A Field Manual of Scientific Protocols for Downstream Migrant Trapping within the Upper Columbia Monitoring Strategy

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Section 1: Introduction

Background and Objectives

Columbia River Basin anadromous salmonids have exhibited precipitous declines over the past 30 years, with several populations now protected under the Endangered Species Act (ESA) (Schaller et al. 1999; McClure et al. 2002). A comprehensive monitoring strategy needs to be implemented to reduce the uncertainties surrounding the declines, and the strategies required to reverse this trend. Data collected from current and historical monitoring programs are generally not adequate or reliable enough for the purposes of ESA assessments and recovery planning (Tear et al. 1995; Campbell et al. 2002; Morris et al. 2002). In addition, monitoring programs for anadromous salmonids in the Columbia River Basin have typically been initiated to evaluate the effects of specific management actions, such as the demographic effects of hatcheries. As such, data are most appropriately viewed at the scale of the subpopulations and populations for which they were derived. However, the ESA requires assessments of species and their habitat at multiple spatial scales – from specific reaches, to subpopulations, populations, and the ESA management unit of Pacific salmon, the Evolutionary Significant Unit (ESU), which is a distinct population or group of populations that is an important component of the evolutionary legacy of the species.

Current monitoring programs for Pacific salmon did not develop as a cohesive design, thus aggregating existing data from a myriad of independent projects creates challenges in addressing these spatially complex questions. These problems arise because information is often not collected in a randomized fashion (Larsen et al. 2004), sampling techniques and protocols are not standardized across programs, and abundance, distribution, population dynamic, and demographic data for species and their habitat is often not available (Tear et al. 1995; Campbell et al. 2002; McClure et al. 2002). As recovery planning has focused more effort on tributary habitat restoration to mitigate for the mortality resulting from the Federal Columbia River Power System (FCRPS) the limitations of historic and current sampling programs have become increasingly apparent.

The Integrated Status and Effectiveness Monitoring Program (ISEMP – BPA project #2003-0017) has been created as a cost effective means of developing protocols and new technologies, novel indicators, sample designs, analytical, data management and communication tools and skills, and restoration experiments. These tools are designed to support the development of a region-wide Research, Monitoring and Evaluation (RME) program to assess the status of anadromous salmonid populations, their tributary habitat, and restoration and management actions.

The ISEMP has been initiated in three subbasins: Wenatchee/Entiat, WA, John Day, OR, and Salmon River, ID, with the intent of designing monitoring programs that can efficiently collect information to address multiple management objectives over a broad range of scales. This includes:

• Evaluating the status of anadromous salmonids and their habitat;

• Identifying opportunities to restore habitat function and fish performance, and

• Evaluating the benefits of the actions to the fish populations across the Columbia River Basin.

The multi-scale nature of this goal requires the standardization of protocols and sampling designs that are statistically valid and powerful, properties that are currently inconsistent across the multiple monitoring programs in the region. This smolt trapping and trap efficiency monitoring protocol is a component of the overall ISEMP, and while it stands alone as an important contribution to the management of anadromous salmonids and their habitat, it also plays a key role within ISEMP as it is built on a standardized format following Oakley et al. (2003) that all of the ISEMP protocols adhere to.

This status and trend monitoring protocol was developed using existing trapping protocols, input from partners and contractors implementing smolt trapping, and a review of the current scientific literature. This protocol will be revised and updated over time following standardized methods described in Appendix E.

Downstream migrant trapping of juvenile salmonid can be a valuable tool to estimate relative abundance, production, size, survival, migration timing and behavior (Volkhardt et al. 2007). Of significance to status, trend and effectiveness monitoring programs, simple mark-recapture methods can be used with downstream migrant traps to estimate total freshwater production, and enable the estimation of mortality or survival between life stages (e.g., egg-to-smolt) (Volkhardt et al. 2007). The objectives for juvenile trapping activities are to estimate abundance (production), size and condition for populations or subgroups of anadromous salmonid stocks. Additionally, the operation of rotary screw traps provides an opportunity to deploy tags in captured juveniles to estimate out-of-subbasin survival. These goals are consistent with the Upper Columbia Monitoring Strategy (UCMS, Hillman 2006).

This protocol was primarily designed for juvenile trapping programs being implemented in the Upper Columbia River Basin. This protocol may provide general guidance broadly applicable to other Columbia River subbasins; however, prior to implementation it would benefit from review by trapping practitioners in specific subbasins to incorporate local needs and environmental conditions.

Section 2: Sampling Design

This protocol is designed to standardize sampling procedures implemented at specific sites to estimate abundance/production of populations or subgroups. The UCMS (Hillman 2006) serves as the general framework and reference for the statistical and sampling designs at the basin and subbasin scale such as the selection of index populations or subpopulations where juvenile trapping is then implemented.

Statistical Design

There are several statistical methods available to estimate the abundance/production of anadromous salmonid downstream migrants using downstream migrant traps. The focus of this protocol is to streamline the mark-recapture methods utilized throughout the study basin. This statistical method relies on daily smolt trapping and mark-recapture estimates of trap efficiency to accurately determine production and/or out-migrant populations. The most common mark-recapture statistical designs include: stratified (temporally) mark-recapture, stratifying trap efficiency, and modeling trap efficiency (Volkhardt et al. 2007). The most appropriate and cost effective statistical design will depend upon the characteristics of the stream and population(s) being sampled at a site.

All three of these designs are currently being implemented in Columbia River Basin watersheds due to the highly variable nature of streams that support anadromous salmonid populations. All of these approaches share a common daily trapping sampling scheme but vary in their approach to account for changes in trap efficiency throughout the migration period. Therefore the method selected for estimating migrant abundance directly influences the way in which trap efficiency trials are implemented, especially their frequency, the number of fish targeted for daily marking, and the marking methods necessary. Furthermore, successfully meeting the precision goals for abundance estimates will require an ongoing adaptive approach to field sampling based upon timely feedback from personnel performing data analysis for the site.

Stratified Mark-Recapture

The stratified mark-recapture method estimates abundance of migrants over short discrete periods of time, or strata (few days to a week), in which a trap efficiency trial is paired with a recapture period (Carlson et al. 1998). The benefit to such an approach is that when trap efficiencies are modified by any source, these changes can be identified for discrete strata (e.g., 3 to 7 day periods). If stream conditions or trap operations modify trap efficiencies within the duration of a stratum, the paired trap efficiency trial may not well represent the actual recapture rates for the interval. When trap efficiencies are changing rapidly an option may be to shorten stratum length (e.g., 1 to few days) though the minimum stratum time period may be dictated by length of time it takes for marked fish from the efficiency trial to pass by the recapture point.

An alternative general recommendation of Roper and Scarnecchia (2000) is to estimate trap efficiencies for each day (i.e., a stratum = 1 day) even if recaptured fish from the trap efficiency trial are recaptured over several days. This requires the use of distinct marks to identify the specific efficiency trials as recapture of fish from several daily trials will overlap (Roper and Scarnecchia 2000). The length of time it takes for all marked fish to pass the recapture site is determined by the migration rate of the species and the distance of the upstream release from the recapture site but can be as few as 2 to 3 days (Carlson et al. 1998, Roper and Scarnecchia 2000). Another alternative to account for trap efficiency variability within temporal strata is to mark and release fish daily with the same mark. Mark and recapture numbers can then be pooled for the stratum to estimate trap efficiency for that period.

The most cost effective approach to attain the desired level of confidence in abundance estimates will be dictated by the numbers of migrating fish and the variability in capture probability within strata. The stratified mark-recapture method can be a useful method when discharge to recapture rates cannot be adequately modeled as is required in the modeling of trap efficiency rates method. The stratified mark-recapture method can be performed with one or two traps though the use of a single trap is most cost-effective (Carlson et al. 1998).

Stratified Trap Efficiency

The stratified trap efficiency mark-recapture method is the estimation of trap efficiencies for a range of discrete conditions. These condition strata can be predetermined relative to anticipated changes in trap position and flow conditions. Strata can also be established post-trapping season by identified periods of similar trap efficiency based upon interpretation of efficiency trial results. An example of the later is that used by Seiler et al. (2004) on Cedar Creek where a stratified mark-recapture design (weekly strata) was implemented and later analyzed with a stratified trap efficiency approach for time periods that had similar trap efficiencies (multi-week strata). The stratified mark recapture approach can also be useful when the modeling of trap efficiencies do not result in a strong relationship between an environmental variable (e.g., discharge) and trap efficiency (see Seiler et al. 2004, Green River).

Modeling Trap Efficiency

The modeling trap efficiency mark-recapture method can be used when trap efficiencies have a strong relationship with an environmental variable such as discharge or turbidity. These relationships are typically estimated with regression and over a wide range of conditions for the environmental variable being used (Volkhardt et al. 2007). Where such relationships exist, daily trap efficiencies can be estimated based upon the regression equation and daily value of the environmental variable. Unlike stratified mark-recapture methods that can account for all potential changes to trap efficiencies on short time intervals (1 day to week), the modeling of trap efficiencies is only targeting changes in trap efficiency related to a single environmental variable.

When stream conditions cause a modification in trapping procedures, to the extent that the independent variable has a significant departure in the prior relation toward trap efficiency, a new regression relationship must be established or alternative methods employed to estimate abundance for these periods. An example of this is Seiler et al. (2004) on the Wenatchee that developed relationships for two separate trap locations that were used during the trapping season. Additionally, the U.S. Fish and Wildlife Service (USFWS) has successfully related efficiency to discharge on the Entiat River utilizing a variety of trapping positions by targeting a fixed trap rotational speed through a variety of flow conditions (Matt Cooper, USFWS, pers. comm.). Trap efficiency trials are typically done throughout the trapping season as with other trapping designs though the primary goal is to capture a wide range of conditions for the environmental attribute of interest and not a standardized period of time.

Site Selection

The focus of this protocol is to provide procedures for the site selection and monitoring of single populations or subpopulations of targeted anadromous salmonids. At the subbasin scale, several trapping sites may be necessary to effectively monitor targeted species where several populations or subgroups are present. Several factors must be considered when selecting an appropriate site for the monitoring of a discrete population or subpopulation.

Trapping locations should be located downstream of the spawning grounds for the population or sub-population to be monitored. Traps are best located as far down in the watershed as is practical as the distribution of juvenile rearing sites can extend downstream of spawning areas and even include other tributaries (Volkhardt et al. 2007).

Large variations in stream flows can be problematic for downstream migrant trapping and may require selection of alternative trapping sites (Murdoch et al. 2000). Appropriate trapping sites must also have appropriate low flow and high flow trapping positions that can yield appropriate rates of capture in each position. In smaller streams, low flow considerations include selecting sites that can provide sufficient velocities and depths to operate the trap. The specific flows required to operate downstream migrant traps are provided in the Field Methods discussion of trap section. The geomorphic characteristics of the stream channel must also be considered when selecting trapping sites. Stream flows must enter traps in a straight line and pools and other areas with sharp changes in direction and large back eddies should be avoided (Volkhardt et al. 2007).

Sites below hatchery release points should also be avoided if possible to minimize the impact of large influxes of non-target fish on trapping operations, unless trapping programs include hatchery related goals (e.g., evaluating post-release survival of hatchery fish). Additionally, the access and security of the site should be considered. Preferable sites have easy access for daily trapping procedures, secure areas to store equipment and operate live wells (24 hours), vehicle access to install trap and enable the use of boats if needed, and appropriate structures for securing trap in place with cabling.

Sampling Frequency and Timing

An annual sampling frequency will be implemented at status and trend monitoring sites. The timing and duration of sampling at sites will be dictated by the migration timing of the population or sub-population being monitored. Ideally, traps will be operated for 24 hours a day for the entire period of downstream migration. It is acknowledged that many factors in the Upper Columbia can potentially prohibit continual trapping and include: permitting requirements; funding constraints; high flows and debris loads; and the presence of recreational river users. Trapping programs will need to decide how best to meet juvenile trapping goals when constrained by less-than-ideal conditions. For example, where nocturnal migration patterns have been validated, juvenile migrant traps have been operated from dusk to dawn rather than over 24 hour periods (Matt Cooper, USFWS, pers. comm.).

Precision and Detecting Change

To successfully meet status and trend population monitoring objectives, abundance estimates will require sufficient precision. This protocol does not attempt to establish targeted levels of precision for abundance estimates as the desired level of precision will be dictated by the questions the data are intended to inform.

One factor that can influence the precision of abundance estimates is the trap efficiency that is attainable at a trapping location. A review of the results for smolt trapping programs within the Columbia River Basin, which included several species and sizes of juvenile salmonids, indicates that sites that can yield higher trap efficiencies tend to result in more precise abundance estimates (Figure 1). These results also indicate that the various statistical and sampling designs can attain confidence intervals of less than +/- 20% of abundance over a wide range of average annual trap efficiencies (10% to 45%; Figure 1). The two trapping reports included in this review which reported the lowest average annual trap efficiencies (below 2%), failed to yield useful confidence intervals and were not reported.

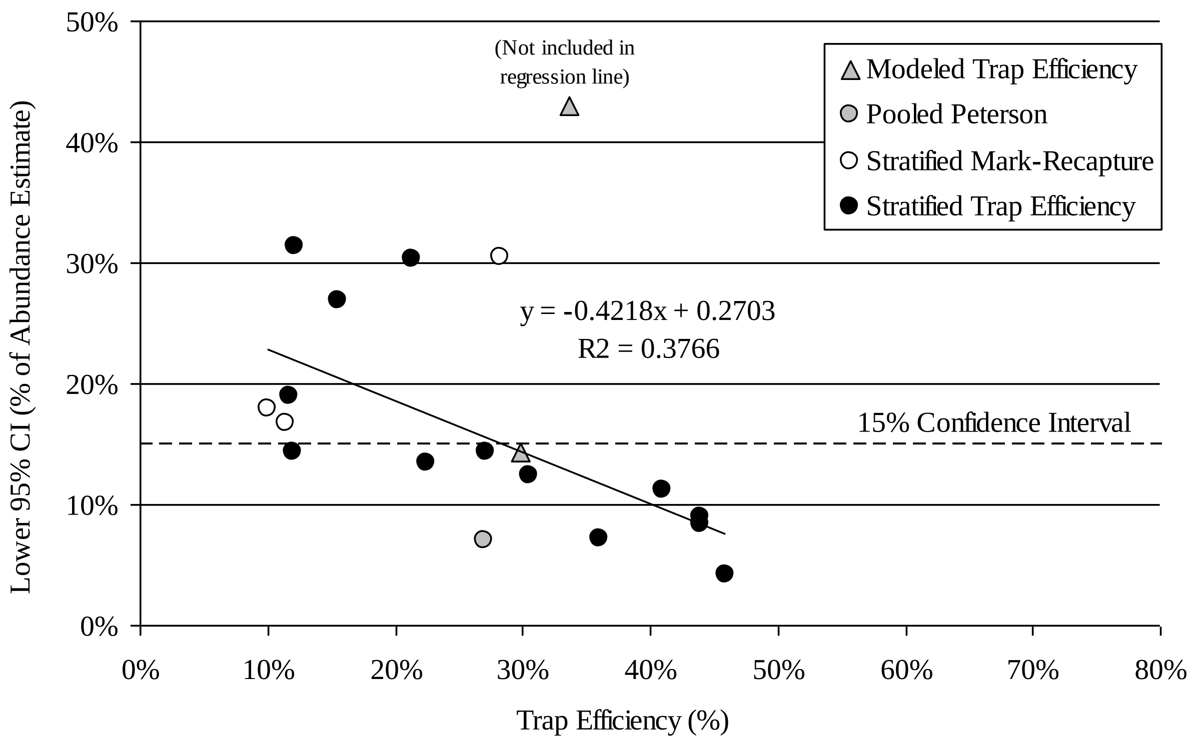

Figure 1. Trap efficiencies and related lower 95% confidence intervals for abundance estimates (% abundance) for downstream migrant trapping programs in the Columbia River Basin. The regression trend line does not include the one outlying Modeled Trap Efficiency data point or traps without reported 95% confidence intervals.

Trap efficiency generally varies greatly over the course of a trapping season. Sites with low trap efficiencies may need improvements in site location or equipment to increase efficiencies in order to successfully meet precision goals. Multiple traps can be potentially be used at sites with low trap efficiencies to increase efficiencies. Sites that cannot meet precision goals may need reevaluation and the consideration of alternative trapping sites.

Section 3: Site Selection

References:

Murdoch et al. (2000); Volkhardt et al. (2007); Rayton (2006)

Equipment:

Maps of spawning distributions for the target species; stream flow records if available; water velocity meter; general field reconnaissance equipment.

Concept:

Selecting appropriate smolt trapping sites will include: the identification of the downstream extent of spawning reaches and migration timing of target species; establishing the full migration period for target species; assessing the variation in stream flow and stream velocities through the migration period; considering channel morphology, identifying areas with appropriate access and security for trapping equipment, and identifying hatchery release locations.

Procedure:

Step 1: Identify the downstream extent of spawning grounds for the population/sub-population to be monitored. At a minimum potential trapping locations will be downstream of this point. Traps are best located as far down in the watershed as is practical. The distribution of juvenile rearing sites can extend downstream of spawning areas and can even include other tributaries (Volkhardt et al. 2007).

Step 2: Use existing data or that from nearby watersheds to establish the full migration period of the species of interest for the given river.

Step 3: Select an appropriate trapping location:

a) Use stream flow records or field observations and the full migration period to evaluate the variations in flow for the given river throughout the migration period. Large variations in stream flows (Murdoch et al. 2000) or insufficient flows within the migration period may require selection of alternative trapping sites.

b) Select potential sites that have that have both appropriate low flow and high flow trapping positions throughout the migration period and that can yield appropriate rates of capture in each position. In smaller streams, low flow considerations include the ability to operate the trap in the stream thalweg that can provide sufficient velocities and depths to operate the trap.

i) Inclined plane scoop traps: water velocities of 1m/sec are appropriate for most species, though steelhead retention may require flows greater than 2m/s (Volkhardt et al. 2007).

ii) Inclined plane Humphrey traps: efficient operating velocities are 1.5 to 2 m/sec with minimum water velocities of 0.9 m/sec (Volkhardt et al. 2007).

iii) Rotary screw traps: sufficient water velocities are 0.8 to 2 m/sec, ideally with a minimum of 5 to 6 rotations per minute (rpm) and a maximum of 13 rpm (Volkhardt et al. 2007).

c) Select potential sites where stream flow is moving at a straight line when entering the trap, avoiding pools and other areas with sharp changes in direction and large back eddies (Volkhardt et al. 2007).

d) Select potential sites that have: easy access for daily trapping procedures; secure areas to store equipment and operate live wells (24 hours); vehicle access to install trap and enable the use of boats if needed; and appropriate structures for securing trap in place with cabling.

e) In general, avoid sites below hatchery release points to reduce unwanted by-catch unless trapping goals include evaluations of post-release survival of hatchery fish or other hatchery related goals.

Section 4: Trap Selection

References:

Volkhardt et al. (2007)

Equipment:

N/A

Concept:

There are several types of trapping equipment that can be used to estimate the abundance of downstream migrating anadromous salmonid smolts. For the larger stream orders that are the focus of this monitoring program, two primary types of traps are used: inclined plane traps and rotary screw traps. Both of these trap designs are efficient at trapping a wide range of stream orders. Fyke net style traps can also be an effective tool to capture smolts in smaller stream orders where flows are insufficient to operate other traps types, though these smaller stream orders are typically not selected for monitoring within this program.

There are a variety of types of inclined plane traps, though they share the same basic design comprised of a screened wedge shaped trap typically supported by a pontoon barge. Inclined plane trap designs include those with stationary screens (scoop traps) and those with traveling screens such as the Humphrey trap (Volkhardt et al. 2007). Those with traveling screens are powered with either a paddle wheel assembly or with an electric motor (12V DC; Volkhardt et al. 2007). Inclined plane traps may also be fitted with trash drums that reduce the impact of debris on the trap and live box. Scoop traps without traveling screens accumulate more debris and require more frequent cleaning than either rotary screw traps or traveling screen traps (Volkhardt et al. 2007).

Sufficient water velocities are required for the proper functioning of inclined plane traps. When using inclined plane scoop traps, water velocities of 1m/sec are appropriate for most species though steelhead retention may require flows greater than 2m/s (Volkhardt et al. 2007). Inclined plane Humphrey traps operate efficiently at velocities of 1.5 to 2 m/sec with minimum water velocities of 0.9 m/sec (Volkhardt et al. 2007). Smaller motorized incline plane traps (e.g., motorized Humphrey trap) can successfully be used in smaller streams that lack the velocity to operate a non-motorized incline plane trap or a rotary screw trap (Volkhardt et al. 2007).

Rotary screw traps are similarly supported with a pontoon barge though the trapping mechanism is a screened cone shaped funnel. The cone rotates in the water column passively powered by water flowing through the trap which interacts with the tapered flights inside the cone causing it to rotate. Screw traps are manufactured with two optional cone diameters, 1.5 m and 2.5 m. Similar to inclined plane traps, captured fish are held in a live well at the downstream end of the trap. Screw traps are generally better suited to larger streams that have sufficient water depths and velocities to operate the trap throughout the migration period (Volkhardt et al. 2007). Rotary screw traps operate efficiently at water velocities of 0.8 to 2 m/sec, ideally with a minimum of 5 to 6 rotations per minute (rpm) and a maximum of 13 rpm (Volkhardt et al. 2007). While rotary screw traps are most commonly passively operated by stream flow, motorized designs (12V DC) have been used in low stream flow applications to ensure minimum rotational velocities can be sustained (Volkhardt et al. 2007).

Inclined plane traps capture smaller fish (<80 mm) at higher rates though the retention of larger fish such as steelhead smolts may require flows greater than 2m/s. Traps with traveling screens and baffles are more efficient at capturing these larger fish than scoop traps, although they are not as efficient as rotary screw traps. Screw traps can more efficiently capture larger migrants such as steelhead smolts due to the design of their flights, though data suggests they are less efficient at capturing smaller (<80 mm) fish possibly due to greater noise generation (Volkhardt et al. 2007).

Procedure:

Step 1: Select a downstream migrant trap well suited to the environmental conditions of monitoring site.

a) Screw traps are generally better suited to larger streams that have sufficient water depths and velocities to operate the trap throughout the migration period (Volkhardt et al. 2007). Rotary screw traps, sufficient water velocities are 0.8 to 2 m/sec, ideally with a minimum of 5 to 6 rotations per minute (rpm) and a maximum of 13 rpm (Volkhardt et al. 2007). Screw traps are manufactured with two optional cone diameters 1.5 m and 2.5 m. The smaller cone size combined with a smaller pontoon barges have successfully been used in smaller streams (Volkhardt et al. 2007). The ability to adjust cone depths on rotary screw traps give some flexibility to accommodate lower flow conditions given sufficient stream flows to meet minimum rotational velocities.

b) Inclined plane traps may be less constrained by shallow water depths because screen depths are adjustable and water velocities of 1m/sec are appropriate for most species (Volkhardt et al. 2007). Efficient operating velocities for Humphrey traps are 1.5 to 2 m/sec with minimum water velocities of 0.9 m/sec (Volkhardt et al. 2007). Scoop traps without traveling screens accumulate more debris and require more frequent cleaning than either rotary screw traps or traveling screen traps (Volkhardt et al. 2007).

Step 2: Consider the size of the species that are the focus of trapping efforts.

a) Screw traps can more efficiently capture larger migrants such as steelhead smolts due to the design of their flights, though data suggests they are less efficient at capturing smaller (<80 mm) fish, possibly due to greater noise generation (Volkhardt et al. 2007).

b) Inclined plane traps capture smaller fish (<80 mm) at higher rates though the retention of larger fish such as steelhead smolts may require flows greater than 2m/s. Traps with traveling screens and baffles are more efficient at capturing these larger fish than scoop traps though are not as efficient as rotary screw traps.

Section 5: Trap Installation

References:

Murdoch et al. (2000); Volkhardt et al. (2007); Rayton (2006)

Equipment:

Trap and pontoon structures, anchor cables, winches, fish processing and survival/mortality trial equipment, staff gauge, safety equipment for recreational river users, weir panels, trash racks, gang planks, boats.

Concept:

N/A

Procedure:

Step 1: Prior to the installation and operation of smolt traps, ensure that the appropriate permits have been obtained including those of federal, state and local agencies. Among others, required permits may include: Section 10 Incidental Take Permits from NOAA Fisheries; Hydraulic Project Approvals from state fish and wildlife agencies; Scientific Collection Permits from state fish and wildlife agencies; Bridge Attachment Permits from state departments of transportation; and Shoreline Exemptions from city or county governments (Rayton 2006).

Step 2: Document the exact trap location using maps, GPS coordinates, site descriptions, and photographs. In general the location of traps should remain the same from year to year unless data analysis indicates a site cannot yield precise estimates of abundance and/or a site proves unsuitable.

Step 3: If the site is not near a permanent gauging station, install a staff gauge at the site to enable the recording of daily stage measurements for all flows that will be encountered.

Step 4: Transport trap to site and assemble if required.

Step 5: Identify appropriate anchoring locations and install appropriate cabling and highlines as dictated by conditions at trap site and trap configuration. Ensure that the cabling configuration is appropriate for the site including safety considerations for potential recreational river users. Identify appropriate low flow and high flow trapping positions and ensure cabling infrastructure is in place to enable the safe and efficient transition from one position to the other.

Step 6: Secure trap in place at the appropriate trapping location. Ensure that cabling and winch configuration allows sufficient manipulation of trap position as river conditions change.

Step 7: Install the protective measures necessary for the safety of recreational river users including: the marking of wires and cabling with bright colored flagging; signage to instruct boaters on safe trap avoidance; flashing lights, and deflectors to prevent trap entry (Rayton 2006).

Step 8: Install any additional trapping equipment required for trap function or access. This may include weir panels, trash racks, gang planks, boats, and cabling or ropes for ferrying boats if applicable.

Step 9: Install a safety cable to the downstream end of the trap. This is commonly attached to the pontoon farthest from the bank where the safety cable is anchored to allow the trap to swing to the bank facing downstream in the event of front cable failure (Volkhardt et al. 2007). Anticipate the method of trap retrieval in the event that the trap relies upon the safety cable configuration (e.g., prior winch installation).

Step 10: Ensure that the trap functions appropriately in the position selected, that stream and rotational velocities are appropriate for the trap equipment used, that stream flow is moving at a straight line into the trap, and that trap noise is not excessive.

Step 11: Assemble and install all necessary equipment required for fish processing, holding fish for anesthetic recovery and handling/marking survival trials. Establish sites and any necessary equipment for upstream and downstream fish releases.

Section 6: Period of Trap Operation

References:

Murdoch et al. (2000); Volkhardt et al. (2007)

Equipment:

N/A

Concept:

Downstream migrant traps should be operated continuously 24 hours per day throughout the entire period of downstream migration to the extent feasible. In some months environmental conditions (e.g., ice) may prohibit the operation of traps throughout the full migration period. Additionally, varying flow regimes, debris loads, recreational river use and funding or permitting constraints can impede continuous trapping goals.

Procedure:

Step 1: Use existing data or that from nearby watersheds to establish the full migration period of the species of interest for the given river. For newly established monitoring sites where the migration period is not well know, the full extent of the migration period should be identified in the first year of trapping.

Step 3: Operate downstream migrant traps continuously (24 hours per day) throughout the period of downstream migration to the extent feasible.

Step 4: Identify two trap locations, one for low flow and one for high flow conditions, in order to successfully operate downstream migrant traps continuously throughout the migration period. The timely and safe transition between these sites can be achieved by anticipating the flow conditions that will be encountered and the prior installation of trapping infrastructure at alternate sites (e.g., trash racks for woody debris).

Step 5: Check traps at a frequency dictated by field conditions.

Section 7: Daily Trap Operation

References:

Murdoch et al. (2000); Volkhardt et al. (2007); Rayton (2006)

Equipment:

Equipment to clean trap of debris (e.g., pressure washer, brushes); stopwatch; holding containers for fish captured; portable aerators; staff gauge (established at start of field season), and a turbidimeter, secchi disk or a turbidity data logger as needed.

Concept:

Traps should be checked at a frequency dictated by field conditions, e.g., once per day when the numbers of captured fish are low, minimal daytime migration is occuring, and the capture of piscivorous fish is infrequent, or during periods of very low migration, checking traps every other day may be sufficient. Traps should be checked as frequently as necessary to address debris loading and rain on snow events, spring snowmelt, and late autumn leaf fall. The U.S. Fish and Wildlife Service and Washington Department of Fish and Wildlife smolt trap programs utilize a night shift schedule with hourly scheduled live-box checks to minimize fish stress and mortality during these time periods.

The daily monitoring of stream attributes will include temperature, river stage, discharge and possibly turbidity. Estimating total migrant abundance with a modeled trap efficiency design relies on the daily monitoring of stream attributes such as discharge or stage, and turbidity. Stage data is useful for both establishing relationships between river flows and trap efficiencies, and more generally to inform trapping operations of changes in flows. Where established U.S. Geological Service or Washington Department of Ecology gauging stations are adjacent to or near trap locations, these sites can provide reliable flow data often taken at numerous intervals throughout the day over the course of trapping season and may improve modeled trap efficiency to flow relationships. When trapping operations are not near permanent gauging stations, daily river stage can be recorded with a staff gauge installed at the site at the start of the trapping season. If turbidity is used as a variable in trap efficiency relationships, this measurement should be taken daily at the trap location. Measurements can be made with a turbidimeter, secchi disk or a turbidity data logger.

Personnel Requirements and Training

Each monitoring agency is responsible for training the personnel who will be running the traps, carrying out the capture, handling and PIT tagging of the fish, and loading the data into P3 and uploading the data to an ATM and to PTAGIS.

Procedure:

Step 1: Check traps at a frequency dictated by field conditions. Create a new data collection event in the database for each day, each trap visit, or if there is a change in crew, field conditions, or trap operation. For example, if the trap is not fishing for more than 30 minutes within a given day, create three distinct data collection events - one for the time before the trap was stopped, one for the time the trap was stopped, and one for the time after the trap restarted. For each data collection event, record the start and end time for trap operation. The start time is typically the end time from the previous event; however, each event must have the start and end time recorded independently.

a) For newly established sites traps should be checked twice per day (dawn and dusk) to determine the extent of migration during the day (Murdoch et al. 2000).

b) At a minimum, trapping periods should be stratified to coincide with differences in capture rates (Volkhardt et al. 2007). At sites where significant migration occurs during the day, traps should be checked twice per day. As the probability of capture can vary during daylight hours through increased trap avoidance, having day/night stratified data can enable better estimates of abundance for periods when the trap is not operating.

c) Traps can be checked once per day or possibly once every two days when the numbers of captured fish are low, minimal daytime migration is occurring, and the capture of piscivorous fish is infrequent. Permitting requirements may have additional constraints.

d) Traps should be checked twice per day or more frequently if the numbers of fish captured are high and could exceed the capacity of the trap live well or the efficient and timely processing of the fish captured.

e) Consider the presence of larger piscivorous fish when establishing the frequency of trap visits as increased predation can occur in the trap live well during periods when piscivorous fish are migrating.

f) Traps should be checked as frequently as necessary to address debris loading (leaf litter, algae, woody debris, ice and snow) that can impact trap functionality or increase smolt mortality. Rain on snow events, spring snowmelt, and late autumn leaf fall can inhibit trap functionality through increased debris loads.

Step 2: Estimating total migrant abundance with a modeled trap efficiency design relies on the daily monitoring of stream attributes such as discharge or stage, and turbidity.

a) Record river stage daily at the staff gauge if one was installed at the site. Trap operations can use stage data that is useful for both establishing relationships between river flows and trap efficiencies, and more generally to inform trapping operations of changes in flows.

b) Where turbidity is used as a variable in trap efficiency relationships it should be measured daily at the trap location. Measurements can be made with a turbidimeter, secchi disk or a turbidity data logger.

Step 3: When using a rotary screw trap daily measurements should be taken to ensure the rotational velocity of the trap cone is operating within the desired range. If a hubometer is in use record the reading and the time. Rotational velocities (rpm) can be estimated by the number of revolutions over several minutes with aid of a stopwatch. If a hubometer is in use it can be used to record the total revolutions for the time period. Where a hubometers is not installed a discriminating mark can be made on the outside of the cone and revolutions counted over the time period. Record on trapping data sheets the rpm results.

Step 4: Record the time when the trap ceases fishing and the time when the trap resumes fishing. Minimize down time in which the trap is not fishing if the trap must be stopped for cleaning or retrieving fish from the live well.

Step 5: Clean the trap and live well of accumulated organic debris at each site visit.

Step 6: Inspect the trap to ensure it is functioning properly and has not been damaged and record the trap status.

Step 7: Record trap position (e.g., high/low flow position). In general, for a given trapping location (e.g., low flow position) avoid moving the trap or making weir modifications that cause undocumented changes in trap efficiency. If stream flow velocity is insufficient for trap performance or trap efficiencies are poor this will warrant trapping modification. These modifications should be made without violating the established statistical methods. Record the date and time when trap or weir modifications are made and a description of the changes.

Step 8: Transfer fish from the trap live well to a holding container for enumeration, measuring length and weight, DNA samples, and marking if an efficiency trial is necessary.

Section 8: Daily Fish Handling

References:

Murdoch et al. (2000); Volkhardt et al. (2007); Rayton (2006); Terraqua (2008);

Equipment:

Dip nets, buckets, anesthetic and trays, scale, measuring board, live boxes for holding and recovery, PIT tag scanner, thermometer, portable aerators, table salt, and ice packs.

Concept:

Daily fish handling procedures include the identification and enumeration of fish, fish measurements needed, the recording of marks and tags and water temperatures and should follow the protocols outlined in “A Field Manual of Scientific Protocols for the Capture, Handling, and Tagging of Wild Salmonids in the Upper Columbia River Basin using Passive Integrated Transponder (PIT) Tags within the Upper Columbia Monitoring Strategy” (Terraqua 2008).

Procedure:

Step 1: Record the time at which the trap is checked as the trapping end time. Record the time the live box was previously empty as the trapping start time.

Step 2: Record water temperatures and the time fish are processed for each site visit. Additionally, if fish handling permits have maximum water temperatures thresholds, water temperatures may need to be monitored throughout the processing period at times where thresholds could be exceeded.

Step 3: Place fish of the target species retrieved from the trap live well in an anesthetic bath (MS-222, 50-60 mg/l, Appendix C), identified to species and life stage, and enumerated (Murdoch et al. 2000). MS-222 can acidify water and this is remedied by the addition of sodium bicarbonate (Baking Soda) to buffer the anesthetic solution. Anesthetic does not need to be applied if it is possible to correctly enumerate and identify fish without it. The addition of non-iodized salt (NaCl @ 1 tbls/gal.) or PolyAqua (1 tsp/5 gal) to holding containers and the addition of ice packs when water temperatures exceed 12°C can help reduce fish handling stress. Dissolved oxygen and pH should be monitored if a water quality problem is suspected. Morphology based life stage categories for non-anadromous fish include fry, juvenile, and adult; anadromous species include fry, parr, transitional (often referred to as pre-smolt), and smolt (Murdoch et al. 2000). Morphology based life stages for anadromous species can be identified by: fry having a fork length less than 50mm, parr having clear distinct parr marks, transitional fish having fading parr marks, and smolts having a silvery appearance, frequently with a black band on the posterior edge of the caudal fin (Murdoch et al. 2000). Anesthetized fish should be allowed time to fully recover prior to downstream release. Fish not subjected to anesthetic can be released immediately downstream of the trap.

Step 4: Large fish species (>300 mm) such as steelhead kelts, adult salmon or large residents (e.g., whitefish, suckers) should be enumerated and quickly returned to the stream as most trap operators are only equipped to handle and transport juveniles.

Step 5: Record any fish mortalities relative to the time of their death. Any dead fish in the live box should be identified, enumerated, and recorded as having FishStatus equal to “Dead” and MortalityType equal to “On Arrival”. For any fish that die during handling or marking, record MortalityType as “handling” or “marking” respectively.

Step 6: Examine all fish for trap efficiency trial marks (e.g., fin clips). Marked fish are to be recorded as a recapture, the type and location of mark noted, and measured for fork lengths (to nearest mm) and weights (to nearest 0.1 g). Recaptured marked fish are not to be used for additional efficiency trials and should be released downstream of the trap after they have recovered. Record all injuries.

Step 7: Scan all salmonids regardless of species and origin for the potential presence of PIT tags as per the ISEMP PIT tagging protocol (Terraqua 2008). PIT tag numbers, fork lengths (to nearest mm) and weights (to nearest 0.1 g) will be recorded for all PIT tagged fish. The recording of lengths and weights for PIT tagged fish can be limited to target species where time and/or the abundance of fish is a limitation. Recording lengths and weights for PIT tagged non-ESA fish and incidentals are not required due to trapping needs and constraints. Trapping operations may be counting several thousand fish and do not have sufficient time to run several hundred length and weights on non-target species. Trap operator is responsible for uploading recapture files to PTAGIS at least weekly (Terraqua 2008).

Step 8: Processed fish subjected to anesthetic should be allowed to fully recover and then released downstream of the trap in an area of calm water and a significant distance downstream to avoid unintentional recapture. In order to prevent daily predator interactions, fish release locations should be varied if possible. Fish not subjected to anesthetic can be released immediately after processing. Record the time when fish are released.

Section 9: Daily Fish Measurements

References:

Volkhardt et al. (2007); Murdoch et al. (2000)

Equipment:

Dip nets, buckets, anesthetic and trays, scale, measuring board, live boxes for holding and recovery, PIT tag scanner, thermometer, portable aerators, table salt, and ice packs.

Concept:

N/A

Procedure:

Step 1: A minimum of 30 fish of each target species will be randomly sampled from the daily catch, placed in an anesthetic bath (MS-222, 50-60 mg/l), and measured for fork lengths (to nearest mm) and weights (to nearest 0.1 g). Fish collected and measured for trap efficiency trials can fulfill this objective.

Step 2: Processed fish subjected to anesthetic should be allowed to fully recover and then released downstream of the trap in an area of calm water and a significant distance downstream to avoid unintentional recapture. In order to prevent daily predator interactions, fish release locations should be varied if possible. Fish not subjected to anesthetic can be released immediately after processing. Record the time when fish are released.

Section 10: Trap Efficiency Trials

References:

Volkhardt et al. (2007); Murdoch et al. (2000); Roper and Scarnecchia (2000); Carlson et al. (1998); Steinhorst et al. (2004); Terraqua (2008);

Equipment:

Dip nets, buckets, anesthetic and trays, scale, measuring board, watch, marking equipment, live boxes or aerated tanks for recovery and survival/mark retention trials, appropriate containers to transport fish to release site, and timer activated self-releasing live boxes if used.

Concept:

The frequency of trap efficiency trials are determined by the statistical method used to estimate abundance. Prior to more refined site specific guidance through the analysis of trapping data, this protocol recommends using 100 fish for trap efficiency trials. If trap efficiencies fall below 7% greater numbers will likely be required to keep from introducing bias into trap efficiency estimates. If sufficient numbers of a particular species or life stage are unobtainable, release groups of less than a 100 may be used and subsequently pooled over several trials. Additionally, an abundant surrogate wild species/life stage or hatchery fish may be utilized provided the efficiency of the surrogate to the target species can be validated. Efficiency trials should be stratified by wild/hatchery fish, fish of different size classes and all target species. Fish for efficiency trials will be randomly selected, measured, marked, allowed to recover and released during the time period of their migration (i.e., day/night). Trials will occasionally be performed to estimate tagging and handling survival, and loss of marks.

Standardizing methods used for mark-recapture trap efficiency trials is important for meaningful and comparable estimates of trap efficiency and total abundance of downstream migrants. Protocols should provide guidance on procedural and analytical methods to attain abundance estimates, and must also provide a means to validate the meeting of the statistical assumptions of mark-recapture estimates. Murphy et al. (1996; as cited in Volkhardt et al. 2005) summarized the basic assumptions of the Peterson method that apply to trap efficiency estimates which include: (1) the population is closed; (2) all fish have the same probability of capture in the first sample; (3) the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly; (4) marking does not affect catchability; (5) fish do not lose their marks; and (6) all recaptured marks are recognized.

The frequency of trap efficiency trials are determined by the statistical method used to estimate abundance, which depends upon the characteristics of the stream and population(s) being sampled at a site. The most common mark-recapture statistical designs include: stratified (temporally) mark-recapture, stratifying trap efficiency, and modeling trap efficiency.

Stratified mark-recapture designs estimate the abundance of migrants over short discrete periods of time, or strata (3 to 7 days), in which a trap efficiency trial is paired with a recapture period (Carlson et al. 1998, Volkhardt et al. 2007). There are four alternative approaches that vary in the frequency of trap efficiency trials, frequency of marking fish, and marking requirements.

1. Perform a trap efficiency trial once every 3 to 7 days depending on strata length as dictated by the statistical design (Carlson et al. 1998). If the recapture period is less than the stratum length, a single mark can be used throughout the trapping season.

2. Mark and release fish daily with the same mark for a given stratum. Mark and recapture numbers for the stratum is then pooled to estimate trap efficiency for the period. This

approach can be useful if the numbers of fish captured daily are low and insufficient to perform an efficiency trial with one day's catch.

3. If trap efficiencies are changing rapidly an option may be to shorten stratum length to 1 to 3 days. If the frequency of trials is shorter than the recapture period, different marks will be needed to accurately assign fish to their trial.

4. Perform trap efficiencies daily (i.e., stratum = 1 day) even if recaptured fish from the trap efficiency trial are recaptured over several days (Roper and Scarnecchia (2000). This method requires the use of a different mark each day to identify the specific efficiency trials as recaptures from several daily efficiency trials will overlap.

Stratified Trap Efficiency designs estimate trap efficiencies for a range of discrete conditions such as changes in flow and turbidity, changes in trap position and weir panels, and changes in the size of fish throughout the trapping season (Volkhardt et al. 2007). Strata can be predetermined relative to anticipated changes or established post-season by identifying periods of similar trap efficiency based upon interpretation of efficiency trial results. The frequency of marking and releasing fish for efficiency estimates ranges from 1 to 3 days on average for Columbia River trapping programs, with daily marking being the most common.

Modeled Trap Efficiency designs are used when trap efficiencies have a strong relationship with an environmental variable such as discharge or turbidity. These relationships are estimated with regression and over a wide range of conditions for the environmental variable being used (Volkhardt et al. 2007). Therefore the timing of trap efficiency trials is dependent upon changes in stream conditions and not on a fixed strata length. Efficiency trials should be performed throughout the migration season to capture the greatest possible range of environmental conditions. When stream conditions cause a modification in trapping procedures, such as moving the trap to different positions within the channel cross section (e.g., high/low flow positions) new regression relationships must be established or alternative methods employed to estimate abundance for these periods. The total number of efficiency trials needed to establish a regression model is dependant upon the strength of the relationship between trap efficiency and the environmental variable used. At a minimum the F statistic for the regression should exceed the test statistic by a factor of four or more (Volkhardt et al. 2007, Draper and Smith 1998). For Columbia River trapping programs using the modeled trap efficiency design, efficiency trials are performed on average every two weeks, with an average of 13 trials performed for the season.

For newly established monitoring sites it is recommended that a stratified mark recapture design be implemented along with the collection of environmental data (e.g., stage/discharge). This will provide sufficient data to analyze the specific characteristics of the site and prescribe for subsequent years the most cost effective statistical/sampling design. The daily marking of fish should also be considered even if daily marks are pooled for weekly strata. Roper and Scarnecchia (2000) demonstrate that trap efficiencies on successive days can vary widely even when the numbers of recaptures are high (30-40, age 0+ Chinook salmon). Furthermore, traps at new monitoring sites should be checked twice a day to determine the extent of daytime emigration (Murdoch et al. 2000). If substantial daytime emigration occurs Murdoch et al.

(2000) recommends conducting trap efficiency trials both at night and day. Trap efficiencies can vary for fish migrating at night versus during the day. If substantial daytime migration is occurring and differences in capture probabilities exist, relying solely on nighttime trap efficiency rates could potentially bias abundance estimates.

Protocols should provide guidance on the numbers of fish to be marked for trap efficiency and mark-recaptures activities. Trap efficiencies and numbers of fish caught daily will vary for each monitoring location and throughout the season at the same location. Therefore, establishing a single recommendation of the number of fish to mark for trap efficiency trials is not the most practical. Prior to more refined site specific guidance through the analysis of trapping data, this protocol adopts the recommendations of Murdoch et al. (2000). Murdoch's (2000) smolt production protocol for the Upper Columbia River basin recommends using no less than 100 marked fish for trap efficiency trials. It is important to ensure that the minimum number of recaptured fish is sufficient to keep from introducing bias into trap efficiency estimates. Steinhorst et al. (2004) and Roper and Scarnecchia (2000) suggest a minimum of 7 recaptures are needed to reduce bias in trap efficiency and abundance estimates. While this criterion can be met with 100 marked fish at trap efficiencies exceeding 7%, greater than 100 fish will be needed if trap efficiencies fall below 7%. With increased flows migration rates typically increase and trap efficiencies decrease which may require a greater number of fish to be marked for efficiency trials.

Separate trap efficiency trials should be performed for wild and hatchery fish, fish of different size classes and all target species. Trap efficiencies can vary by rearing history, size and species as the equal probability of capture is a standard statistical assumption for mark-recapture estimates. Probability of capture may also vary within an age class (i.e., 1+, 2+ etc.) if the size distribution within an age class is substantial. Deviations from these recommendations should be justified through formal testing, though it may be beneficial as the justified lumping of age classes can reduce the number of trap efficiency trials required.

The routine testing of the equal probability of capture assumption is straightforward and does not necessarily require the collection of additional data. A Kolmogrov-Smirnov (KS) can be applied to marked and recaptured fish to test for differences in capture probability relative to size within or among age classes (Seber 1982, Thedinga et al. 1994, Carlson et al. 1998). Seber (1982) recommends comparing lengths of recaptured fish with those of the release group that are not recaptured and therefore requires the identification of individual fish. As the individual marking of fish may be costly or prohibitive Carlson et al. (1998) offer two alternatives: 1) measure all fish lengths in the marked group, measure lengths of recaptures and censor identical lengths from the marked sample, or 2) compare the sizes of all marked fish to all recaptured fish, though this modestly violates the assumption of independent samples (Carlson et al. 1998). Mayer et al. (2006) provides a good example of the testing for differences in capture probabilities for aged 1+, 2+ and 3+ steelhead smolts which were justifiably lumped after significant differences were not detected.

For some sites meeting the minimum number of marked fish for a trap efficiency trial is problematic. This is especially valid for steelhead. Often fish are collected and held to increase the numbers for a marked release. However, permit requirements often limit the time fish are held to a maximum of three days. In these situations where the minimum number for a marked release is not achieved a surrogate wild species or hatchery fish is utilized or smaller marked release groups are pooled over several trials and similar trapping conditions to achieve efficiency estimates.

In some cases where wild migrants occur in very low numbers, hatchery fish or other more abundant salmonid species have been used to establish efficiency estimates. Under these circumstances meeting the equal probability of capture assumption is tenuous and should be tested. There may be opportunities to test assumptions of equal catchability during peak migration periods when greater numbers of wild migrants may be caught and used for trap efficiency trials that are paired with trap efficiency trials of hatchery fish.

Fish to be used in trap efficiency trials should be randomly selected, anesthetized, measured, marked, and allowed sufficient time for recovery. The fish must also be flagged in the database as participating in an efficiency trial (set TagType equal to “new efficiency trial”). If only a proportion of the daily catch is used for the trap efficiency trial, ensure that the fish are a random sample (mark recapture assumption) from the entire catch of the targeted size class and species. The potential size selectivity of dip netting fish at random from the live well can be tested by comparing the fork lengths of fish from the efficiency trial sample to the fork lengths of all fish captured of that size class/species for the day. It is preferable to measure all fish participating in trap efficiency trials. Is some case it is not feasible to measure all fish, such as when 1,000 to 2,000 fish are marked. Where the numbers of fish participating in trap efficiency trials prohibits the measurement of all fish, a minimum of 100 fish should be measured for lengths and weights.

Fish for trap efficiency trials should be marked consistent with the requirements of the statistical design being implemented at the site. If PIT tags are used, procedures should conform to those published by PTAGIS and Terraqua (2008) Upper and lower caudal or right and left pelvic fin clips can be used for marking parr and smolt sized fish and marks can be alternated to differentiate between tagged groups on recapture (Murdoch et al. 2000). Fry should be marked with dye (Murdoch et al. 2000). Bismark Brown “Y” dye can be used at a concentration of 0.25 to 0.4 g of powdered dye to 5 gallons (18.93 liters) of water (Rayton 2006; Appendix D). Marked fish should be allowed sufficient time for recovery. Murdoch et al. (2000) recommends allowing fish to recover in a live pen for at least 8 hours prior to transport and upstream release.

The distance of upstream release of marked fish within trap efficiency trials is significant because of the increased potential for mortality or delayed migration, both of which may bias trap efficiency results (Roper and Scarnecchia 2000). After accounting for potential bias in mark recognition, Thedinga et al. (1994) estimated that mortality between two trapping locations, a distance of 17 km was 21% for sockeye salmon smolts. Estimating mortality associated with the distance of upstream releases is typically not an attribute of downstream migrant trapping protocols and therefore must be minimized through appropriate field methods. The minimum distance for releases is that which ensures the random mixing of marked and unmarked fish which is a trap efficiency assumption (Carlson et al. 1998). Thedinga et al. (1994) found that releases 1 km upstream of the trap satisfied that assumption though shorter distances may also be appropriate. Volkhardt et al. (2007) recommend a stream morphology based release distance of two pool/riffle sequences, though no greater than 0.3 km above the trap in small streams. The minimum release distances used by Venditti et al. (2006) were approximately 0.4 km or at least two riffles and one pool above the trap.

In light of the highly variable release distances reviewed, this protocol adopts a general minimum upstream release distance of 1 km consistent with Murdoch et al. (2000) and a maximum release distance of two pool/riffle sequences where this exceeds 1 km. Shorter release distances may be appropriate, especially for trapping operations in smaller streams. Upstream releases may require access to the river through private property and may be limited by bank accessibility. Where access to recommended release sites is limited, alternative release sites will need to be established to the nearest landowner and both river bank accessible site. Often a bridge crossing provides the most practical location for marked release sites under a variety of flow conditions. Additionally, a particular species or life stage may exhibit influence on the distance of the release location. Large yearling Chinook and steelhead smolts often migrate quickly and this combined with their size reduces the likelihood of mortality over the trial interval compared to smaller fry or parr. Smaller species and life stages may need to be released in closer proximity to the trap to minimize travel time and associated mortality. Release sites that vary from the recommendations should be tested for conformity with the following assumptions: 1) migration is not delayed; 2) mortality is not increased, and 3) marked and unmarked fish are randomly mixed.

Marked fish should be released evenly across the width of the river if feasible, or equally along each river bank in calm water (Murdoch et al. 2000, Rayton 2006). Marked fish should also be released during the time strata in which they were captured to reduce predation (Volkhardt et al. 2007). Fish captured overnight should be released after sunset and those captured during the day released after sunrise (Murdoch et al. 2000). If migration occurs primarily at night and traps are not checked at dusk, nighttime releases can be accomplished with the use of timer activated, self-releasing live boxes at the release site (Volkhardt et al. 2007).

Mark or tag loss and tagging and handling mortality can bias trap efficiency and abundance estimates so assumptions of tag retention and survival should routinely be tested in smolt trapping operations. Mark and tag retention cannot be assumed to be 100% especially for those fish marked with ink (e.g., Panjet instrument). Furthermore, when using ink-based marks, mark retention can vary by ink color and fish species. Using a Panjet instrument, Thedinga et al. (1994) found that mark retentions for migrants after 24 hours were 100% for coho and Chinook, 96% for sockeye and 97% for steelhead with blue and black marks having better retention (98-99%) than red marks (90%).

Mortality associated with handling and marking can also exist and can vary by species. Thedinga et al. (1994) found that average handling mortality for Panjet marked fish held 24 hours was 5% for sockeye smolts and 1% for coho, Chinook and steelhead. Most handling mortality (stress induced) typically occurs within 24 hours (Barton et al. 1986, Matthews et al. 1986, as cited in Thedinga et al. 1994). Mortality estimates performed by holding fish over a 24 hour period may be sufficient though Carlson et al. (1998) recommends a minimum of two days.

Estimates of tagging and handling survival, and mark loss should be performed for trap efficiency marked groups at the start and several times throughout the trapping season. These two assumptions can be easily tested with the same group of marked fish prior to their use to estimate trap efficiencies. Fish should be held a minimum of 24 hours in aerated tanks or live wells, recounted and mortalities noted, and marks or tags inspected.

Procedure:

Step 1: Establish the frequency of trap efficiency trials and the marking of fish for the monitoring site. When performing mark-recaptures procedures, note on field dataforms the statistical/sampling design being used, the targeted frequency of efficiency trials, and the begin/end dates for stratum that the efficiency trial represents.

Step 2: Establish the numbers of fish to be marked for trap efficiency and mark-recapture activities.

Step 3: Perform separate trap efficiency trials for wild and hatchery fish, fish of different size classes and all target species.

Step 4: Select and process fish to be used in efficiency trials. Anesthetize, record lengths and weights, mark, and allow sufficient time for recovery.

a) Selecting fish for efficiency trials: If only a proportion of the daily catch is used for the trap efficiency trial, ensure that the fish are a random sample (mark-recapture assumption) from the entire catch of the targeted size class and species. The potential size selectivity of dip netting fish at random from the live well can be tested by comparing the fork lengths of fish from the efficiency trial sample to the fork lengths of all fish captured of that size class/species for the day.

b) Anesthetize fish in a bath of anesthetic (MS-222, 50-60 mg/l, Appendix C) and measure fish lengths and weights. The fork lengths of fish should be measured to the nearest millimeter and weights should be measured to the nearest 0.1 g (Murdoch et al. 2000). Record all newly marked fish used in efficiency trials as “new efficiency trial”. It is preferable to measure all fish participating in trap efficiency trials. Where the numbers of fish participating in trap efficiency trials prohibits the measurement of all fish, a minimum of 100 fish should be measured for length and weight.

c) Mark fish for trap efficiency trials consistent with the requirements of the statistical design being implemented at the site. Record the number of fish marked and any deficiencies in meeting the targeted quantity. If PIT tags are used, procedures should conform to those published by PTAGIS and Terraqua (2008). Upper and lower caudal and/or pelvic fin clips can be used for marking parr and smolt sized fish and marks can be alternated to differentiate between tagged groups on recapture (Murdoch et al. 2000). Fry should be marked with dye (Murdoch et al. 2000). Bismark Brown “Y” dye can be used at a concentration of 0.25 to 0.4 g of powdered dye to 5 gallons of water (Rayton 2006; Appendix D). Record the mark employed and stratum end date if appropriate.

d) Allow marked fish sufficient time for recovery. Allow fish to recover in a live pen for at least 8 hours prior to transport and upstream release (Murdoch et al. 2000). Record the time that fish were released.

Step 6: Release marked fish upstream of the trap at an appropriate distance upstream. This protocol recommends a minimum upstream release distance of 1 km consistent with Murdoch et al. (2000) and a maximum release distance of two pool/riffle sequences above 1km to the nearest available location where both river banks can be accessed in all flow conditions. Shorter release distances may be appropriate, especially for trapping operations in smaller streams or when releasing smaller species and life stages to minimize travel time and associated mortality. Upstream releases may require access to the river through private property and may be limited by bank accessibility. Release sites that vary from the recommendations should be tested for conformity with the following assumptions: 1). migration is not delayed; 2). mortality is not increased, and 3). marked and unmarked fish are randomly mixed. Marked fish should be released evenly across the width of the river if feasible, or equally along each river bank in calm water (Murdoch et al. 2000, Rayton 2006).

Step 7: Release fish during the time strata in which they were captured to reduce predation (Volkhardt et al. 2007). Fish captured overnight should be released after sunset and those captured during the day released after sunrise (Murdoch et al. 2000). If migration occurs primarily at night and traps are not checked at dusk, nighttime releases can be accomplished with the use of timer activated, self-releasing live boxes at the release site (Volkhardt et al. 2007).

Step 8: Perform trials to estimate tagging and handling mortality, and mark loss of trap efficiency marked groups. Assumptions for mark-recapture methods include no increased mortality for marked fish in the efficiency trial and no loss of marks between marking and recapture. These assumptions should be tested at the start and throughout the trapping season for each species, life stage and type of mark utilized. It is recommended that tagging and handling mortality and mark retention trials should occur during the peak emigration period at each life-stage and/or as changes in environmental stressors are expected to exert higher mortality (e.g., as temperatures begin to approach lethal limits). These two assumptions can be easily tested with the same group of marked fish prior to their use to estimate trap efficiencies. Fish should be held a minimum of 24 hours in aerated tanks or live wells, recounted and mortalities noted, and marks or tags inspected. Most handling mortality (stress induced) typically occurs within 24 hours (Barton et al. 1986, Matthews et al. 1986, as cited in Thedinga et al. 1994). Mortality estimates performed by holding fish over a 24 hour period may be sufficient though Carlson et al. (1998) recommends a minimum of two days. If fish die during the holding period, record MortalityType as “tagging”. If fish shed a tag during holding period, flag TagShed as true.

SECTION 11: DATA MANAGEMENT

Data management framework

The ISEMP Data Management effort is designed to develop standardized tools and procedures for the organization, reduction, and communication of monitoring data and methods within ISEMP pilot basins located in the Wenatchee and Entiat subbasins, WA, John Day, OR, and Salmon River, ID. Beginning in 2004, a pilot project has been under development aimed at integrating four primary data management tools: Automated Template Modules (ATMs), the Status Trend and Effectiveness Monitoring Databank (STEM databank), Protocol Editor (PE), and the Aquatic Resources Schema (ARS). The STEM Databank is the central data repository for the ISEMP project. It was developed by the Scientific Data Management Team at NOAA-Fisheries to: (1) accommodate large volumes of data from multiple agencies and projects; (2) summarize data based on how, when, and where data were collected; (3) support a range of analytical methods; (4) develop a web-based data query and retrieval system, and (5) adapt to changing requirements. This fully-normalized database structure allows the incorporation of new attributes or removal of obsolete attributes without modification of the database structure. Data can be summarized in a variety of formats to meet most reporting and analytical requirements.

Successful data management systems require a user interface that is intuitive to the user and that increase the efficiency of the user's workflow. The ATMs are a collection of forms that allow users to enter and view data in a format that is familiar to biologists. Each ATM has forms for entering new data, reviewing existing data, and updating existing data. Additionally, each ATM has a switchboard to help guide the user to the correct forms.

The general layout of the forms includes a header section to display information about the data collection event and a series of tabs that display detailed observational data. The header section describes the general characteristics about when, where, and how the data was collected or observed. The header section always includes the site, the start date and time, and the protocol. Additionally, the header section may include general characteristics about the sampling reach or unit, environmental conditions, weather conditions, water temperature and visibility, presence of fish, and protocol deviations. A series of tabs below the header section display detailed observations that occurred during the data collection event in spreadsheet format. Tabs vary between the different ATMs, but typically include a tab for crew and for equipment.

Data entry forms perform the critical function of validating data at the time of data entry. For categorical attributes, users are only allowed to select from acceptable categories as defined by the protocol. Similarly, values entered for continuous attributes are checked to ensure values are within the expected range. Data entry forms are "protocol aware". The database includes tabular data that specifies details about the protocol. All categorical fields on data entry forms have pull-down lists that limit the values a user can enter for the field. The pull-down lists reference the protocol documentation tables and only display values that are defined for the active protocol. Similarly, for continuous values, the forms check the expected range as defined in the protocol and warn the user if the entered value falls outside of the expected range. Users can choose to modify the value or accept the value as it was entered. The use of "soft" bounds on continuous values is an effective validation strategy for ecological data, where data often follows a normal distribution with long tails as opposite to a discrete distribution common to financial data.

The ATMs also apply an innovative approach to solving the species code issue. Short species code abbreviations are often used by field biologist to speed data recording in the field. However, every agency or program uses a uniquely defined set of species codes that are appropriate for their geographic location and data gathering requirements. When data containing these idiosyncratic species codes are submitted to regional data warehouses, the codes often become meaningless or indecipherable. A simple solution requires field biologist to define their species codes as tabular data in the database. The definition for each species code includes the scientific name, life stage, age class, run, and origin. Scientific name is the only required field and the name must be recognized by a taxonomic authority. Forms in the ATMs allow users to select from the list of defined species codes. When a species code is selected, the forms store all five fields in the data table. This ensures that the definition of the code is never separated from the raw data and facilitates efficient analysis by allowing users to select or aggregate on any one of the five fields that make up a species code.

Protocol Editor is a data dictionary, user-friendly tool for describing the list of all attributes collected by a given protocol that includes a description of the data type, units of measure, number of characters or digits, number of decimal places, and list of acceptable values for all attributes collected by a protocol. Protocol Editor allows the ATM to be calibrated to a given protocol and allows the ATM to ensure consistency between the protocol and the data entered for that protocol. Protocol Editor follows the same rules established by Protocol Manager (a protocol documenting tool being developed by U.S. Bureau of Reclamation). A protocol is defined as a collection of methods, where each method consists of the list of attributes to be recorded by the data collector. The name of attributes is restricted to attributes defined by the ARS; however, users are allowed to create an alias name for the attributes. Metadata entered into Protocol Editor can easy be exported in a tabular format for importing into Protocol Manager.

The ARS is the collection of database tables that store data entered into the ATM forms. The ARS was developed to support agencies within the Columbia River Basin manage, document, and analyze aquatic resources data. The ARS aims to define a standardized data structure for storing and processing water quality, fish abundance, and stream habitat data. The ARS is robust against variations between data collection protocols, supports procedures for increasing data integrity at the time of data entry, and supports proper analysis and summarization of aquatic resources data.

There are multiple observation methods used to document fish abundance – electro-fishing, snorkeling, seining, observation stations, and a variety of traps. Regardless of how the observations are made, all fish observations are stored in the fish table and the observation method is recorded in the data collection event table. Fish can be observed as individuals (potentially including length, weight, sex, activity, etc) or as a count of individuals with similar characteristics (e.g. count by species and size class). Again, both types of observations are stored in the same table, where count is set to "1" if the record represents an individual. Foreign keys allow fish observations to be associated with an electro-fishing pass or a habitat unit within the site. Fish can also have individual tags (e.g. pit and radio), group tags (e.g. code wire tags), or group markings (e.g. fin clip). Tags and markings are all sorted in a single table. A many-to-many relationship exists between tags and fish, such that a fish can have many tags and a tag can belong to many fish. Finally, lookup tables are used to define species codes and fish size class.

Data handling

Data can either be entered directly into PTAGIS P3 software or written into datasheets in the field and later transcribed into P3. Data entry and handling is described in detail in "A Field Manual of Scientific Protocols for the Capture, Handling, and Tagging of Wild Salmonids in the Upper Columbia River Basin using Passive Integrated Transponder (PIT) Tags within the Upper Columbia Monitoring Strategy" (Terraqua 2008). Field practitioners should be careful to avoid transposing errors when writing and entering data, and should be sure that all data are clearly legible. In the case that data is entered into datasheets in the field practitioners should be in the practice of making photocopies of data sheets, and designating a copy as the Master Copy. The Master Copy can be edited by reviewers using red ink who should initialize and date any edits. Future copies of the Master Copy should either be made in color or clearly show these post-survey edits. Step by step procedures for entering smolt trapping and trap efficiency data are described in "A Field Manual of Scientific Protocols for the Capture, Handling, and Tagging of Wild Salmonids in the Upper Columbia River Basin using Passive Integrated Transponder (PIT) Tags within the Upper Columbia Monitoring Strategy" (Terraqua 2008).

Data Archival Procedures

This section is under development by the ISEMP Data Analysis Team and will be included in the next revision of this working version.

Data Analysis

This section is under development by the ISEMP Data Analysis Team and will be included in the next revision of this working version.

Data Reporting

The data collection agencies are responsible for preparing an annual report that will follow the outline below covering the juvenile trapping period:

1. Brief abstract (limit 600 words).

2. Standard introduction provided by ISEMP plus brief description of specific project(s) covered in report.

3. Concise description of project area/map.

4. Description of methods and materials used to perform tasks.

5. Summary of results, including:

    i) number of smolts for populations or sub-groups,

    ii) number of fish caught/tagged,

    i) number of days trap operational,

ii) efficiency trial results for smolt trap,

iii) and brief discussion of results by task (problems encountered, suggestions for future work).

6. If necessary, supplemental electronic copies of summarized field data in spreadsheet or GIS format.

The annual report shall be submitted to the BPA Project Manager/COTR and the ISEMP coordinator. Guidelines for preparing the report can be found at http://www.efw.bpa.gov/Integrated_Fish_and_Wildlife_Program/ReportingGuidelines.pdf. The Upper Columbia Data Steward is responsible for generating an annual report to the Watershed Action Teams, Project Sponsors and monitoring agencies that will include a summary of the juvenile trap operations by tributary and subbasin. Reporting procedures are provided in SOP#10 Data Analysis and Reporting.

Section 12: References

Barton, B. A., B. Schreck, and L. A. Sigismondi. 1986. Multiple acute disturbances evoke cumulative physiological stress responses in juvenile chinook salmon. Transactions of the American Fisheries Society 115:245-251.

Campbell, S. P., A. Clark, L. H. Crampton, A. D. Guerry, L. T. Hatch, P. R. Hosseini, J. J. Lawler, and R. J. O'Connor. 2002. An assessment of monitoring efforts in endangered species recovery plans. Ecological Applications 12: 674–681.

Carlson S.R., L.G. Coggins Jr., and C.O. Swanton. 1998. A Simple Stratified Design for Mark–Recapture Estimation of Salmon Smolt Abundance Alaska Fishery Research Bulletin 5(2):88-102.

Draper, N.R. and H. Smith. 1998. Applied regression analysis, 3rd edition. John Wiley & Sons, Inc.

Hillman, T. W. 2006. Monitoring Strategy for the Upper Columbia Basin; Second draft report. *Prepared for*: Upper Columbia Salmon Recovery Board, Bonneville Power Administration, and National Marine Fisheries Service.

Larsen, D. P., P. R. Kaufmann, T. M. Kincaid, and N. S. Urquhart. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 61: 283-291.

Matthews, G.M., D.L. Parker, S. Achord, and T.E. Ruehle. 1986. Static seawater challenge test to measure relative stress levels in spring Chinook salmon smolts. Transactions of the American Fisheries Society 115: 236-244.

Mayer, K., M. Schuck, S. Wilson, and B. Johnson. 2006. Assess salmonids in the Asotin Creek watershed: 2005 Annual report. Prepared for the U.S. Department of Energy, Bonneville Power Administration. 37 pp.

McClure, M. M., E. E. Holmes, B. L. Sanderson, and C. E. Jordan. 2002. A large-scale, multispecies status assessment: Anadromous salmonids in the Columbia River Basin. Ecological Applications 13: 964-989.

Morris, W. F, P. L. Bloch, B. R. Hudgens, L. C. Moyle, and J. R. Stinchcombe, 2002. Population viability analysis in endangered species recovery plans: past use and future improvements. Ecological Applications, 12: 708–712.

Murdoch, A., K. Petersen, T. Miller, M. Tonseth, and T. Randolph. 2000. Freshwater production and emigration of juvenile spring chinook salmon from the Chiwawa River in 1998. Report No. SS99-05, Washington Department of Fish and Wildlife, Olympia, WA.

Murphy, M.L., J.F. Thedinga, and J.J. Pella. 1996. Bootstrap confidence intervals for trap efficiency estimates of migrating fish. National marine Fisheries Service, Juneau, AK.

Peitz, D.G., S.G. Fancy, L.P. Thomas, and B Witcher. 2002. Bird monitoring protocol for Agate Fossil Beds National Monument, Nebraska and Tallgrass Prairie National Preserve, Kansas. Prairie Cluster Prototype Monitoring Program, National Park Service, U.S. Department of the Interior.

Rayton, M. D. 2006. Field Manual: Okanogan basin monitoring and evaluation program rotary screw trap protocols. Colville Confederated Tribes.

Roper, B.B., and D.L. Scarnecchia. 2000. Key strategies for estimating population sizes of emigrating salmon smolts with a single trap. Rivers 7(2):77-88.

Schaller, H. A., C. E., Petrosky, and O. P. Langness. 1999. Contrasting patterns of productivity and survival rates for stream-type chinook salmon (*Oncorhynchus tshawytscha*) populations of the Snake and Columbia Rivers. Canadian Journal of Fisheries and Aquatic Sciences 56: 1031–1045.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Charles Griffin and Company, London.

Seiler, D., G. Volkhardt, P. Topping, L. Fleischer, T. Miller, S. Schonning, D. Rawding, M. Groesbeck, R. Woodard, and S. Hawkins. 2004. 2003 Juvenile Salmonid Production Evaluation Report: Green River, Wenatchee River, and Cedar Creek. Washington Department of Fish and Wildlife, 90 pp.

Steinhorst, K., Y. Wu, B. Dennis, and P. Kline. 2004. Confidence Intervals for Fish Out-Migration Estimates Using Stratified Trap Efficiency Methods. Journal of Agricultural, Biological, and Environmental Statistics 9(3):284–299

Tear, T. H., J. M. Scott, P. H. Hayward, and B. Griffith. 1995. Recovery plans and the endangered species act: are criticisms supported by data? Conservation Biology 9: 182-195.

Terraqua. 2008. A Field Manual of Scientific Protocols for the Capture, Handling and Tagging of Wild Salmonids in the Upper Columbia River Basin using Passive Integrated Transponders (PIT) Tags: 2008 Working Version. Compiled by Terraqua Inc, Wauconda, WA, *for* Bonneville Power Administration's Integrated Status and Effectiveness Monitoring Program.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. 14:837-851.

Terraqua. 2008. A Field Manual of Scientific Protocols for the Capture, Handling and Tagging of Wild Salmonids in the Upper Columbia River Basin using Passive Integrated Transponders (PIT) Tags: 2008 Working Version. Compiled by Terraqua Inc, Wauconda, WA, *for* Bonneville Power Administration's Integrated Status and Effectiveness Monitoring Program.

Venditti, D. A., A. Kohler, C. Bretz, N. Brindza, J. Lockhart, A. Brimmer, and K. A. Apperson. 2006. Idaho Supplementation Studies Brood Year 2003 Cooperative Report: August 1, 2003 – July 31, 2005. Prepared for U.S. Department of Energy, Bonneville Power Administration. 65 pp.

Volkhardt, G.C., S.L. Johnson, B. Miller, T.E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane traps. Pages 235-266 *in* D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Volkhardt, G., P. Topping, L. Fleischer, T. Miller, S. Schonning, D. Rawding and M. Groesbeck. 2005. Juvenile Salmonid Production Evaluation Report Green River, Wenatchee River, and Cedar Creek. Prepared for the Washington Salmon Recovery Funding Board. 106 pp.

Appendix A: Attribute Table

This section is under development by the ISEMP Data Management Team and will be included in the next revision of this working version.

Appendix B: Datasheets

This section is under development by the ISEMP staff and will be included in the next revision of this working version.

Appendix C: Application of MS-222

This section will be included in the next revision of this working version.

Appendix D: Application of Bismarck Brown “Y” Dye

This section will be included in the next revision of this working version.

Appendix E: Protocol Revision Log

As new information becomes available and juvenile trapping efforts are refined, the protocol will be revised. Effectively tracking past and current protocol versions are important for data summaries and analyses that utilize data collected under different protocol versions. Protocol Editor will house previous and current protocol versions and the dates of their implementation. Reviews will be performed for all proposed changes to the protocol and the Upper Columbia Data Steward notified so the version number can be recorded in the project metadata and any necessary changes can be made to database structure (Peitz et al. 2002). Consistent with the recommendations of Oakley et al. (2003) this protocol includes a log of its revision history. The revision history log (adapted from Peitz et al. 2002) will track the protocol version number, revision dates, changes made, the rationale for the changes, and the author that made the changes. Revisions or additions to existing methods will be reviewed by ISEMP staff prior to implementation. Major revisions such as a complete change in methods will necessitate a broader review by outside technical experts. When the protocol warrants significant changes the protocol version and date on the title page should be updated to reflect the new version. Version numbers should increase incrementally by hundredths (e.g., Version 1.01, 1.02 etc.) for minor changes and by the next whole number (e.g., version 2.0, 3.0 etc.) for major changes (Peitz et al. 2002).

PROTOCOL REVISION HISTORY LOG

Previous Version #	New Version #	Revision Date	Author	Changes Made	Reason for Change

(adapted from Peitz et al. 2002)