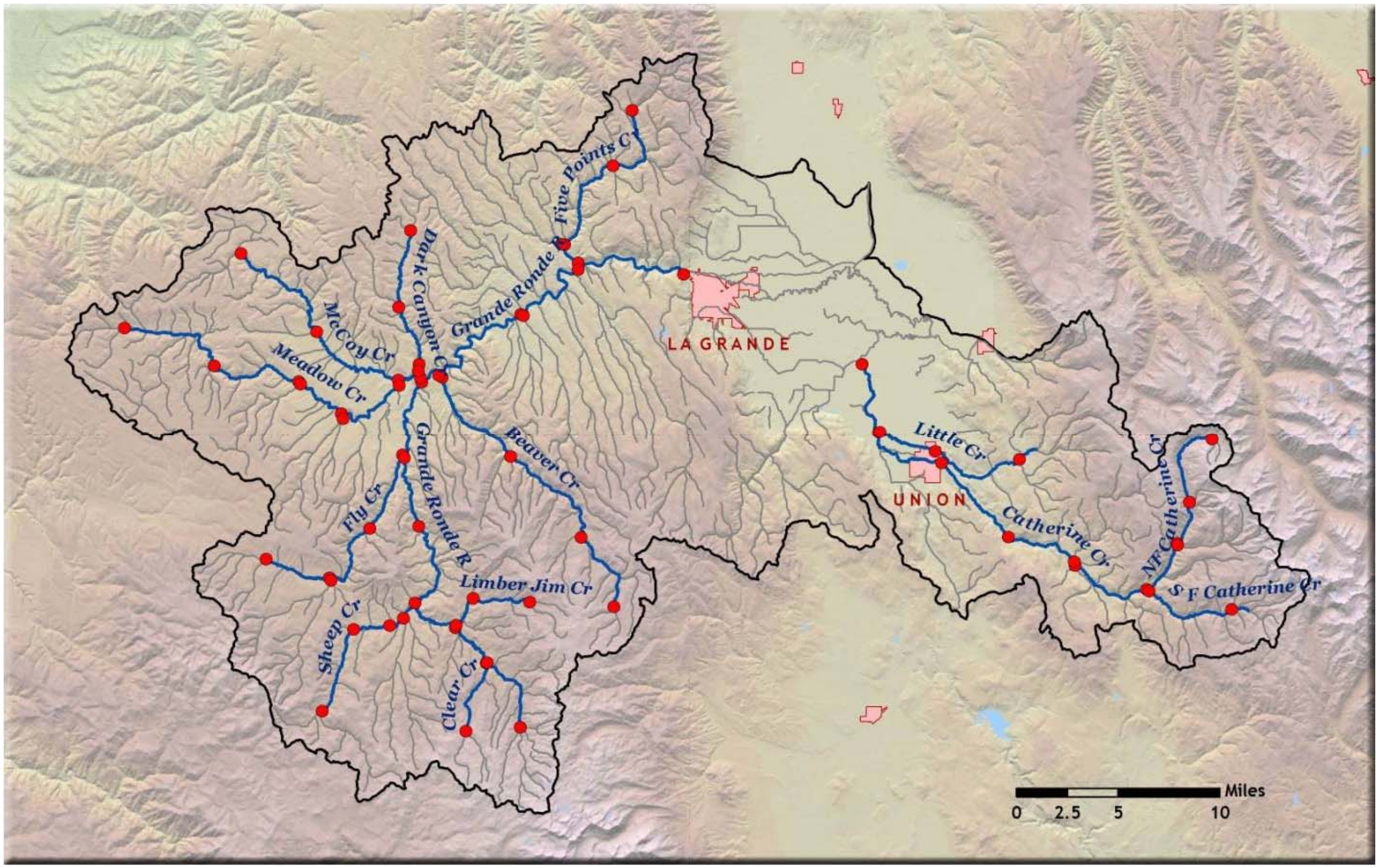

Figure 3. The Upper Grande Ronde and Catherine Creek study watersheds with proposed stream cross-section and water temperature monitoring sites indicated with a red circle.

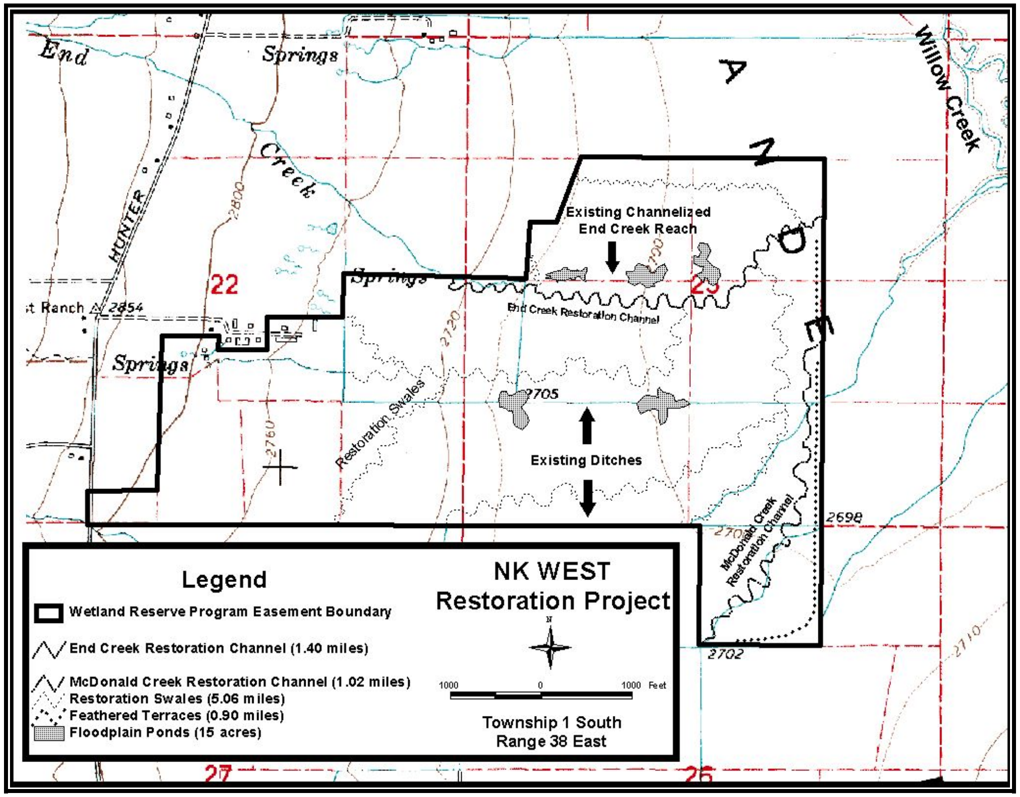

Figure 4. A PCSRF project area located on the Rice, Davidson, and Dake properties within the End Creek sub-watershed approximately 1 mile upstream from the junction with Willow Creek, in the Grande Ronde subbasin. The project encompasses approximately 1.4 miles of End Creek, 2 miles of McDonald Creek, 1 mile of the South Fork Willow Creek,and 5.06 miles of secondary channels (shallow swales). The project is located in T1S, R38E sec. 22, 23, 26 Willamette Meridian, elevation 2700 feet. See Figure 1, Project Vicinity Map. From CTUIR (2005), PCSRF proposal: NK West/End Creek & McDonald Creek Restoration Projects,Grande Ronde Fish Habitat Enhancement.

Appendix B

Modeling

In order to measure these sites with variation and extrapolate to the entire regions the following equations could be used to estimate the mean attribute by the unit (reach scale) and extrapolate for the entire sub0basin bases on the stratification chosen:

(a) $$\overline{M}_{i,s} = \frac{1}{n}\sum_{l=1}^{n} M_{j,s_l}$$

Where M is the average habitat attribute measured (e.g. fine) in stream, (s) in for a reach within a strata of segment (i) measure in time (t)

(b) $$\operatorname{var}\left(M_{i,s}\right) = \left(\frac{\left(1-\frac{n}{N}\right)}{n-1}\right)\sum_{l=1}^{n}\left(M_{i,s_l} - \overline{M}_{i,s}\right)^2$$

Where n is the number of samples observed out of the entire sample-space (N)

To extrapolate to the entire basin for that attribute, we would multiply the average estimate by the entire sample-space estimate (N).

The conceptual model developing a Stage-Based Recruitment Relationship

The basic model of population dynamics is an adapted Beverton-Holt model spawner recruit model (Beverton and Holt 1957) applied to Chinook salmon (Hilborn and Walters 1992). The model can be easily extended to steelhead and resident salmonids as well. The basic structure of the model is:

(1) $$R_{t+1} = \frac{aS_t}{b+S_t}$$

where R_{t+1} is the recruits in time t+1, S_t is the spawners in time t, and a and b are parameters of the model. Harvest rate (u_t) is incorporated as follows:

(2) $$N_{i+1,t+1} = \frac{aN_{i,t}}{b + N_{i,t}}\left(1 - u_{t+1}\right)$$

where $N_{i,t}$ is the number of individuals in stage i at time t. In this case, the subscript t refers to the generation of salmon, ignoring the fact that many salmon return to spawn at different ages. Mousalli and Hilborn (1986) used a sequence of Beverton-Holt models to represent the different life history stages of salmon and Sharma et al. (2005) further modified the above models to directly relate the model parameters to habitat quality and quantity. The approach is an extension of Moussali and Hilborn's model (1986) shown below:

(3) $$N_{i+1,t+1} = \frac{N_{i,t}}{\frac{1}{p_{i,t}} + \frac{1}{c_{i,t}} N_{i,t}}$$

where $N_{i,t}$ is the number of individuals alive at the beginning of life history stage *i* at time *t*, p_i is the "productivity" at stage *i* (the maximum survival rate from stage *i* to *i +1*) and c_i is the "capacity" (the maximum number of individuals that will survive from stage *i* at time *t* to stage *i+1* at time *t+1*).

This model (Figure 2) can be used to represent a n-stage life history model; or in the case of spring Chinook salmon, a six-stage freshwater life cycle model that tracks spawners ($N_{1,t}$), eggs ($N_{2,t}$), emergent fry ($N_{3,t+1}$), summer parr ($N_{4,t+1}$), pre-smolts ($N_{5,t+2}$) and smolts ($N_{6,t+2}$) and adults ($N_{7+x,t+2+x}$), allowing for both ocean survival rate (o_{t+x}), and harvest (u_{t+x}), to change over time (t+2+x years). Note, the time subscript is calendar year for the life-cycle starting with spawners N_1, at a particular year t. The juvenile life cycle occurs in t+1, in t+2 smolts emigrate, the adult's life cycle stage occurs in t+2+x (where x can be 1, 2 or 3 for spring Chinook), and the adults mature in year t+2+x during which they are either harvested or return to their natal streams to spawn. Immature fish stay another year in the ocean. For modeling, we assume known proportions of the population maturing in year t+2, t+3, t+4 and t+5). These parameters will of course be influenced by ocean conditions and we also assume known estimates of survival from one age class to the next in the ocean.

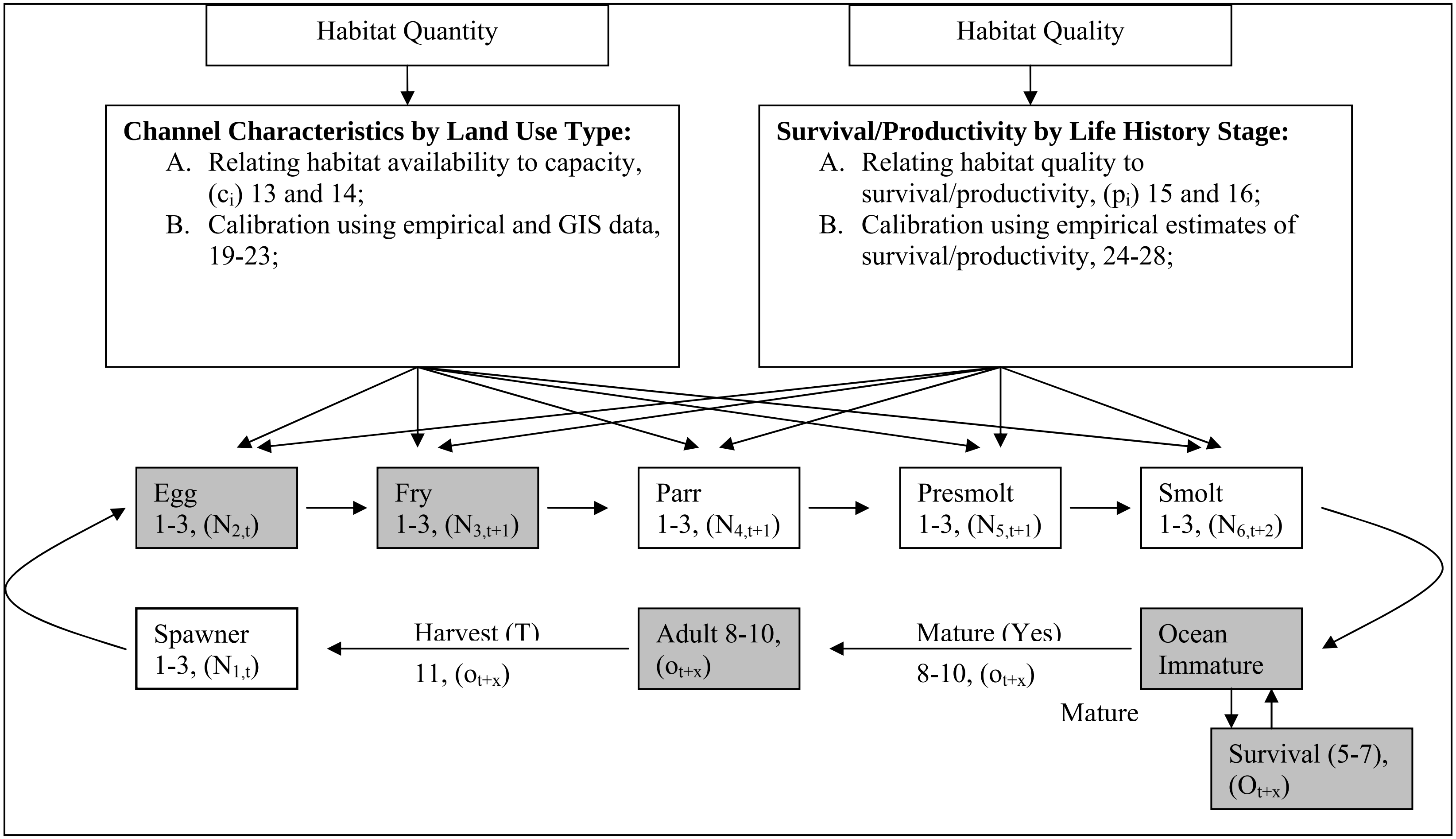

Figure 2. Schematic illustrating how the model develops relationships between habitat quantity (capacity) and quality (survival/productivity) to stage-based abundance and productivity and population growth rate. Grey boxes indicate those life stages for which abundance will be inferred, notation in parentheses refers to model parameters, and numbers within the boxes refer to equations in Section 2. Note that we define “spawners” as adults that return to a tributary to spawn, this number may or may not be corrected for pre-spawning mortality.

For the above notation and for the spring Chinook life-cycle, p_1 is fecundity per spawner, c_1 is the carrying capacity for eggs, p_2 is the survival from egg to fry at low densities, c_2 is the maximum fry production as determined by the total amount of rearing area available, p_3 is the maximum fry to summer parr survival, c_3 is the maximum production of summer parr dependent on summer rearing area, p_4 is the maximum summer parr to pre-smolt survival, c_4 is the maximum production of pre-smolts accounting for density dependence in that life-cycle stage. Finally, p_5 is the maximum pre-smolt to smolt survival, and c_5 is the maximum production of smolts dependent on over-wintering rearing area (for purpose of our modeling we collapse p_3 and p_4 into one parameter and instead incorporate all the density dependence from fry to the pre-smolt lifecycle stage).

Ocean immature adult life cycle stages.

Spring Chinook salmon are assumed to mature at 3, 4 or 5 years of age after spending 1, 2, or 3 years respectively in the ocean. Although some adults may return at age six, the proportion of the overall population represented by this age class is assumed to be negligible. As such, the subsequent stages are now broken into a yearly time step (i.e. 3, 4 or 5 year olds translate to N_8, N_9, or N_{10} respectively).

(4)
$$N_{7,t+2} = \frac{N_{6,t+2}}{\frac{1}{Z_{t+2}} + \frac{1}{c_{6,t+2}} N_{6,t+2}}$$

N_7 is the number of individuals that make it from the smolt life-stage in the Salmon River to the ocean life cycle stage at the same age. The effect of c_6 is assumed to be negligible, and the Dam (Z) survival is the only effect on the outmigrating smolts. For simplification purposes, we multiply equation (3) above from the smolt life cycle stage, N_5 by the the passage survival (Z).

Since ocean fisheries are negligible on this stock, we assume only NM (o_{t+3}) from age 1 (N_7) ocean to age 2 ocean (N_8) or 2+ to 3+ in real age, and c_5 is the ocean capacity for age 2+ fish. We assume sequential Maturation followed by Natural Mortality for all subsequent ages in the ocean.

For age 3+ (or ocean age 2, N_7) we have:

(5)
$$N_{8,t+3} = \frac{N_{7,t+2}}{\frac{1}{o_{t+3}} + \left(\frac{1}{c_{7,t+2}} N_{7,t+2}\right)}$$

For age 4+ (or ocean age 3, N_8) we have:

(6) $$N_{9,t+4} = \frac{N_{8,t+3}\left(1-M_8\right)}{\frac{1}{o_{t+4}} + \left(\frac{1}{c_{8,t+3}} N_{8,t+3}(1-M_8)\right)}$$

(7) $$N_{10,t+5} = \frac{N_{9,t+4}\left(1-M_9\right)}{\frac{1}{o_{t+5}} + \left(\frac{1}{c_{9,t+4}} N_{9,t+4}(1-M_9)\right)}$$

Mature terminal adult life cycle stages.

Most of the fisheries take place in river for spring Chinook salmon and steelhead. The vulnerability of cohorts by age is determined in the following manner:

(8) $$N^T_{8,t+3} = \left(\frac{N_{7,t+2}}{\frac{1}{o_{t+3}} + \left(\frac{1}{c_{7,t+2}} N_{7,t+2}\right)}\right) M_8$$

(9) $$N^T_{9,t+4} = \left(\frac{N_{8,t+3}\left(1-M_8\right)}{\frac{1}{o_{t+4}} + \left(\frac{1}{c_{8,t+3}} N_{8,t+3}(1-M_8)\right)}\right) M_9$$

(10) $$N^T_{10,t+5} = \frac{N_{9,t+4}\left(1-M_9\right)}{\frac{1}{o_{t+5}} + \left(\frac{1}{c_{8,t+4}} N_{9,t+4}(1-M_9)\right)}$$

Accounting for harvest by age, we have the remaining spawners by age shown in eq (11).

(11) $$N^T_{5+i,0+i} = N^T_{5+i,0+i}(1-u_{0+i})$$

Where i ranges from 3 through 5, and thus we have a fishery (u_{0+i} is the harvest rate for adults returning to spawn) on N_8, N_9 and N_{10} respectively in the terminal areas at time 3, 4 and 5 respectively.

Developing a relationship between habitat quality/quantity and recruitment.

In the previous section, a relationship was developed to measure adult to juvenile (stage-based) productivity/survival. That relationship assumed static freshwater habitat conditions. To directly relate the quality and quantity of stream habitat to productivity and capacity (p_i, and c_i), respectively, we assumed that freshwater habitat quality is directly related to land use in the basin. It should also be noted that empirical measures of habitat availability will be collected during the course of the study, thus potentially negating our reliance on landcover as a predictor of habitat quantity and quality. Nonetheless, a coarse GIS-based tool, such as that developed below, could prove to be a useful tool to assist in the prioritization of habitat actions using this approach..

Table 3. Land cover by area in River watershed (A_k x $L_{,q,k}$).

Landuse Classification	Currently Available(m^2)[A]	Available Post-Reconnection (m^2)[B]	Productivity Scalar (E)[C]
Forest (Old Grow	X1	Y1	1
Forest (Second Gr	X2	Y2	0.7
Agriculture	X3	Y3	0.7
Rangeland	X4	Y4	0.65
Urban	X5	Y5	0.5
Other	X6	Y6	0.5

.
[C]Forest habitat is assumed to represent pristine conditions, and thus sets the upper limit for productivity. Productivity in other classifications is decremented based on assumed anthropogenic impacts.
Note that the productivity scalar values are fictitious, and are provided solely for illustrative purposes. These scalars will be developed based on empirical data collected over the course of the project.

A habitat matrix (Table 4) derived from data collected over the course of this experiment will be used to transform stream area within land use classes into available habitat area (in m^2) for the watershed. The stream habitat categories were based on the Fisheries Habitat Relationships ((FHR), Bisson et al. (1981)). The seven categories were pools, cascades, glides, riffles, runs, spawning gravel, and other (Table 2). We did not distinguish between pools and ponds which would have required estimates of pond area, a stream-specific attribute not obtainable from land-use characteristics. The pools category encompasses all pool and pond habitats available (i.e., trench pools, plunge pools, lateral scour pools, mid-channel scour pools, dammed pools, alcoves, beaver ponds and backwater pools).

Table 4. Conversion matrix used to transform habitat classification into habitat type ($M_{j,q}$).

Landuse Classification	Proportional Habitat Type					
	Pools	**Cascades**	**Glides**	**Riffles**	**Rapids/Runs**	**other**
Forest (Old Growth)	60%	0%	5%	30%	5%	0%
Forest (Second Growth)	50%	0%	10%	30%	10%	0%
Agriculture	40%	0%	10%	40%	10%	0%
Rangeland	20%	0%	20%	40%	20%	0%
Urban	0%	0%	0%	0%	100%	0%
Other	10%	0%	20%	50%	20%	0%

Note that habitat proportions are fictitious and are provided solely for illustrative purposes.

To estimate the amount of a habitat type j in watershed k at time t $(H_{k,j})_t$, we begin with the area (m^2) of stream in watershed k with species appropriate gradient (A_k) and the percent of area in watershed k in land use class q at time t $(L_{qk})_t$ from Table 4. Note that the sum of the $L_{q,k}$ is equal to A. The percent of stream habitat types j (pools, cascades, glides, riffles, rapids/runs and other) found in land use class q ($M_{j,q}$) is taken from Table 4 and is assumed to be constant over time unless specific habitat actions have occurred which might be expected to change those values. We estimate the amount of habitat type j in watershed k at time t $(H_{k,j})_t$ via the equation:

$$[H_{k,j}]_t = A_k \times \sum_{q=1}^{n} \left[[M_{j,q}] \times [L_{q,k}]_t \right] \tag{13}$$

Note in the notation above A_k is the overall area and $L_{q,k}$ is a proportion describing how that area is distributed. Thus, Table 4 already has the proportion ($L_{q,k}$) multiplied by A_k.

Capacity estimates were calculated for currently available and reconnected habitat as a function of the different types of land use and available stream habitat. The number of individuals in each life-history stage, i (eggs, fry, parr and pre-smolts) that could be maintained per square-meter of each habitat type j ($D_{j,i}$) will be estimated empirically. Note that if the spawner numbers are below seeded habitat levels, then the c(k,j) will be an underestimate. The best solution to this problem would be to do a sensitivity analysis by serially increasing the observed number of juveniles per unit area of the habitat available.

For the purposes of demonstrating the model we used coarse estimates (Table 6) to calculate stage-specific capacities for watershed k in life history type i at time t $(c_{k,i})_t$. Incidentally, the $(c_{k,i})_t$ corresponds to the c_i in equation 3 for a particular life stage, for a particular watershed k, and thus has a time dynamic. Because carrying capacity data specific to the watershed is unavailable, we utilized published values for coastal coho salmon for this demonstration (Table 5; based on Nickelson et al., 1992a and 1992b). However, these data provide information for only four life stages (spawner to egg, egg to fry, fry to winter pre-smolt, and pre-smolt to smolt), thus we had to assume there was no density dependence from fry to summer parr and incorporated only the productivity parameter from this life-cycle stage for this demonstration:

(14) $$\left[c_{k,i}\right]_t = \sum_{j=1}^{n}\left[H_{k,j}\right]_t \times \left[D_{j,i}\right]$$

Table 5. Capacity estimates by habitat type, measured as individuals per m^2.

Habitat type	Egg to Fry	Fry to Presmolt	Presmolt to Smolt	Spawner to Egg
Pools	2.275	1.55	0.7625	0
Cascades	0	0.2	0	0
Glides	1.8	0.08	0.1	0
Riffles	1.2	0.01	0.01	0
Rapids	0.6	0.01	0.01	0
Other	1.8	1.05	0.5	0
Spawning Gravel	0	0	0	833

The productivities for each stage (p_i) are assumed to be related to the land use in each watershed – implicitly incorporating the impact of land use on the hydrologic regime, so that a watershed with a high percentage of forest would have higher productivity (survival) than an urbanized area because stream flows would be more stable, sediment loads would be relatively lower, summer temperatures would be lower, etc. (these assumptions will be tested as described in the next section). For a given watershed k, we used an average of the percent area in each land use class $(L_{q,k})_t$ weighted by its relative productivity ($E_{i,q}$ in Table 3) and the overall survival from one stage to the next (S_{ri}; Table 6) obtained from Bjornn (1978) for spring Chinook salmon. Because data are limited, for the purposes of this example we have made $E_{i,q}$ a constant that does not change by life stage. It is anticipated that $E_{i,q}$ will vary based on life-history based productivities specific to a given mainstem reach or tributary, which are a function of habitat conditions in the watershed.

Table 6. Stage-based survival estimates ($\mathbf{S_{ri}}$).

Life Stage	Estimated Survival
Egg to Smolt	0.67
Fry to Smolt	0.6
Parr to Smolt	0.56
Presmolt to Smol	0.9
Spawner to Egg	1,750

Note that the values presented in this table do not match those from Bjornn (1978). Bjornn's (1978) values were used as model inputs (applied to existing habitat), while these are just for illustrative purposes..

Thus productivity can be calculated as:

(15) $$p_{i,t} = Sr_i \times \frac{\sum_{q=1}^{n}\left[E_{i,q}\right]\times\left[L_{q,k}\right]_t}{\sum_{q=1}^{n}\left[L_{q,k}\right]_t}$$

where:

p_i = Density independent productivity for stage i dependent on the relative importance/relationship between productivity and land use in that stream.
$E_{i,q}$= Scalar showing the importance of land-use type (q) for overall productivity (in Table 4).
Sr_i = average maximum survival rate from one stage to the next in the fresh-water life history of the species given average conditions (Tables 2-4) compared to a baseline in the best possible habitat suited for their survival. Note that the life cycle based productivities (p_i) are equivalent to the productivities in equation 3, and have a time dimension to them.

We can rewrite equation 3 in terms of the land use based productivity and capacity estimates, by freshwater life history stage for the species being modeled in watershed k as:

(16) $$N_{k,i+1_t} = \frac{N_{k,i_t}}{\dfrac{1}{Sr_i \times \dfrac{\sum_{q=1}^{n}\left[E_{i,q}\right]\times\left[L_{q,k}\right]_t}{\sum_{q=1}^{n}\left[L_{q,k}\right]_t}} + \dfrac{1}{A_k \times \sum_{j=1}^{n}\left[\left[\sum_{q=1}^{n}\left[M_{j,q}\right]\times\left[L_{q,k}\right]_t\right]\times\left[D_{j,i}\right]\right]} N_{k,i_t}}$$

All the freshwater stages occur at different seasonal or monthly time-steps, but in the same calendar year time-step shown in equation 3, other than the smolt life cycle stage, which occurs in the next year.

Based on the above model the following can be evaluated:

- Have habitat reconnections increased habitat capacity?
- Has habitat quality improved as a result of habitat reconnections?
- Have changes in habitat quantity and quality increased capacity and productivity?

An Empirical Approach to Estimating the Effects of Habitat Actions

Based on data collected over the first phase of this project, we could also empirically model changes to the population dynamics over time (equations 3 to 11). We could either empirically estimate the change in productivity as a function of some change in habitat quality (e.g. the effects of increased flow on juvenile survival), or weight them based on land-use class as shown in equation 15.

We propose to use a linear regression between stage based abundance (or productivity, either N_i or p_i) and habitat variables to examine the relationship between juvenile abundance and habitat characteristics. The new equation will be of the form:

(17) $$p_i = \alpha + \beta V_{i,s} + \varepsilon_s$$

Where p_i is stage based productivity in stream *s*, $V_{i,s}$ is the independent stream or watershed variable (pool density, pond density, flow etc.) in stream *s*, α is a constant, β is the slope parameter of the variable ($V_{i,s}$) and ε is the normal additive error.

We propose to use the normal likelihood to find the best estimates of our parameters. Likelihood profiles of the slope parameter can be generated as:

(18) $$L(\beta \mid \alpha, p_i) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{\left((p_i) - (\hat{p}_i)\right)^2}{2\sigma^2} \right]$$

Estimation of Habitat Quantity and Quality and Juvenile and Adult Abundance

The previous section developed a model-based approach employing GIS-based and empirically derived estimates of habitat area as a function of land-use categories to estimate stage-based habitat capacity, survival, and productivity. Although the GIS-based and empirical methods could be used independently, a much more robust and sensitive model can be constructed if empirical estimates are used to: 1) construct the relationship between the availability of habitat types within land-use classifications and 2) develop the relationships between habitat types and stage-based survival and productivity. This Section details the estimators that will be used by the model developed in the previous section.

This Section develops the estimators required to:

1. deconstruct land-use categories into constituent habitat types;
2. obtain juvenile densities within land-use categories;
3. construct population trajectories;
4. obtain stage-based survival and abundance estimates, and consequently p_i; and
5. obtain adult escapement estimates.

Obtaining habitat proportions and estimating rearing densities within land-use categories.

We propose to employ a cross-sectional sampling design by land use type (L_{qk}) described by equation 13. Based on this information we can determine the following parameters, ($M_{j,q}$) by land use type and (L_{qk}); i.e. the percent pool, ponds, riffles etcetera composing a particular land use classification with a certain gradient classification. Likewise, by employing electrofishing and snorkeling, we can generate juvenile density estimates within land-use categories.

Assuming that we can logistically implement a balanced cross-sectional design with n stream segments in each land-use classification (determined through a random sample of all such segments N in that land-use type); then sample mean (19) and variance (20) of habitat types (pool, riffle etc.) by land-use category can be computed as:

(19) $$\overline{M}_{j,q} = \frac{1}{n}\sum_{l=1}^{n} M_{j,q_l}$$

(20) $$\mathrm{var}\left(M_{j,q}\right) = \left(\frac{\left(1-\frac{n}{N}\right)}{n-1}\right)\sum_{l=1}^{n}\left(M_{j,q_l} - \overline{M}_{j,q}\right)^2$$

Based on equation 19 and 20 and the Delta method (Casella and Berger 1992) we can calculate the variance of $(H_{k,j})_t$ (the amount of habitat in a given watershed at a given time).

Similarly if electrofishing and snorkeling are used to simultaneously estimate rearing densities by habitat classification, we can determine densities as a function of habitat type ($D_{j,i}$), thus the mean and variance can be calculated as:

(21) $$\overline{D}_{j,i} = \frac{1}{n}\sum_{l=1}^{n} D_{j,i_l}$$

(22) $$\operatorname{var}(D_{j,i}) = \left(\frac{\left(1 - \frac{n}{N}\right)}{n-1} \right) \sum_{l=1}^{n} \left(D_{j,i_l} - \overline{D}_{j,i} \right)^2$$

Estimating capacity as a function of habitat.

Using the Delta method, we can calculate the variance of $(c_{k,i})_t$ (juvenile capacity as a function of habitat type). Depending on the covariance between $(H_{k,j})_t$ and $D_{j,i}$ (i.e. if they are independent), we can calculate the variance of each combination of $H_{k,j}$ and $D_{j,i}$.

For example, since each $H_{k,j}$ is distributed $N(\mu_{k,j},\sigma_{k,j})$ and each $D_{j,i}$ is distributed $N(\mu_{j,i},\sigma_{j,i})$ then the overall variance is:

(23) $$\operatorname{var}(c_{k,i}) = \sum_{j=1}^{n} (\mu_{k,j})^2 (\sigma_{j,i})^2 + (\mu_{j,i})^2 (\sigma_{k,j})^2 - \operatorname{cov}(H_{k,j}, D_{j,i})$$

Note that equation 23 calculates variance for estimates of carrying capacity (equation 14). Simulations will be used to estimate expected adult returns by incorporating the variances and distributions estimated from equations 19-23. By re-sampling the distribution on each variable for the freshwater life history stage and employing estimates of variability in ocean survival and maturation from one age to the next, we can simulate expected population trajectories at some time t based on the starting population size. These exercises may be particularly useful for predicting the potential benefits of additional tributary reconnections or other habitat actions, to determine which life-stage(s) are limiting population recovery, and to predict the response size that must be generated by habitat actions to reach replacement.

Juvenile abundance estimates.

For anadromous species at each stage (adult to egg, egg to fry, fry to parr, parr to presmolt, presmolt to smolt, and smolt to adult) we need either: 1) a reach specific population estimate or 2) an overall estimate of the population which could then be parsed to reaches using a proportional estimator. For either method, we propose to use electrofishing to deploy marks, thus enabling the calculation of abundance and survival via mark-recapture. PIT tags will be used to mark fish greater than 60 mm fork length, while Bismark-Brown dye or fin clips will be used to mark fish smaller than 60 mm fork length. Alternatively, the abundance and survival of fish less than 60 mm fork length could be reconstructed from adult escapement and the abundance of fish that survive to exceed 60 mm fork length (parr). Identical methods will be employed for resident salmonids (e.g., rainbow trout) with the exception that smolt to adult survival will be replaced by juvenile to reproductive adult survival (most likely based on length).

For most of our mark-recapture experiments we chose to use a simple two-stage mark-recapture estimate that would correspond with the stage-based model developed in the previous sections. Thus, there is no need for a Cormack-Jolly-Seber estimate taking multiple recapture data over time, although it may be appropriate in some cases (e.g., for resident salmonids). In short, abundance to a certain life-history stage is used to estimate a proportion surviving to different stages (i.e. a rate). Thus, the dimensions of the estimators differ, one is a number, and the other is a rate (e.g., percent survival per unit time).

Reach specific population estimates.

To derive reach specific abundance estimates based on mark-recapture, we will rely on multiple pass electro-fishing to deploy marks within the reach(es) of concern by life-cycle stage:

(24) $$\hat{N}_{i,t} = \frac{(n_{i,t}+1)(n_{e,t}+1)}{m_{e,t}+1} - 1$$

(25) $$v[\hat{N}_{i,t}] = \frac{\hat{N}_{i,t}(n_{i,t}-m_{e,t})(n_{e,t}-m_{e,t})}{(m_{e,t}+1)(m_{e,t}+2)}$$

where $\hat{N}_{i,t}$ is the abundance in the reach for stage i at time *t*, $n_{i,t}$ is the number of juveniles marked in stage i at time t, $n_{e,t}$ is the total number sampled in the life-cycle stage at time t (the second pass) and $m_{e,t}$ is the number of fish in that sample with the mark.

Estimates of survival can be calculated iteratively from equation 26 (derived from equation 3):

(26) $$p_{i,t} = \frac{1}{\dfrac{N_{i,t}}{N_{i+1,t+1}} - \dfrac{1}{c_{i,t}} N_{i,t}}$$

As $\hat{N}_{i,t}$ and $\hat{N}_{i+1,t=1}$ will be known with a certain precision (from equation 25). We could use Bootstrapping techniques to calculate the precision of $p_{i,t}$.

In addition, since we will have multiple mark-recapture experiments in a certain land-use classification, we can use the following equations to estimate the variability in $p_{i,s}$ (survival) by land use class q (L_{qk}):

(27) $$p_{i,t} = \frac{1}{n}\sum_{l=1}^{n} p_{i,t_l}$$

(28) $$\mathrm{var}(p_{i,t}) = \left(\frac{\left(1 - \frac{n}{N}\right)}{n-1} \right) \sum_{l=1}^{n} \left(p_{i,t} - \overline{p}_{i,t}\right)^2$$

Where N is the total number of possible streams that could be sampled for the Mark-recapture experiment in that watershed, and n is the number actually sampled.

Proportional allocation of composite abundance to derive reach specific abundance estimates.

For anadromous species at the smolt life-cycle stage, we can obtain an estimate of aggregate abundance via mark-recapture of the number of smolts leaving the Lemhi using existing rotary screw traps to generate recaptures. Equations 24 and 25 will work in this case as well, but the system of interest is larger if sampling and tagging effort is equivalent within reaches of interest (i.e., existing and reconnected habitat (st)), such that each habitat has x_i tags deployed in them, proportional partitioning of the overall estimate can be used to derive tributary specific smolt numbers using equation 28(a) and 28(b):

28(a) $$n_{i,t} = \sum_{i=1}^{s} x_i \text{ and } \hat{N}_{st(t)} = \frac{m_{(st)}}{m_{e,t}} \hat{N}_{i,t}$$

where $n_{i,t}$ is the unique stream (st's) recapture, and it is partitioned into the particular streams contribution ($\hat{N}_{st(t)}$) for the entire population obtained via standard operation of existing rotary screw traps.

(28 (b) $$\mathrm{var}\left[\hat{N}_{st(t)}\right] = \left(\frac{m_{(st)}}{m_{e,t}}\right)^2 \mathrm{var}(\hat{N}_{i,t})$$

where $\hat{N}_{i,t}$ is the abundance in the reach for stage i at time *t*, $n_{i,t}$ is the number of juveniles marked in stage i at time t, $n_{e,t}$ is the total number sampled in the life-cycle stage at time t (the second pass) and $m_{e,t}$ is the number of juveniles (smolts or fry) in that sample with the mark.

Stage-based survival estimates for anadromous or adfluvial species within stream reaches of interest (i.e., existing and reconnected habitat) can be generated using PIT tag recaptures generated at fixed extended length PIT tag arrays deployed at the downstream end of the reaches of interest. To do so, fish will be PIT tagged upstream of the tandem arrays (A and B) with n number of Pit tags via electrofishing efforts previously described. These PIT tags will be detected downstream at each of the tandem extended length PIT tag arrays yielding a minimum survival estimate out of a given tributary (or the upper mainstem Lemhi) for a particular life-stage.

If n fish are PIT tagged in a reconnected stream or the mainstem and we have tandem extended length Pit tag arrays, then we can estimate proportional survival in a given tributary or the mainstem by life stage. For example, if we have n PIT tags detected, with x detected at PIT tag array 1, y detected at PIT tag array 2, and a total of c unique detections then:

28 (c) $$p_i = \frac{c}{n}$$

We assume Binomial properties and estimate the associated SE (σ):

28 (d) $$\text{With SE } (\sigma) = \sqrt{\frac{\frac{c}{n}\left(\frac{n-c}{n}\right)}{n}}$$

Alternatively we could use direct recaptures or proportional hazard methods (e.g., SURPH; Lady et al. 2001), but the difference between the two estimates in preliminary simulations is statistically insignificant. We then simulate sample size and mortality for different combinations using equations 28c and 28d to yield estimates of precision (Figure 3).

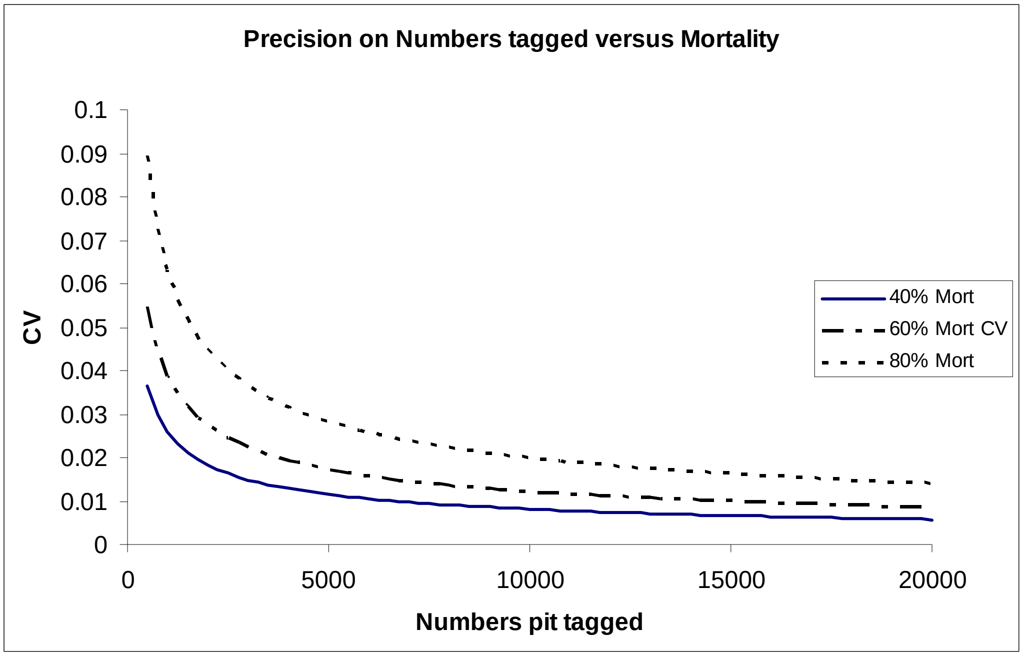

Figure 3. Precision of mortality estimates as a function of PIT tagging effort.

Adult abundance estimates.

Estimates of reach specific adult escapement must be generated to evaluate juvenile abundance as a function of adult escapement (productivity). Redd counts provide an index of adult abundance for Chinook salmon, however variance typically cannot be estimated for these surveys. In this section we develop a mark-recapture based method that utilizes adult PIT tagging in concert with extended length PIT tag arrays to enable reach specific adult escapement estimates via proportions. It should be noted that alternative methods, such as the use of video weirs or Dual Frequency Identification Sonar (DIDSON) arrays at a lower mainstem site as well as in individual tributaries could provide an alternative to an adult capture facility should such a facility be logistically infeasible.

Adults will be captured and marked at a location as close to the mouth of the mainstem River as logistically feasible. Dependent on whether mark recovery effort is equivalent among tributaries, we can estimate tributary specific escapement via a proportional estimator or by tributary specific mark-recapture.

A simple mark-recapture could be used to determine the adult escapement for the entire river (using equations 28(e) and 28(f)):

28(e) $$\hat{N}_{i,t} = \frac{(n_{i,t}+1)(n_{e,t}+1)}{m_{e,t}+1} - 1$$

28(f) $$v\left[\hat{N}_{i,t}\right]=\frac{\hat{N}_{i,t}\left(n_{i,t}-m_{e,t}\right)\left(n_{e,t}-m_{e,t}\right)}{\left(m_{e,t}+1\right)\left(m_{e,t}+2\right)}$$

Where $\hat{N}_{i,t}$ is the adult escapement in the particular stream (or streams in our case) at time t, $n_{i,t}$ is the number of adults marked at the capture facility, $n_{e,t}$ is the total number of adults sampled in all the streams above the capture facility and $m_{e,t}$ is the number of adults in that sample (recaptured) with the mark (possibly a pit-tag or external mark).

So, if tributaries (st) comprised this population estimate and each had m(st) tagged adult recoveries, based on **equal sampling effort**:

Then,

28 (g) $$\hat{N}_{st(t)}=\frac{m_{(st)}}{m_{e,t}}\hat{N}_{i,t}$$

where m(st) is the unique stream (st's) recapture of adults and is partitioned into the contribution of a particular stream ($\hat{N}_{st(t)}$) from the entire population.

Using a proportional estimator, we can also obtain estimates of variance as shown below:

28 (h) $$\mathrm{var}\left[\hat{N}_{st(t)}\right]=\left(\frac{m_{(st)}}{m_{e,t}}\right)^2\mathrm{var}(\hat{N}_{i,t})$$

Instead of employing the proportional estimator directly on the entire population we could use adjusted the number of marked fish $n_{(st)i,t}$ in each tributary based on the numbers recaptured assuming equal sampling effort across all tributaries.

28 (i) $$n_{(st)i,t}=\frac{m_{(st)}}{m_{e,t}}n_{i,t}$$

28 (j) $$\hat{N}_{(st),t}=\frac{\left(n_{(st)i,t}+1\right)\left(n_{(st)e,t}+1\right)}{m_{(st)e,t}+1}-1$$

28 (k) $$v\left[\hat{N}_{(st),t}\right]=\frac{\hat{N}_{(st),t}\left(n_{(st)i,t}-m_{(st)e,t}\right)\left(n_{(st)e,t}-m_{(st)e,t}\right)}{\left(m_{(st)e,t}+1\right)\left(m_{(st)e,t}+2\right)}$$

If PIT tags are deployed on adults at the capture facility, PIT tags can be interrogated at the extended length PIT tag arrays. This will give indirect proportions of the number tagged in the individual tributaries.

Thus, we can derive a tributary specific escapement as:

28 (l) $$n_{(st)i,t} = p_i n_{i,t} \text{ and } \sum_{i=1}^{s} p_i = 1$$

Where p_i is the proportion of the initial marked population observed in stream (st) $n_{i,t}$ is the number of adults marked at the capture facility, $n_{(st)i,t}$ is the number of those initially marked from the stream (st). Equations 28(e) and 28(f) are used again to generate tributary specific escapement estimates.

Tributary specific adult abundance estimates for resident species will be generated as described by equations 24 and 25.

Hypothesis Testing

The previous Sections have developed the information needs, and estimators by which we can evaluate the effects of habitat actions on life-stage specific abundance and productivity/survival of anadromous and resident species.

This Section summarizes how specific questions of interest will be evaluated including:

1. have tributary management actions changed habitat availability and what are the effects of tributary reconnections on stage-based carrying capacity (i.e., potential productivity);
2. have other habitat actions (e.g., increased riparian cover or dike removal) changed stage-based productivity/survival;
3. have tributary habitat actions changed fish distribution;
4. is fish condition similar in reconnected versus existing habitat (i.e., what is the quality of reconnected tributary habitat relative to existing habitat)?

Has habitat availability changed, and what are the effects of the changes on potential productivity/survival?

Since we will have multiple replicate estimates of stage-based abundance and survival as a function of land-use classification (from 1 to n, Land use defined as habitat attribute in stream segment (i) measured within a particular Land use type (q)) , we can implement a binomial test in GLM (R software) with the logit link to determine how changes in habitat availability within land-use type would be expected to change potential productivity. Preferably, we will be able to implement a balanced study design (equally replicated measures of stage-based abundance and survival by land-use type); however an unbalanced design can also be tested, though analyzing the results statistically will be more complicated. Thus we can determine whether habitat attributes varies as a function of land-use classification as follows:

(29) $$\ln\left(\frac{M_{i,s}}{1-M_{i,s}}\right)=\beta_0+\sum_{q=1}^{n}\beta_q\, factor(LandUse_q)+\varepsilon$$

$$Y_i \sim Binomial(n,p)$$

H_0: $\beta_1 = \beta_2 = \ldots\ldots = \beta_n = 0$

H_a: $\beta_1 \neq 0$ and/or $\beta_2 \neq 0$ and/or $\ldots\ldots \beta_n \neq 0$

Variance estimates will be generated by R, and approximate those from equations 1 and 2 when used as a simple test of proportions incorporating the sum of the variances as the correction factor (standard error of the difference) in pair-wise comparisons. Variance will be partitioned using an Analysis of Variance (ANOVA).

Assuming that habitat modification has increased the abundance of particular types of habitat (pools etc.), we can evaluate the effects of such changes on potential productivity. Based on the data obtained, we can employ a Binomial test using Generalized Linear Models with the logit link, with weights based on the sample size tagged for each starting N_i. Thus, this equation can be used to estimate changes in survival/productivity based on channel reconnection using a pre/post comparison.

(30) $$\ln\left(\frac{p_{i,s}}{1-p_{i,s}}\right)=\beta_0+\sum_{q=1}^{n}\beta_q\, factor(LandUse_q)+\varepsilon$$

$$Y_i \sim Binomial(n,p)$$

H_0: $\beta_1 = \beta_2 = \ldots\ldots = \beta_n = 0$

H_a: $\beta_1 \neq 0$ and/or $\beta_2 \neq 0$ and/or $\ldots\ldots \beta_n \neq 0$

Results will be analyzed using an Analysis of Variance (ANOVA). Variance of the estimates will come directly out of the analysis.

Effects of other habitat actions on potential productivity.

A number of other habitat actions (e.g., creation of pool habitat) will be occurring in addition to (or as a result of) tributary modifications. The effects of these actions on potential productivity can be evaluated via a control versus treatment framework (as shown in equation 30), or using a cross-sectional design implemented as an Analysis of Covariance (ANCOVA) as follows:

(31) $$\ln\left(\frac{p_{i,s}}{1-p_{i,s}}\right)=\beta_0+\beta_1 WS+\sum_{qi=2}^{n}\beta_q\, factor(LandUse_q)+\sum_{qi=n+1}^{2n}\beta_q WS: factor(LandUse_q)+\varepsilon$$

$$Y_i \sim Binomial(n, p)$$

WS refers to any of a number of covariates (e.g., flow)

Y(i) refers to the dependent variable and is equivalent to $\ln\left(\frac{p_{i,s}}{1-p_{i,s}}\right)$

H_0: $\beta_1 = \beta_2 = \ldots\ldots = \beta_{2n} = 0$

H_a: $\beta_1 \neq 0$ and/or $\beta_2 \neq 0$ and/or$\ldots\ldots\beta_{2n} \neq 0$

Effects of flow and other factors of interest on potential productivity.

Since we have a cross-sectional design (e.g., replication across data of concern such as flow rate) for the watershed, and assuming a given watershed variable ($V_{i,s}$) of interest has sufficient contrast then we can show how manipulations in a certain watershed trait (e.g. flow or predator-density) will effect potential productivity (p_i) .

(32) $$\mathrm{p}_{\mathrm{i,s}} = \alpha + \beta V_{i,s} + \varepsilon_s$$

where p_i is the estimated stage based productivity in stream s, $V_{i,s}$ is the independent stream or watershed variable (pool density, pond density, flow etc.) in stream s, α is a constant, β is the slope parameter of the variable ($V_{i,s}$) and ε is the normal additive error.

Assuming normality and using the error structure described in equation 33, we can calculate the most likely outcome of manipulating a habitat attribute and thus estimate the change in overall productivity expected for some types of habitat modifications. We can also use the relationship derived in equation 26 directly in the stage-based equations.

(33) $$L(\beta \mid \alpha, p_i) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left[-\frac{\left((p_i)-(\hat{p}_i)\right)^2}{2\sigma^2}\right]$$

Effects of channel reconnection on juvenile distribution and abundance.

Changes in habitat quantity and quality are not the only expected outcomes of channel modifications. For example, such changes are expected to be most beneficial to Chinook salmon and steelhead only if newly available (reconnected) habitat is actually utilized.

Alternatively, for resident species, channel reconnections are expected to restore connectivity among tributary populations. In either case, there is a clear need to evaluate the effects of channel modifications on the distribution of fish in the watershed

Measures of juvenile abundance by life history stage corrected for spawner abundance within a given habitat classification will be used in a pre/post treatment analysis. For each life cycle stage and location, we develop the following model in GLIM (R-software):

(34) $$N_i = \beta_0 + \beta_1 S_{i-1} + \beta_2(Q) + \beta_3(S_{i-1})(Q)$$

Where Q=0 if it is pre-treatment data and Q=1 if it is post data, S_{i-1} is the number of spawners (or index) associated with N_i for that life-cycle stage in a particular reach that would have an effect of the habitat action.

The study design will be unbalanced as a result of having fewer post-treatment data than pre-treatment data (maximum of 5 versus 20 or more years of pre-treatment data). Hence the order in which variables are used in the analysis will be very influential (alternatively we could use only 5 randomly selected pre-treatment points to compare with the post-treatment data).

The hypothesis will be:

H_0: $\beta_2 = \beta_3 = 0 | \beta_1$

H_a: $\beta_2 \neq 0 | \beta_1$ and/or $\beta_3 \neq 0 | \beta_1$

Analysis of Covariance (ANCOVA) will be used to test if there are any changes in distribution pre or post treatment.

Evaluating changes in fish or habitat condition in a pre versus post framework.

We have described methods to evaluate the effects of increased habitat availability on potential productivity using a empirical approach that develops relationships between measures of juvenile abundance and survival as a function of land-use categories, and habitat modification activities. This section develops methods to analyze changes in:

1. habitat proportions within land-use categories and
2. stage-based stream productivity.

Although the quality of habitat should be reflected in stage-based survival estimates, it may be of use to also empirically evaluate the condition of fish inhabiting different habitats (e.g., existing versus reconnected habitat) as a proxy for the relative quality of reconnected habitat. There are several measures of juvenile condition that may be used to address this issue:

1. juvenile length at age (e.g., length of parr);
2. juvenile weight at age (e.g., weight of parr); and
3. juvenile condition factor (weight/length^3) .

These values can be tested in a pre versus post or control versus treatment framework.

Pre-experiment data on fish attributes (e.g., size or weight) before reconnections (F(pre)), versus the same measures after reconnection (F(post)), collected at existing rotary screw traps, enables a test of the reconnections using the following methods:

(35) $$F = \beta_0 + \beta_1 Q + \varepsilon$$

$\varepsilon \sim N(0,\sigma^2)$

If F(pre) then Q=0 and of F(post) then Q=1.

H_0: $\beta_1 = 0$

H_a: $\beta_1 \neq 0$

A closed form solution can also be derived for the mean and variance of the pre and post components using the following equations:

36) $$\overline{F}(pre/post) = \frac{1}{n}\sum_{i=1}^{n} F(pre/post)_i$$

(37) $$\text{var}\left(F(pre/post)\right) = \left(\frac{\left(1-\frac{n}{N}\right)}{n-1}\right)\sum_{i=1}^{n}\left(F(pre/post)_i - \overline{F}(pre/post)\right)^2$$

It may be impossible to know the sampled fraction (n/N), however with sufficient samples we could calculate the approximate variance as follows:

(38) $$\text{var}\left(F(pre/post)\right) = \left(\frac{1}{n-1}\right)\sum_{i=1}^{n}\left(F(pre/post)_i - \overline{F}(pre/post)\right)^2$$

If we have no pre-treatment data for fish condition, the effects of differing levels of stream connectivity on fish condition (F) can be evaluated in a treatment versus control framework as follows (similar tests for habitat proportion and stream productivity are presented in previous sections):

(39) $$F = \beta_0 + \sum_{i=1}^{n}\beta_i (tr_i) + \varepsilon$$

tr_i refers to any of a number of treatments (e.g., flow augmentation)

H_0: $\beta_1 = \beta_2 = \ldots\ldots = \beta_n = 0$

H_a: $\beta_1 \neq 0$ and/or $\beta_2 \neq 0$ and/or$\ldots\ldots\beta_n \neq 0$

NOTE 1: ODFW MAY ALREADY HAVE MUCH OF THE JUVENILE AND ADULT DATA BY LIFE CYCLE STAGE (ODFW 2007).

Adding Environmental Data to the Model (THE CLIMATE CHANGE CONNECTIONS)

Recent approaches in salmon management have modeled the species within a life-cycle framework. Lawson et al. (2004) and Logerwell et al. (2004) demonstrated how using Generalized Additive Models, fitting data with non-linear techniques, appear to capture inter-annual variation in coho. A similar approach could be developed here taking the estimates of recruitment to a particular life-cycle stage and adding subsequent life-cycle stages population sizes with external covariates that are hypothesized to be of key importance in survival for Spring Chinook salmon in the Columbia, e.g. flow and Sea surface temperature for smolt to age 2 recruitment (SST, Scheuerell et al. 2006, Magnusson 2004).

The method used takes estimates of life cycle stage abundance derived from eq 1-3 above and adds covariates to it (eq. 40).

$$N_{i+1,t+1} = \frac{N_{i,t}}{\frac{1}{p_{i,t}} + \frac{1}{c_{i,t}} N_{i,t}} e^{\varepsilon_t} \tag{40}$$

$$N_{i+1,t+1} = N_{i,t}\ \mathrm{e}^{\alpha\left(1 - \frac{S_{t-2}}{\beta}\right)} e^{\varepsilon_t} \tag{41}$$

Where ε_t is the error term in the relationship.

Rearranging some terms in the equation, we can rewrite (29) above with additional covariates (such as flow) below (eq 42, note $p_{i,t}$ and $c_{i,t}$ are re-parameterized here to equal 1/α and 1/β respectively).

$$\left(\frac{N_{i,t}}{N_{i+1,t+1}}\right) = (\alpha) + \beta N_{i,t} + \phi_i X_{i(t)} + er_t \tag{32}$$

Now, $X_{(i)t}$ is the value of the I^{th} covariate in year (t) related to the life cycle stage abundance. This formulation assumes that covariates play no density dependent relationship in the production relationship.

Appendix C: Details of Habitat Monitoring and Evaluation Design

Experimental design

Due to the large size of the stream systems being studied, and the fact that land ownership may make much of these streams inaccessible to monitoring of certain variables, a representative reach approach will be necessary to provide estimates of average condition of fish habitat and riparian areas distributed throughout the stream networks. The NOAA TRT designation of watershed area supporting the spring Chinook populations will be used to define the sampling universe. Within those geographic bounds, the TRT mapping of intrinsic spawning area will be used to define the sampling area. Reaches will be classified by channel gradient, watershed area class, and valley width class. These and other measures of intrinsic potential will be evaluated as classification metrics to serve as a monitoring framework within which the core habitat metrics identified will be evaluated. These decisions will be made by evaluating literature on this subject and in consultation with PNAMP cooperators. Estimates of habitat quality within a subsample of reaches in these categories will provide a means of calculating weighted average habitat conditions.

Methods for Monitoring and Evaluating Results

Relationships between habitat condition and biological response (survival, growth rate) will be compiled, evaluated, or synthesized from available literature. Although available literature on fish-habitat relationships is extensive and will be evaluated, a study by McHugh et al. (2004) is an excellent model for our work but also presents various issues that appear could be further considered and improved. For example, the potential impact of summer water temperature regimes on summer rearing survival will be assessed from available literature.

There appears to be a need to provide more substantiation of the impact of thermal regime to a spring Chinook population. McHugh et al. (2004) developed an intriguing mathematical expression of juvenile summer rearing survival based on mean daily temperature, but unfortunately, the data from which it was constructed were not explicitly described, making its adoption a matter of faith. It was assumed that a mean daily water temperature of 17.8°C was a critical threshold for direct mortality impact. Daily survivals were multiplied together for 152 consecutive days of summer rearing to compute the overall survival during this period. Indirect effects of thermal regime on survival via growth limitation were not considered. This method was assembled from three studies conducted on spring Chinook, rainbow trout, and brook trout. It is questionable how well mean daily temperature represents survival, despite whatever relationships were extracted from these three papers, due to the highly variable relationship between mean daily and maximum daily temperature among streams. Even though the answers provided by their summer rearing temperature model appear reasonable, it is questionable whether the form of this model is universally applicable or even highly appropriate for spring Chinook.

This proposed study will evaluate means to express survival as a product of thermal regime. This work will require consideration of the influence of mean daily temperature, maximum daily temperature, and number of consecutive days of exceeding a threshold. In addition, this study will be able to provide a spatially-explicit estimate of survival that can be weighted for level of use. Given the potential for juveniles to be able to perform intrabasin migration to seek optimal thermal conditions, it will be important to understand the spatial distribution of thermal conditions and migration impediments.

McHugh et al. (2004) utilized a function relating surface fine sediment to survival to emergence for spring Chinook based on an assumption that surface fines are highly related to subsurface fines. While this is a reasonable assumption in the absence of data, this study will explore this relationship. A confirmation of the identity between surface and subsurface fines will facilitate substituting surface fines as an indirect measure of subsurface fines.

McHugh et al. (2004) acknowledged the importance of streamflow but did not include it in their model. Streamflow is frequently identified as a key limiting factor for abundance and productivity in streams of the Columbia basin. This study will examine the influence of streamflow on rearing area available and water temperature.

Justification of Sample Size

Although comprehensive estimates of habitat conditions within all stream segments, stream reaches, and channel units of a stream network (see Frissell et al. 1986) are desirable and are sometimes attempted (Hankin and Reeves 1988, Dolloff et al. 1993), it can be more tractable to stratify the stream system into habitat unit and geomorphic categories and take a representative sample of these. Within habitat units, randomly selected points will be sampled for point measures of habitat features such as fine sediment. Prior to commencing field work, we will conduct a statistical evaluation of the significance of mean or maximum substrate particle size on the spacing of sample points for substrate fines and estimation of overall particle size distribution. This analysis will be conducted using computer synthesized particle distributions (random, clumped) and variable grid spacing. This analysis will be used in designing a device for effectively sampling particles to assess percentage fines and the particle size distribution. The Wolman pebble count method for estimating substrate particle size distribution relies on the average of 100 randomly selected particles in a given channel unit. However, this method is subject to inherent bias against the small particle sizes which is a critical parameter affecting salmonid survival. Also, our statistical evaluation will assess appropriate sample sizes for achieving desired precision levels under a wide range of particle distributions.

Water temperatures will be taken at strategic locations defined by the confluence of major tributaries with the mainstem. Points just upstream and downstream of these confluences in well-mixed flows will also be sampled for water temperature. Water temperature will be measured hourly, a sample frequency convention that satisfies water temperature modeling needs (Boyd and Kasper 2003). It has been found that temperatures follow diel trends that vary randomly to an insignificant extent between hourly intervals.

Riparian vegetation will be measured in a spatially comprehensive manner using remote sensing (LIDAR) in year 1. In subsequent years, analysis and interpretation of these data will be conducted. Vegetation canopy density and height will be averaged by pixel (1 x 1m). Solar radiation through the canopy will be treated in water temperature modeling by calculating light extinction according to an angular canopy density based on vertically projected canopy density, riparian vegetation width, canopy height, and stream margin topography. Fish-eye lens digital imagery of direct solar radiation potential (integrated canopy opening along the solar path through the canopy) for selected points in the stream shaded by various classes of riparian vegetation will be correlated with empirical measurement of direct solar radiation with a solar pyrheliometer. Instream measurements of solar radiation interception and angular canopy density will be made using LIDAR imagery as a means to stratify stream reaches. These measurements will be made in locations (i.e., channel center, margins) compatible with Heat Source model data needs.

<u>Compatibility of Data Collection with Historical and Regional Data (Other data sources)</u>

Other data, summarized from USFS and BLM reports by Huntington 1994, appear to be available in agency reports. Habitat parameters estimated for selected stream reaches in a variety of streams in the Grande Ronde basin include: reach length, maximum water temperature, channel gradient, channel type, valley form, channel form, stream width, active channel width, mean residual pool depth, W/D, percentage pool, pools/mile, percentage streambank stability, LWD pieces/mile, percentage embeddedness, percentage surface fine sediment, percentage shade, and dominant riparian vegetation. Although it is unclear what exact methodologies were applied to these estimates or how representative the estimates were of the reach lengths reported, it is likely, based on knowledge of typical methods applied in many past studies, that certain measurements could be lacking in accuracy. For example, it is likely that channel gradient was merely estimated from topographic maps available. Although accurate surveying equipment has been available for many years, more crude means have typically been used by field crews. Today, it is more typical to use precision survey level devices to measure channel gradient, although in large river monitoring it is more practical to use map-derived gradients due to the great distances involved in surveying water surface slope (Hughes, pers. comm..). In addition, high precision LIDAR mapping of topography is also available to accurately map channel gradient to estimate spawning or rearing potential stream reaches. Streambank stability measurements probably followed methodology laid out by Platts et al. (1983), but bank angles are not consistently related to stability as employed by soil engineers. Refinements to streambank stability measurement need to be made in order to more meaningfully represent the potential of streambanks to contribute sediment to channel substrate. Percentage shade was typically estimated using a spherical densiometer which has been recognized as not providing measurements that are accurate and relevant to water temperature modeling. Water temperature recording devices are now available that are accurate to ± 0.2°C rather than ± 1.0°C. The availability of FLIR data currently makes it more reliable to extrapolate data from temperature monitoring stations to entire stream reaches based on knowledge of water temperature distribution patterns and influx of cold or warm water. Percentage shade by riparian vegetation on a reach or stream network basis now can be more accurately estimated using LIDAR rather than from a limited number of field point estimates.

McIntosh (1995) and McIntosh et al. (1994a) conducted a resurvey of habitat conditions in the Upper Grande Ronde focusing on pool availability. This survey was able to show a 50-year trend in pool frequency change. Pool frequency can be mapped on a spatially extensive basis using GPS equipment and pre-existing GIS mapping. This will provide a good contrast with past data.

An effort will be made to evaluate current habitat condition against data able to be attributed to specific stream locations from past surveys. Only data believed to be captured using consistent and reliable methods will be contrasted with current data.