**Workshop Proceedings Report**

**Smolt Survival Estimation:**
**Issues of Interest to Investigators and Managers**

**18 April, 2003**

## 1.0 Introduction

In the Columbia-Snake river System, Federal fishery agencies Mid-Columbia public utility districts (PUDs) regularly conduct a variety of mark-recapture survival studies to evaluate impacts of river conditions and hydro-plant operations on migrating smolts. Over the last decade new miniaturized electronic tags and a variety of experimental designs have been used to estimate smolt survival. The result has been the generation of large set of survival estimates as reported by different research agencies and firms. Fishery managers have at times questioned which types of estimates are most appropriate for particular applications. The federal Studies Review Work Group (SRWG) and PUDs convened this workshop with the purpose of clarifying the strengths and limitations associated with different experimental approaches. To accomplish this they invited a select group of investigators and fishery managers to participate the workshop.

This workshop focused on four specific types of smolt survival estimates including, project (reservoir & dam), dam, reservoir, and passage route (spillway, powerhouse, etc). Also of interest were investigations that compare survival under different operations or passage facility configurations. System survival estimates, those that extend over long river segments spanning several dams and reservoirs, were not emphasized as a topic. That topic is being addressed by the federal Research Monitoring and Evaluation Work Group that is addressing needs identified in the NMFS 2000 FCRPS Biological Opinion.

Tag systems covered in the workshop include those prominently used in the Columbia Basin and were restricted to PIT, radio, and acoustic tags. Balloon tags were not addressed in this forum, since their applications and interpretation of the data generated were clear to the sponsors of the workshop.

For this workshop investigators were asked to focus their information by addressing specific topics and questions posed by the steering committee, provide examples from their research relevant to the questions, and offer a rationale for any conclusions they may offer. The format of the workshop was an interactive exchange between the audience and a panel. There were no formal presentations by panel members. The audience was a mixture of fishery managers and investigators involved in smolt passage issues. Panel members included Steve Smith (NOAA), Chuck Peven (Chelan PUD), John Skalski (UW), Stuart Hammond (Grant PUD), Shane Bickford (Douglas PUD), and Tim Counihan (USGS). At the start of each session the topic was introduced by the moderator and a series of questions presented to the panel for their responses and

perspectives. Attendees (Appendix A) then shared their observations or directed more specific questions to the panel members.

The goal of this workshop is to provide the fishery managers with a clearer understanding about what experimental methods are suitable for estimating smolt survival for different management needs or decisions. Also, the managers sought to determine if it is practical to establish general guidelines or standards for selecting appropriate mark-recapture tools and experimental designs to generate certain types of survival estimates. To address these issues the steering committee identified specific topics they wanted discussed. Those topics generally defined the sessions of the workshop, although overlap was inevitable. This proceedings report is organized according to those general topics. The flow of the report generally follows the sequence of discussions as they occurred.

## 2.0 Sources and Extent of Bias

- Are there any inherent sources of bias associated with particular mark-recapture tools and/or experimental designs?
- To what extent might experimental protocols affect study results, but still be informative enough to make sound decisions regarding the population at large?
- To what extent do release protocols or locations affect estimates in terms of bias or precision?
    - Do hose releases, forebay releases, or release timing (often systematic), consistently result in bias or an unacceptable level of uncertainty or imprecision? Under what applications are such approaches satisfactory?

Where and how experimental groups of tagged fish are released is an important feature in the design of survival studies. A common protocol is the generic paired-release method, where a treatment group is released at the upstream terminus of the zone of interest, and a reference or control group is released at a downstream site bounding the response zone. Most of the survival studies discussed in the workshop employ variants of this generic method. The alternative approach is the single release strategy, which omits the control release. This method is commonly applied for generating inriver survival estimates through extended reaches, such as the entire Lower Snake or Lower Columbia River.

The session started of with Steve Smith providing an overview of PIT-tag based survival estimates as pertaining to this topic. Panel members followed this lead and provided observations, which were augmented by comments from other attendees. Following is a distillation of those discussions.

There are two broad classes of release protocols that can be used to estimate smolt passage survival, those involving the release of a single experimental group and those where a paired treatment and control releases are made. Following is the discussion of those as pertaining to the topic posed to the panel.

### 2.1 Single Release Models- PIT Tags

Since 1993, NMFS and other research groups have been developing and refining procedures for estimating smolt survival associated with passage through the FCRPS. One approach for estimating survival past one or more reservoir and dam pool complexes relies on releasing PIT-tagged index groups upstream from the reach of interest. Using the Jolly-Seber-Cormack model, survival of these marked groups is estimated. The expanse of the reach over which survival can be estimated is largely dictated by the locations of PIT tag detectors in the Snake and Columbia rivers.

PIT tag detectors are situated in smolt bypass systems incorporated in power houses at some dams. As such, only the fraction of the smolt population entering the powerhouse and guided (by screens) into the bypass can be interrogated. If the bypass is selective for a particular segment of the smolt population, there is concern that the resultant survival estimates may reflect the response of only that class of smolts that are guided, rather than the population at large. NMFS investigators noted that smaller smolts of certain species appear to be intercepted and guided more readily by diversion screens in turbine intakes. Also, there is information indicating that yearling chinook smolts further advanced in the state of physiological development are guided more readily than less smolted counterparts. In either case, the selective process could weight the resultant estimates to represent smolts with those attributes. This is a concern if either size or degree of smolt development affects passage survival.

Unlike the PIT detection systems, properly designed radio and acoustic tag detection systems sample the entire tagged population arriving at a dam. As a consequence, certain constraints associated with the potential selectivity of the screens and thus PIT sampling systems are alleviated.

Regardless of the type of tag employed (PIT, radio or acoustic), the survival estimates generated using the single release model reflect all effects, not just passage-related impacts. For example, if the health or general condition of the tagged groups are poor, survival observed during migration past dams may be lower than if estimated using a healthy or robust population. Certainly across years or among hatchery or wild populations we would expect differences in fish vitality or condition, which no doubt contribute to the observed variability in survival estimates. Also, any tagging related effects will be expressed as component of the mortality expressed through the river zone being monitored. This is of particular concern for radio and acoustic tags, which involve surgical or gastric implantation

## 2.2 Paired Release Models

Any of the processes as described with the single release model can influence the magnitude of survival estimated. To alleviate this problem, investigators regularly employ a paired release protocol for estimating survival through a river segment. Under this design, the response zone is blocked by releasing a treatment group at the head of the reach, and a control (reference) group at the terminus of the reach of interest. As long as the two groups are not spatially-temporally spaced too far apart, key model assumptions are not violated and the survival estimates are sound.

### 2.2.1 Project Survival Estimates

Based on years of experience with different electronic tags and assorted species, the community of investigators recommends that one pool and dam complex (a project) is the appropriate scale for such designs. Often control release can lag treatment groups by 1-3 days depending on the length of the project. Site- or species-specific conditions may alter this rule, but in general it provides a sound guideline in most cases where the intent is to estimate smolt survival past a single hydroelectric project. Conducting studies on this spatial and temporal scale ensures that both treatment and control groups traverse the common reach en route to the detector systems during about the same timeframe, thus encountering similar conditions. Extending the time or distance between treatment and control releases, increases the probability that the groups will encounter the control zone during different timeframes and may encounter different conditions. This could affect the survival estimate.

To consistently produce sound project survival estimates, two or more separate sampling sites should be established downstream from the response zone (dam and pool) of interest. This recommendation holds, regardless of the type of tag employed. Thus far, PIT, radio, and acoustic tags have all been used successfully to estimate project survival. By convention the PIT-based survival estimates have always been considered the "gold standard". As radio tags and then acoustic tags came into use for survival studies, investigators conducted comparative parallel survival studies matching PIT tags against the active types.

These comparative studies have yielded similar project survival estimates when certain conditions are adequately satisfied. First, the groups tagged with different devices need to use fish from the same source and of similar condition. Also, the experiments must be synchronized in both temporal and spatial aspects, i.e., groups tagged with active or passive tags should be released at the same time and place. Such studies conducted by NMFS and Chelan PUD have shown that survival estimates from PIT and radio or acoustic tags are similar, typically within a few percentage points of each other (cite Chelan & NMFS studies). However, investigators for Grant PUD noted that in some cases where the condition of PIT tagged and radio tagged fish were not comparable and of different quality, the survival estimates did not comport well (Appendix B). In part this may be associated with expression of some delayed effects that surface later in the migration and could be detected with PIT tags, since the detection systems are many kilometers downstream from the treatment zone.

There are other concerns regarding the use of PIT versus either active tag. PIT tags are inherently longer-lived (years), compared to either radio or acoustic tags (a few weeks). Consequently, PIT tagged fish can be observed longer and further in their migration and have the capacity to reflect any delayed effects (if they exists) that may be expressed later in the migration. However, several years of studies conducted at RI have revealed that delayed effects are not apparent, because PIT-based and radio/acoustic-based survival

estimates have consistently been similar. PIT tagged fish in those experiments migrated several hundred kilometers to the furthest PIT detectors in place at Bonneville Dam. Even over that extended a distance, delayed effects were not apparent.

In summary, when using any of the three electronic tags, paired release protocols can provide unbiased estimates of smolt survival through a project (dam and reservoir combined). Tags will yield similar survival estimates when the same populations are used across tag types. There are also performance characteristics of each tag that can affect study designs, as discussed in a following session.

### 2.2.2 Dam and Reservoir Survival

Effects incurred while migrating through a hydroelectric project can be blocked into one of two zones: those associated with mechanisms within the reservoir (e.g. predation), or those incurred while passing the dam structure. Knowing which zone is responsible for how much mortality would assist managers in formulating and targeting effective mitigation actions. For example, if reservoir mortality explains most of the smolt loss, then predator control may receive increased emphasis. Whereas high mortality at the dam would suggest passage improvements are in order. For these reasons there has been considerable effort directed at separately estimating reservoir and dam survival of smolts.

Considerable effort has been directed at developing experimental protocols, which separately estimate reservoir and dam survival. Overall, these efforts have yielded mixed results and interpretations. For several years, Chelan County PUD has explored a variety of designs using radio and acoustic tags to separately estimate dam and pool survival at Rock Island Dam. The experimental and analytical approaches they examined included; a variant of the paired release where treatment groups are liberated across the forebay, "virtual releases" (described later herein) and an analytical approach that estimates pool and dam survival components from a paired release-project survival estimate.

Consistently, in the mid-Columbia smolt passage survival past the dam was been overestimated. In most cases this bias was obvious, because dam survival was near or exceeded 100%. This is clearly unreasonable, because there have been a number of independent studies indicating that survival through turbines was below that.

The virtual release design is unique in that a transect (acoustic or telemetry) is established within a few hundred yards of the dam. Tagged smolts released upstream that are detected at this transect constitute an experimental group for estimating survival from that transect past the dam to another control release site established in the tailrace. This approach was attempted in 2002 at Rock Island using acoustic tags. The resultant estimate of dam survival did not align with project survival estimates generated with either acoustic or PIT tags. So, the approach has been abandoned at this time for Chelan PUD studies.

At Wanapum and Priest Rapids dams, attempts to estimate dam survival alone have produced estimates that vary considerably from year to year. At Wanapum they observed

inconsistency among estimates across years and questioned the reliability of the estimation methods (Appendix B). Investigators believe that variable fish quality used in the studies may account for some of the observed variability. Most of their efforts have focused on forebay releases of radio tagged smolts. They will be experimenting with moving the release site further upstream in 2003. In contrast, at Priest Rapids Dam, dam survival estimates generated with radio tags has been consistent regardless of the forebay release site selected.

Investigators from USGS describe a different experience. They reported that they have provided separate estimates of dam survival, and they believe the estimates to be generally representative. Those studies have been staged at dams in the lower Columbia and employ radio telemetry techniques.

In general, the consensus at the workshop was that as yet, no one has devised a method that consistently produces reliable independent estimates of pool and dam survival throughout the basin. Bias or high variability among estimates are commonly observed in the mid-Columbia studies, whereas USGS investigators report sound dam survival estimates at the lower-Columbia projects.

### 2.2.3 Route-specific Survival Estimates

Two approaches have been employed to estimate the survival through individual passage routes at dams (turbine, sluiceway, spillway, and bypass systems). One relies on radio tagged fish arriving at the dam (from releases well upstream) and distributing themselves naturally across the dam and through different routes. The other method involves intentionally discharging fish (often balloon tags, but radio-tagged fish as well) into a passage route via hose. Both approaches incorporate control releases liberated in the tailrace.

Natural arrival distribution- Chelan PUD has sponsored a series of survival studies at Rock Island Dam in recent years. Some of the radio tag studies produced survival estimates for smolts passing through the spillway and powerhouses. The technique used tagged fish that were released well upstream at the tailrace of Rocky Reach Dam to generate a project survival estimate. Controls were released below Rock Island Dam. Upon arrival at Rock Island Dam the population naturally distributed across and selected passage routes. Radio tagged fish detected passing each route became the treatment group for the route-specific survival estimate. This type of design then yielded two types of estimates, project and route-specific. However, precision attending the passage route estimates was poor in some cases. This was particularly evident for fish passing Powerhouse I. Little water and thus few fish were discharged through that route during the study. As a consequence sample sizes for that route's survival estimate were small inflating the variance. All route-specific survival estimates will have poorer precision that the accompanying project survival estimates. PIT tags are not suitable for this type of study since passage routes can not be documented. The approach has not been tried using acoustic tags.

Hose releases- The tag most commonly deployed via hose is the balloon tag. This workshop did not focus on balloon tag information, since inferences are generally well understood. However, there are general lessons that have relevance to other tags discharged through hoses.

1. Survival estimates are sensitive to release location within the passage route.
2. Estimates are suitable as survival indices, not measures of total effects.
3. Comparing relative survival between several configuration of the same passage route is the most appropriate application, e.g. between two types of turbines.
4. Comparisons across passage routes may be inadvisable given the sensitivity of the estimates to release location, and receiving water conditions, e.g. velocity differential between discharge hose and water in the passage route.

NMFS investigators have used hose releases to deliver both radio-and PIT-tagged smolts into a variety of passage routes at a number of dams. Using different tags enabled them to examine both acute and longer term effects. The noted that the two techniques often generated survival estimates that did not comport. They emphasized that hose delivery systems need to be identical for each tag type, which can be difficult to accomplish. These observations emphasize the principle that relative rather than absolute survival estimates may be more appropriate for estimates generated using hose release methods.

However, the NMFS experience at Ice Harbor Dam yielded a different picture. In that study both types of tags were released across all open spill bays at the dam, using a similar delivery device. In this application the resultant PIT- and radio-based spillway survival estimates were very similar. This suggests that if releases are distributed broadly across a passage route, representative estimates of smolt survival may be obtained that may reflect total effects.

From these discussions the moderator distilled some general guidelines for generating representative survival estimates through projects, reservoirs, past dams and through passage routes.

1. To estimate smolt passage survival through a reservoir and dam (project), the paired release method is preferred. Control groups should be liberated somewhere in the tailrace, the specific location dictated by the geographic bounds of the evaluation zone as defined in the proposal.
2. No reliable method has yet been identified for accurately estimating smolt survival separately either through a reservoir, or at a dam alone.
3. Survival (total effects) through individual passage routes can be reliably estimated using the arrival distribution method with active tags. However, precision associated with each passage route survival estimate varies with the proportion of the population passing that route.
4. For characterizing passage route survival, hose releases with tailrace controls may be suitable for evaluating bypass systems and spillways, but only if spatial coverage across the passage route is thorough.

5. Turbine survival estimates are sensitive to the location fish are released within the turbine intake. Thus evaluations involving the release of fish directly into an intake can be useful for comparing the relative performance among turbines or operating conditions. But the estimates are not useful in quantifying the total effects associated with turbine passage.
6. Targeted hose releases can be useful for focusing on localized effects within the turbine. However, indirect effects incurred in the tailrace can not be adequately represented using controls released at a single location below a dam.
7. Investigators must explicitly specify the nature of the survival estimates they report with respect to whether they constitute relative or absolute estimates. This is a global requirement that spans all types of survival experiments, not just hose release protocols.

Consistently executing Item 7 will help ensure that managers who are charged with tracking performance of different passage strategies can select the most appropriate estimates for use in their assessments.

## 3.0 Performance of Electronic Tags

- To what extent does tag life limit the use of active tags for generating certain survival estimates?
- In what situations should radio tags be surgically or gastrically implanted, and why?
- At what point, or under what circumstances can we dispense with the perceived need to conduct side-by-side comparisons, of PIT versus active tags? Are we there?
- Does the new generation of miniaturized radio tag or acoustic tag offer new opportunities for obtaining certain types of survival estimates?

For active tags (radio and acoustic) the distance and associated elapsed time between release and detection at the sampling sites is limited by tag life. Ideally, tags will remain active throughout the time required for the slowest fish to clear all of the detection sites. Practically, this does not always occur. A population of active tags possesses a unique tag activity expectancy curve. That tag-life curve can be determined by documenting the actual tag life in a laboratory setting. Typically, 30 to 50 tags have been used to construct a performance curve for a population of tags used in a study. Analysts have devised ways to adjust mark-recapture data using such curves.

As indicated in the previous section of this report, the general consensus of attendees was that for spring-migrating species, the zone over which survival is estimated should not be greater than one project (pool and dam). Based on the collective experience of investigators, experimental groups typically clear a project and associated downstream interrogation stations in less than 10-14 days, often considerably so. This has been shown to be adequate in terms of tag life for most electronic active tags employed to date.

There is an associated concern involving time at liberty, USGS and NMFS investigators have observed that beyond about two weeks, surgically implanted radio tags can alter certain behaviors and potentially compromise performance of the host fish. This effect could result in some tag-induced mortality beyond the base line mortality expressed by smolts during migration. The result is that smolt passage survival would be biased low. However, as both radio and acoustic tags are further miniaturized, tag effects may be diminished to a point they are inconsequential over the entire operating life of the tags. These new micro tags (.75-.85 gm) are just starting to be used in formal smolt studies in 2004.

NMFS investigators noted that there is evidence that piscivorous birds may be targeting and preying on radio tagged smolts at rates higher than expected. They referred to studies by OSU biologists that indicated that 12-18% of radio-tagged smolts released in the lower Columbia were consumed by terns. In contrast, during that same period only about 2% of PIT-tagged counterparts were estimated to be consumed by terns. These data are suggestive but not definitive, since radio tags may be easier to detect and retrieve than the smaller PIT tags.

### 3.1 Gastric Versus Surgical Implantation

The previous discussion sets the stage for addressing preferred implantation techniques. Radio-tags can be implanted either gastrically (inserted through the esophagus to the stomach with the antenna trailing out the mouth) or surgically, placed in the body cavity through incisions in the ventral body wall. Acoustic tags have only been implanted surgically.

NMFS investigators described survival differences in smolts that were PIT-tagged or radio-tagged either gastrically or surgically. Based on their observations they recommend that radio tags are only suitable for short-term survival studies (project-scale), whereas PIT-tags can be used in long term studies. Although not discussed in the workshop, in cases where survival studies extend through adult return, it has been observed that PIT tags can be shed when fish near the time of spawning. Depending on the objectives of such investigations, independent estimates of tag shedding rates may be warranted.

USGS investigators extensively use miniaturized radio tags in project survival studies involving smolts. Over the years they have switched from surgical to gastric implantation of radio tags for such studies. They find the tagging procedures are faster and less subject to tagger-specific effects than surgical procedures. However, there is concern that tag regurgitation can be pronounced with the use of increasingly smaller devices. The larger, more bulky sized miniaturized radio tags lodge more securely in the smolt stomach, preventing most regurgitation. If regurgitation during migration is excessive, the associated reduction in sample size can compromise precision. To offset this, tagging more fish may be required, increasing study cost. Investigators must assess this trade-off using independent estimates of tag regurgitation.

Issues regarding tag effects on host survival, or tag loss due to regurgitation, malfunction or shedding are of principle concern when using single release mark-recapture models. In these cases, smolt mortality will be overestimated. In contrast, the use of paired release protocols can minimize or eliminate such bias in a properly designed study.

There is no antenna projecting from the host when acoustic tags are employed. This reduces drag and potential effects on swimming capability. Also, the presence of an antenna may act as an attractor for certain predators and using acoustic tags avoids this risk. These advantages would favor the selection of acoustic tags if a single release model was being considered. Paired release models should compensate for any unique tag effects associated with radio tag antennas. This has been confirmed in studies where head to head comparisons of survival estimates using different tags have been conducted. For example, at Rock Island Dam in different year's radio and acoustic tag based project survival estimates were compared to PIT tag based estimates. In both comparisons, survival estimates based on the different tags comported well (Appendix C).

In summary, either implantation technique can be adopted. There are tradeoffs associated with the approach selected, but neither tagging method appears to compromise project survival estimates generated with a paired release model.

## 3.2 New Generation of Electronic Tags – Opportunities

### 3.2.1 Radio Tags

Lotek has recently released a new version of miniaturized radio transmitters referred to as nano-tags. USGS has been using these tags in some of their investigations and is pleased with the performance. Compared to the previous generation device, the nano-tag: has a lower battery drain post assembly, is longer-lived during application, has models that are smaller (to 0.80 gm), and provides more unique codes per channel. Advantages include the ability to tag smaller fish (approaching 100 mm), and increase number of unique codes at liberty. This degree of miniaturization will enable investigators to readily tag subyearling chinook and sockeye. This will lay the foundation for pursuing survival studies using those species. However, adequate field testing of this new generation of tags will be required.

As an aside, there was informal hallway discussion that the federal government was going to restrict its agencies in using certain radio frequencies in future years. It appears that the frequency range currently used by USGS will be banned for use by that agency. This will require them to shift to a new frequency. We did not have time to discuss the implications of this to future research, but we highlight it here for further consideration. Apparently, this restriction only applies to federal agencies, and other entities will be permitted access to the frequencies currently in use.

### 3.2.2 Acoustic Tags

In recent years Chelan PUD has been exploring the feasibility of using this device to estimate smolt survival. Results from two years of testing are positive. The manufacturer of the device (HTI) is continuing to make advances in further miniaturization. A 1.0 gm package is now available and a prototype 0.75 gm device is undergoing laboratory and field tests. If successful, this will permit the tagging of subyearling chinook and sockeye down to near 90mm in length. As with the new radio tag devices, this will open the door to survival studies using those species. However, adequate field testing of this new generation of tags will be required.

### 3.3 Side-By-Side Comparisons

Over the last decade, reach and project survival estimates obtained using PIT tags have been considered the standard performance measure in the Snake-Columbia River system. PIT tags are often preferred for this use because the tags remain viable throughout extended migration (up to several years). Also, the interrogation system for smolts extends over hundreds of kilometers, enabling detection of some potential delayed effects, where present. Thus, associated smolt survival estimates are considered to reflect the majority of effects over extended periods in the smolt migration.

However, there are limitations attending the PIT technology. To acquire the precision desired by fisheries managers, it is often necessary to tag tens or hundreds of thousands of individuals for each stock of interest. Often times, smolts in these numbers are not available, or there is reluctance to handle and tag such a large fraction of available run-of-river or hatchery stocks. The range in sample sizes is in part dictated by the absence of PIT detection systems in the upper arm of the Columbia River. For this reason studies stage in those geographic locations require the largest sample sizes. Furthermore, survival estimates for Snake River stocks typically exhibit poor precision through lower Columbia hydroelectric projects; because in–river mortality and transport removals can reduce tag recovery rates through that lower river segment.

These limitations have prompted investigators to evaluate the feasibility of using both radio and acoustic tags for project survival estimates at certain sites, particularly in the upper and lower Columbia. These feasibility studies typically require head-to-head comparisons of survival estimates produced with PIT and the active tags. If estimates are comparable, then active tags can be adopted as a tool in that application. These experiments are expensive, and parties funding such investigations want to know when the decision to adopt the active tag can be made.

NMFS investigators present at the workshop noted that the smolt survival estimates for single projects using PIT and radio tags comport well, in their experience. But, they like using both tags for cross-validation and diagnostic purposes. Even so, they admit that cost concerns and logistic difficulties in properly executing parallel studies constrain indefinite use of the dual tag studies in the future. The NMFS fishery managers stated that they rely on the research branch opinion regarding when it is appropriate to adopt one tool of the other. No decisions were made on this point during the workshop, nor were clear criteria cited.

Investigators conducting survival studies for Grant PUD expressed how difficult it is to properly conduct truly parallel studies using PIT versus radio tags. Ensuring that fish in the two groups are of similar condition and health, and that they were treated similarly during holding and through release has proved challenging. Cases at Grant (Appendix B) and Douglas counties were cited as examples where estimates did not comport well NMFS investigators then reinforced the need to keep all aspects of such side-by-side studies similar, including fish source/stock composition, and fish handling, holding, and release protocols.

Chelan County PUD staff reported that in their experience, both radio tags and acoustic tags have consistently produced project survival estimates that comport well (± 2%) with PIT- based estimates (Appendix C). They attribute this consistency to elaborate measures they implement to ensure uniformity in fish stock selection, handling, holding and transport procedures.

It was suggested that perhaps NMFS biologists should draft a white paper comparing PIT, radio and acoustic tag technologies for applications in smolt survival studies. Topic matter should cover tag performance and effects on host. Later the panel suggested a broader group might take on this task. It was noted that the paper Tom Cooney wrote and appended to the Mid-Columbia Habitat Conservation Plan could provide a good model, and be updated to include more recent information. The guidelines section of this report expounds on this point.

**4.0 Representing a Population**

- In what cases does the selection of fish according to size or condition compromise the utility of certain survival estimates (absolute vs. relative survival), or misrepresent the population-at-large?
- Do all species need to be evaluated at every site? If so, why?

In cases where absolute estimates of survival are required (e.g. mid-Columbia HCP), it is necessary to ensure that the group of fish selected for the study represent the population at large. Until recently, only larger members in the smolt population could be tagged with miniaturized radio and acoustic tags, whereas PIT tags can be implanted in virtually any sized smolt. To what extent has the need to select larger fish skewed results? Analysts have attempted to assess this by calculating survival estimates for different size classes within experimental groups. Analysts at the University of Washington are conducting such assessments and will be reporting results in upcoming research reports. The comparisons are performed by examining hypotheses *a posteriori*, using however many fish fell into assigned size classes. In such situations the confidence intervals can be broad making it difficult to detect true differences in survival related to size, if it exists.

Another related issue involves the practice of selecting healthy fish as candidates for tagging, rather than a random sample from the population-at-large. There was no clear consensus on this point. One argument contends that there is no effect in a paired release

design if treatment and control groups are selected using the same criteria. In contrast, using a random sample from the population at hand could reflect some sensitivity that previously compromised fish have to passage at dams. Although we might be able to make some indirect inference from existing studies, the attendees generally felt that a series of empirical studies should be designed to resolve this matter directly. USGS investigators thought that it would be tractable to design studies that could document any impacts associated with the selection of experimental fish.

To acquire a more complete view of hydropower effects, monitoring fish through to adult return can be instructive. NMFS analysts emphasized that only PIT tags provide this perspective. This feature enables investigators to estimate a variety of population level indicators including SAR and potentially survival of adults during upstream passage. These considerations could play into the initial selection of the tag type, in addition to the primary objectives of the study.

In light of these discussions, attendees generally agreed that investigators need to be explicit in describing selection criteria and how fish selected for tagging fit in the context of the population at large. More directly, these points should be made in the proposal so any limitations regarding inferences can be evaluated prior to authorizing the study.

Is it necessary to conduct survival studies using every species or ESU migrating past a project? Until now, size limitations associated with radio and acoustic tags systems have restricted such applications for subyearling chinook and sockeye. These smaller fish have not been able to accommodate the readily available larger size model of active tags. Now opportunities exist with the recent addition of tags as small as 0.75 gm. Still, tag life is often sacrificed with further miniaturization, presenting a new variable for consideration in trying to estimate survival of slower-migrating ocean-type chinook.

Since hydro operating conditions generally target spring or summer migrants, rather than individual species, is it necessary to study all species? Perhaps a single spring-migrating species could suffice to help optimize hydro operations for smolt survival. If this were the case, then fishery managers said they would focus on the most sensitive species as the appropriate indicator. This could present a dilemma. If species listed as threatened or endangered are deemed most sensitive, then in the upper Columbia steelhead and spring chinook should receive attention, whereas the unlisted sockeye might be de-emphasized. But sockeye could be more sensitive to passage effects at dams, as evidenced by their higher descaling and injury rates. The Mid-Columbia HCP committee uses a unique strategy to balance this dilemma at Rocky Reach Dam in 2002 and 2003. They have prescribed two different spring operating periods, which are triggered by the passage patterns of sockeye. Once the sockeye migration begins to surge at the dam, the spill fraction is increased until they pass the project. Then the standard spring operations are resumed. Further refinement or alteration of this strategy depends on results obtained using a complex of survival and FPE studies to be conducted over the next few years.

Both USGS and NMFS investigators have observed and documented differences in project survival for steelhead and yearling chinook. If the objective is to obtain absolute

estimates of survival for use in modeling or compliance with performance standards, then both species will need to be evaluated. If the objective is to estimate relative survival under different operations or configurations, then using perhaps either species is adequate. Several attendees identified the need to conduct a meta-analysis of yearling chinook and steelhead survival estimates. Reviewing the assorted estimates obtained over the last decade, using a variety of tags and populations could be very instructive.

## 5.0 Standards & Guidelines

- Is it practical to establish standard protocols for conducting the various types of smolt passage survival studies discussed in this workshop? For example, is it practical to establish standard release strategies/locations to produce specific types of survival estimates at all dams?

A number of attendees felt there is a need and perhaps an opportunity to develop a guidelines document that provides direction on some key aspects of study design and execution. NMFS investigators felt researchers could do this, and the document could be updated periodically as our experience and knowledge base increased. In particular, criteria for selection of experimental fish and handling and holding protocols might be standardized for certain types of studies.

The consensus was that PIT tag protocols and procedures are well-established, but in general, the workshop attendees felt there may be some opportunities to establish some guidelines for the design and execution of survival studies using active tags (radio and acoustic). The designation of criteria and conditions for the conduct of certain types of studies would be helpful. The document should cover items like; selection criteria for fish size and condition, conditions that may affect interpretation of estimates, etc. For example, Grant PUD investigators felt survival estimates were compromised in 2001 when flows were extremely low, and smolts migrated slowly. As a result tag expiration confounded estimates.

The goals and objectives of survival studies dictate study designs, including the adherence to any particular sets of guidelines. When objectives are unclear of even obscure, it is difficult to design an experiment that will be satisfactory. Researchers stated that objectives are often poorly stated in the RFPs, which can contribute to poorly crafted proposals. Objectives need to be explicit and clear in RFPs and reiterated in proposals to ensure expectations of managers and investigators are the same. This will expedite the development of a sound study.

There may be broader regional context for individual survival studies. For example, project-specific estimates may have application in regional monitoring and evaluation efforts. Research, monitoring and evaluation plans involving hydroelectric effects are being drafted by the federal agencies under the 2000 NMFS FCRPS BO, and forums like the NPCC Fish and Wildlife Program. In general, those planning efforts rely on a complex of survival studies that have been established in recent years. Once again, PIT-

based estimates afford the ability to monitor survival through adult return, an aspect that may be useful in the broader regional assessments.

In an effort to expedite the drafting of guidelines for the use of active tags in survival studies, it was proposed that a standardization team composed of the panel members, be established. Peven volunteered to chair the effort in its initial stages.

## 6.0 Key Points & Next Steps

*Project survival*-To estimate smolt passage survival through a reservoir and dam (project), any of the three electronic tags (PIT, radio or acoustic), when used in paired release protocols can provide unbiased estimates of smolt survival. Tags can yield similar survival estimates when experimental fish are taken from the same populations and are of similar condition. Control groups should be liberated somewhere in the tailrace, the specific location dictated by the geographic bounds of the evaluation zone as defined in the proposal.

*Reservoir or dam survival*- As yet, no reliable method has been devised to consistently and accurately yield absolute estimates of smolt survival through a pool or past a dam at all sites across the basin. Telemetry has been the preferred tool. Experience varies across research teams, with Mid-Columbia studies producing biased or highly variable results, while investigators in the Lower-Columbia report no such characteristics.

*Route-specific survival*- Absolute survival (total effects) through individual passage routes can be reliably estimated using the arrival distribution method with radio tags. Acoustic tags may have similar capabilities, but this has not yet been demonstrated. However, precision associated with each passage route survival estimate varies with the proportion of the population passing a particular route. Error bounds are often broad. To improve precision would require substantially increasing the number of experimental fish.

Treatment fish released from hoses with tailrace controls may be suitable for characterizing absolute survival associated with passage through bypass systems and spillways. But treatment fish must be thoroughly distributed across the entire passage route, and control fish liberated throughout the area below the route where treatment fish exit.

Turbine survival estimates are sensitive to the location fish are released within the turbine intake. Thus evaluations involving the release of fish directly into an intake can be useful for comparing the relative performance among turbines or operating conditions. But the estimates are not useful in quantifying the total effects or absolute survival associated with turbine passage.

Targeted hose releases can be useful for focusing on localized effects within a turbine. However, indirect effects incurred in the tailrace can not be adequately represented using controls released at a single location below a dam.

Managers will expect that investigators explicitly specify the nature of the survival estimates they generate and report, i.e., relative or absolute. This should be clearly and prominently stated in both the proposals and reports. This is a global requirement that spans all types of survival experiments. This will enable managers to better determine which estimates in the literature are appropriate for specific applications.

The newest smaller types of miniaturized radio and acoustic tags now permits smaller species like sockeye and subyearling Chinook to be used in certain survival studies.

Tag effects on the survival of the host, or tag loss due to regurgitation, malfunction or shedding are of principle concern when using single release mark-recapture models. In these cases, smolt mortality will be overestimated. In contrast, the use of paired release protocols can eliminate such bias in a properly designed study.

Selecting experimental fish of certain condition or size may skew some types of survival estimates. Although paired release models should neutralize most effects, larger fish may endure passage impacts differently than smaller counterparts. Investigators thought that it would be tractable to design studies that could document any impacts associated with the selection of experimental fish. Attendees endorsed such an effort.

*White paper*- It was suggested that perhaps NMFS biologists should draft a white paper comparing PIT, radio and acoustic tag technologies for applications in smolt survival studies. Topic matter should cover tag performance and effects on host. Later the panel suggested a broader group like themselves might take on this task. It is not clear that a formal assignment was given. The COE may approach some investigators to accomplish this task in a timely fashion.

*Guidelines document*- Attendees identified a need to develop a guidelines document that provides direction on some key aspects of study design and execution. Investigators should conduct this effort. The document should be updated periodically as the knowledge base increases. In particular, criteria for selection of experimental fish and handling and holding protocols might be standardized for certain types of studies. This document could be a separate product or part of the white paper. Chuck Peven agreed to chair this effort using the panel as a resource.

*Meta-analysis*- Given the plethora of survival studies that have been conducted and estimates reported in the last decade, attendees identified the need to conduct a meta-analysis of yearling chinook and steelhead survival estimates. A review and distillation of the assorted estimates that have used a variety of tags and populations could be very instructive. This task will be substantial. No party was identified as the analyst.

# Appendix A.

# Agenda & Attendees at the 18 April, 2003 Survival Workshop

**Workshop Agenda**

**Smolt Survival Estimation:**
**Issues of interest to investigators and managers**

**18 April, 2003**
**Duncan Plaza, Training Room**
**Portland Oregon**

**Panel format:** The entire panel will address each issue in sequence. Panel members are asked to expound on the initial questions presented here, but be prepared to field additional questions from participants, during each session.

9:00 Introduction

9:15 Session I – Sources and extent of bias

- Are there any inherent sources of bias associated with particular mark-recapture tools and/or experimental designs?
- To what extent might experimental protocols affect study results, but still be informative enough to make sound decisions regarding the population at large?

10:15 Session II- Release strategies

- To what extent do release protocols/locations affect estimates in terms of bias or precision?
  - Do hose releases, forebay releases, or release timing (often systematic), consistently result in bias or an unacceptable level of uncertainty or imprecision? Under what applications are such approaches satisfactory?

11:15 Break

11:30 Session III- Performance of electronic tags

- To what extent does tag life limit the use of active tags for generating certain survival estimates?
- In what situations should radio tags be surgically or gastrically implanted, and why?

- At what point, or under what circumstances can we dispense with the perceived need to conduct side-by-side comparisons, of PIT versus active tags? Are we there?
- Does the new generation of miniaturized radio tag or acoustic tag offer new opportunities for obtaining certain types of survival estimates?

12:30 Lunch

1:30 Session IV- Representing a population. What is acceptable?
- In what cases does the selection of fish according to size or condition compromise the utility of certain survival estimates (absolute vs. relative survival), or misrepresent the population-at-large?
- Do all species need to be evaluated at every site? If so, why?

2:30 Break

2:45 Session V- Can we establish standards or guidelines for conducting certain types of survival studies?
- For example, is it practical to establish standard release strategies/locations to produce specific types of survival estimates at all dams?

4:00 Adjourn

**Attendees:**

Steve Smith, NOAA, panel
John Skalski, UW, panel
Tim Counihan, USGS, panel
Chuck Peven, Chelan PUD, panel
Stuart Hammond, Grant PUD, panel
Shane Bickford, Douglas PUD, panel
Al Giorgi, BioAnalysts, moderator
Gary Fredricks, NOAA
Dave Robichaud, LGL
Karl English, LGL
Steve Haeseker, USFWS
Cliff Pereira, COE contractor
Shane Scott, WDFW
Rod Woodin, WDFW
Kim Fodea, BPA
Andrew Grassell, Chelan PUD
Brad Eppard, NOAA
Eric Hockersmith, NOAA
John Beeman, USGS
Russell Perry, USGS

Mark Smith, COE
Tom Berggren, FPC
Jerry McCann, FPC
Margaret Filardo, FPC
Catherine Morello, R2 Resources
Marvin Shutters, COE
David Clugston, COE
Rock Peters, COE
Mike Langeslay, COE
Ritchie Graves, NOAA
Steve Rainey, NOAA
Tom Lorz, CRITFC

# Appendix B.

# Submittal from LGL ltd, investigators for Grant County PUD

## Radio-telemetric assessment of project, dam, reservoir and passage-route survival of juvenile salmonids:

## Response to Workshop Questions

Prepared by

Dave Robichaud and Karl English

For

Public Utility District No. 2 of Grant County

### Are there any inherent sources of bias associated with particular mark-recapture tools and/or experimental designs?

When the paired release model (Burnham et al., 1987) is used, survival estimates are unbiased. For example, this model was used to estimate survival through the Wanapum project (e.g., English et al., 2001a). Fish were released in the Rock Island tailrace, and were paired with fish released in the Wanapum tailrace. Survival of the two groups was measured at downstream detection sites. Since the two groups were handled identically (except only for release location), any difference in their survival rates could be attributed to passage through the Wanapum project. As a result, the project survival estimates were unbiased (because any tagging or handling stress affects both groups equally and is therefore factored out of the analysis) using the paired design.

It should be noted that radio-telemetry techniques give us the opportunity to partition the project survival into two components, reservoir and dam survival, without further releases of fish. Using telemetry receivers, fish released in the Rock Island tailrace could be detected in the Wanapum forebay, hence demonstrating survival through the Wanapum reservoir. Dam survival is estimated as a "new paired-release experiment" in which survival of the upstream group (those detected in the Wanapum forebay) is compared to that of the downstream group (fish released in the Wanapum tailrace), and any difference is attributed to dam passage. With this method, some bias is introduced because the upstream and downstream release groups differ in more than just release location. Specifically, the fish in the upstream group have already been given a chance to recover from tagging and handling procedures, and weaker individuals have been weeded out. As such, the upstream release group will be more fit than the downstream release

group, which will result in an overestimation of dam survival, with a concomitant underestimation of reservoir survival. Note that this type of bias is only an issue in the estimation of *dam* and *reservoir* survival with only one release site above the dam. This type of bias is fairly common in radio or acoustic telemetry studies because high detection efficiencies for these tag types allow for the partitioning of project survival into its dam and reservoir components. This bias is generally not an issue for PIT tag studies where only project survival can be estimated due to the low detection rates or lack of detection of PIT tagged fish at the dam being assessed.

Biases could also come about when the battery-life of the radio-tags is similar to the time required for fish to travel through the study area. If a radio-tag expires before the fish has traveled through the study area, the fish will be considered a mortality. In the paired release model, the upstream release groups have farther to travel before leaving the study area than their downstream pairs, hence they are more likely to be erroneously considered as mortalities. Underestimating survival of the upstream release group results in the underestimation of project survival. Studies are designed with the travel distances and flow rates in mind, and for the most part battery-life of the tags is much greater than the time required to pass through the study area (e.g., Robichaud et al., 2002; 2003). However, when river flows are unexpectedly low (as in English et al., 2001a), insufficient battery-life can bias results. Methods have been developed to account for battery-related tag loss (English et al., 2001a; Cowen and Schwarz, in prep). Note however that in the following year, fish were released at Vantage Bridge instead of the Rock Island tailrace in order to reduce the chance of battery expiration. The plan for 2003 is to release at both Rock Island and Vantage Bridge thus allowing estimation of the survival for the entire reservoir, while simultaneously ensuring sufficient battery-life in the case of another slow-water year. Regardless, tags with greater battery-life are being developed.

Assuming large fish survive better than small ones, size-selective tagging will likely result in a biased estimate of survival. Adams et al. (1998a) suggested that fish under 120 mm not be surgically tagged (tags were about 4.6% of the body weight). Brown et al. (1999) found no adverse effects on fish with tags of 12% body weight. Regardless, the current practice is that tags should not exceed 2% of the body-weight of the fish (based on the suggestion in Winter, 1983). Note also that the very large fish are not typically tagged either. Given that the too-small fish outnumber the too-large ones, juvenile survival estimates are likely overestimated in the typical radio-telemetry study. It is important that authors note in their reports that survival estimates apply only to the portion of the population within the size range on the fish tagged. Where possible, the size distribution of the population should be reported and compared to that of the tagged fish (as in Robichaud et al., 2002). Regardless, smaller tags (with adequate battery-life) are being developed.

A corollary of the size-selective tagging (since wild fish tend to be smaller than hatchery-released individuals, Beamish, 1978; Peake et al., 1997) is that survival estimates are more applicable to hatchery fish than to wild. This bias should only be considered if the management goal is to protect wild fish above and beyond the protection afforded to hatchery fish. Note that PIT-tagging methods, because of the large numbers required, are always conducted on hatchery fish, and can therefore never represent the population-at-large, and can never address survival of a wild endangered fish. Because the numbers

required for radio-tagging techniques are much lower, run-of-river fish can be used, and survival of wild fish can be assessed (especially with the new, smaller tags being developed).
It could be argued that the antenna, which dangles externally from the radio-tagged fish, could make fish more vulnerable to predation. Wanapum dam survival has not been biased by differential predation because that which occurred in the Priest Rapids reservoir has been controlled by the Wanapum tailrace releases. The estimation of Wanapum reservoir survival may be biased because there is only one release group traveling through the reach (i.e., there is no paired control group). A greater predation rate on radio-tagged fish would result in survival underestimation; and the degree to which survival is underestimated would increase with length of reach (or time at large) as a result of the cumulative effects of the differential predation. Differences in survival of PIT-tagged and radio-tagged fish might therefore be detectible in a long reach such as the Wanapum reservoir.
Behavior of fish might also result in biased passage-route-specific survival estimates. For example, if individuals that prefer to swim deep are more likely to pass via the powerhouse, then estimates of powerhouse survival may be underestimated since it would be less likely to detect these individuals at downstream locations (the radio-signals attenuate as they pass through water, hence deep tags are harder to detect than shallow ones).

### What criteria needs to be met before a technology used to estimate survival (like radio-tags) can "stand alone" without having to do side-by-side analysis with PIT-tags?

It is important to note that PIT-tagging studies are not free of bias (e.g., PIT-tagged fish are typically of hatchery origin, do not typically match in size distribution that of the run-of-river population, etc.). For example, survival estimates from a radio-tagging study using nano-tags and run-of-river fish (including the small, likely wild individuals) will probably not match those from a standard PIT-tagging study. Hence the quality of a method should be measured in its ability to reduce bias, not in its ability to match results of a simultaneous PIT-tag study. However, doing side-by-side comparisons with PIT-tag studies *is* important to quantify the differences in the results produced, such that old data (based on PIT-tagging methodology) can be compared to newer studies.
The comparison of PIT-tagged versus radio-tagged *project* survival estimates has been done on a number of occasions. Grant County conducted one such study in 2001 (English et al., 2001a), however the PIT-tagged fish were not treated identically to the radio-tagged fish, hence the comparison was severely biased. For example, pre-release radio-tagged fish were held in a separate facility from their PIT-tagged counterparts (disease levels were different between the groups). Also, radio-tagged fish were gently released into the river from a boat, whereas PIT-tagged fish were dumped from a helicopter. Grant County has plans to conduct a revised comparison study in 2003, for which the only difference between groups will be that some are radio-tagged and others are not.
The estimates of *dam* and *reservoir* survival have not yet been compared to PIT-tag results. Because PIT-tags cannot be detected in the forebay, PIT-based survival estimates cannot be partitioned into dam and reservoir components. The only way to estimate reservoir and dam survival using PIT-tag methods is to release fish into the forebay of the

dam in question. The extra release group at each project would result in a 50% increase in the number of PIT-tagged fish required. Given the number of fish needed for decent precision using PIT-tagging, this method would require an incredibly large number of fish.

The completion of the necessary head-to-head comparisons could be expedited if research efforts were coordinated between the various survival study efforts. The application of similar study designs using similar tag types and species at multiple dams would result in more rapid accumulation of information on the biases and limitations of each method. The time required to approve or reject radio-telemetry as a "stand alone" method could be substantially reduced through the coordination of several parallel PIT tag and radio-tag studies conducted at several different dams and reservoirs within a single year.

### To what extent does tag-life limit the use of active tags for generating certain survival estimates?

The tags that we have used in the recent past (Lotek model MCFT 3GM) had a battery-life of 18 days (English et al., 2001b). That is, the manufacturer expected the overwhelming majority of tags to last at least 18 days, expiry commencing thereafter. Some tags tested before the 2001 Grant County study were still pinging after 28 days (English et al., 2001b). Technological improvements allow the new generation of 3GM tags to have a battery-life of 20 days (Herr, 2003a). Battery-life of these tags can be extended to 29 days by programming the tags to ping once every 5 seconds (instead of every 2.5 seconds). However, dam passage can be a rapid event, therefore we expect that too many fish would be missed if we use the reduced ping rate. Battery-life is improving with developing technology. The new Lotek nano-tags that will be used in 2003 have longer battery-life (for a given sized tag) than the MCFT series (Herr, 2003b). The nano-tags that are the same size as the MCFT 3GM tags will last 30 or 43 days, depending on whether the burst interval is set to 2 or 3 seconds. Thus, we no longer have to limit our studies to areas through which fish can pass in 18 days. The technology is currently available to more than double previous battery-life expectancies.

For the most part, battery-life of the tags is much greater than the time required to pass through a Public Utility District in the mid-Columbia area. For example, in 2000 chinook released at Wells and Rocky Reach were successfully tracked through the Grant County study area (Smith et al., 2000). Problems occur when river flows are unexpectedly low as was the case in 2001 (see English et al., 2001a). In 2001, the fish released at Rock Island took too long to reach the Hanford detection sites to allow for the testing of Burnham et al.'s (1987) model assumptions, however survival through the Wanapum project, pool and reservoir could be adequately assessed since travel times to the Priest Rapids forebay were more reasonable. Regardless, methods have been developed to account for battery-related tag loss (English et al., 2001a; Cowen and Schwarz, in prep).

In 2002, Grant County directed the release of fish at Vantage Bridge instead of the Rock Island tailrace in order to reduce the chance of battery failure. The plan for 2003 is to release at both Rock Island and Vantage Bridge thus allowing estimation of the survival for the entire reservoir, while simultaneously ensuring sufficient battery-life in the case of another slow-water year.

We conclude that for the estimation of any given reservoir, dam, project or route-specific survival, the current battery-life of radio-tags does not limit their usefulness. The use of radio-tags is limited only over very long distances or time scales (e.g., survival to the ocean).

### In what cases does the selection of fish according to size or condition compromise the utility of certain survival estimates (absolute vs. relative survival), or misrepresent the population-at-large?

The size distribution of the tagged fish does not typically match that in the population-at-large. Radio and acoustic tags are not applied to small fish because of the general rule that tags should not exceed 2% of the body-weight of the fish. Very large fish (over 200 mm) are not typically tagged either. Larger fish, having not already moved out to sea, are not tagged because they have no apparent migratory behavior, and are thus not considered part of the population of interest (Bryan Nass[1], pers. comm.). The importance of this issue depends on the magnitude of the differences between the tagged fish and the population-at-large and the degree to which survival varies with fish size. The currently available radio and acoustic tags are suitable for representative tagging of hatchery steelhead and yearling chinook. Smaller tags are required for representative tagging of "wild" chinook and sockeye.

During tagging studies, fish of poor condition are generally not tagged. For example, in 2001 the hatchery fish held at the radio-tagging facility developed severe Bacterial Cold Water Disease (English et al., 2001a). It was believed that the holding conditions were chiefly responsible for the proliferation of the disease, hence the rejection of infected individuals resulted in a population of tagged fish the more closely represented the population-at-large. In 2002, the run-of-river fish caught early in the study period were largely infected with Bacterial Kidney Disease (Robichaud et al., 2003). The disease was attributed to a single hatchery release which resulted in large numbers of infected individuals being caught in the juvenile bypass system (gatewell dipping) until early May. Because the infected fish were released by the hatchery into the river, overall survival of the population-at-large was probably reduced relative to normal (and our results were likely overestimates). However, if we consider this single release to be an anomalous event (other hatchery releases that year were of fish in relatively good health; hatcheries typically try to reduce the incidence of disease), then by not tagging infected individuals, we tagged only the portion of the population-at-large that was typical of normal conditions.

### To what extent do experimental protocols affect our study results represent the population well enough to make sound decisions? For example, to what extent do release methods (e.g., hose release, volitional passage or forebay), release timing (often systematic), or species result in bias?

Release sites must be sufficiently far upstream to avoid dead drift through the project. They must also be sufficiently far to allow volitional passage-route choice upon encounter with the dam. In our experience, 4 km appears to be sufficient. These

[1] Bryan Nass, Senior Scientist, LGL Limited. 3736 Riverbottom Road, Ellensburg, WA. 1-509-962-8294.

considerations are not restricted to radio-tagging, but apply to all methodologies considered at this workshop.
The upstream and downstream release groups (for the paired-release model) must be from the same source, and must be handled identically. Downstream of the lower of the paired release sites, the two release groups must experience identical conditions, hence must travel at the same time and the same rate. If they experience differing conditions, then survival differences between groups cannot be solely attributed to the project.

### What informational needs are there that would ensure that surrogate species can be used to estimate survival?

One can infer survival rates from one (tested) species onto another (untested) species when there is *a priori* knowledge that the two species have similar rates of survival. The two species must be the same size, migrate at the same time (so that they encounter the same predator field), migrate in the same part of the river (so that they experience similar currents), migrate at the same depth (so they encounter the dam at the same place, and are exposed to avian predation at the same rate), have a similar pattern of passage-route use, have similar tailrace behavior, etc. There are no two species in the Columbia that meet all these criteria. For example, sockeye are considerably smaller than chinook or steelhead during migration; and sockeye, steelhead and chinook are thought to travel at different depths.
The use of surrogate species can be justified when empirical data demonstrates that one survival rate can be reliably predicted from another (invariably, the precision around the predicted survival estimates will be much worse than those directly measured). The model development would require head-to-head survival comparisons for several years. A minimum of three survival estimates is required for statistical purposes, but in practice many more will be needed. For example, if one expects flow to have a different effect on steelhead survival than on chinook survival, then it may be necessary to include flow-rate data in the predictive model. As such, head-to-head survival data will need to be collected in several years (each) of low, medium and high flow rates. The collection of the data required to develop such a model would be costly, though not logistically very difficult. As indicated above, collaboration and coordination between the various survival studies on the Columbia and Snake rivers could substantially reduce the amount of time require to accumulate the data need to quantify the relationship between the survival rates for a target species and that of a surrogate species.

### Release sites – where should fish be released at each project for each type of estimate, given the tags and designs you employ?

Release sites must be sufficiently far upstream to avoid dead drift through the project. They must also be sufficiently far to allow volitional passage-route choice upon encounter with the dam. In our experience, 4 km appears to be sufficient. These considerations are not restricted to radio-tagging, but apply to all methodologies considered at this workshop.
Specifically, to measure Wanapum project, pool and reservoir survival, fish should be released in the tailraces of Rock Island and Wanapum dams. To measure Priest Rapids project, pool and reservoir survival, fish should be released in the tailraces of Wanapum and Priest Rapids dams. To measure route-specific survival at Wanapum, sample sizes

should be boosted by releasing fish upstream of the Wanapum forebay, for example at Vantage Bridge. If Rock Island and Vantage Bridge releases are considered in the analysis of Priest Rapids route-specific survival, no other releases are necessary. Otherwise a considerably large number of fish will need to be released upstream of the Priest Rapids forebay (either 4 km upstream or in the Wanapum tailrace, the latter being favored because it would also improve the confidence limits around the Priest Rapids reservoir, dam and project survival estimates).

### In what situations should radio-tags be surgically or gastrically implanted, and why?

Gastric implantation has been shown to be a useful technique for adult salmonids in rivers from California to Alaska (e.g., Eiler et al., 1992; Alexander et al., 1996; Koski et al., 1996) and has been used successfully on the Columbia (e.g., Stuehrenberg et al., 1995; English et al., 2001c, 2002). However for small fish, it has been shown that surgical implantation is superior. Movement of the transmitter antenna caused abrasions at the corner of the mouth in all gastrically tagged juveniles, whereas only 22% of the surgically tagged individuals had inflammation around the antenna exit wound (Adams et al., 1998b). Gastrically tagged fish also exhibited a coughing behavior and appeared to have difficulty retaining swallowed food (Adams et al., 1998b). This could explain why Martinelli et al. (1998) found gastrically tagged fish to have reduced growth and reduced condition relative to surgically tagged fish. Moreover, the swimming ability of gastrically tagged fish deteriorated over time, whereas fish with surgical implants improved (Adams et al., 1998a). Surgical implantation is preferred over gastric tagging for juvenile salmonids in all cases except perhaps for very short-term experiments (a few days).

### Does the new generation of miniaturized radio-tags affect obtaining certain types of survival estimates?

The new generation of miniaturized radio-tags will allow smaller fish to be safely tagged. The model of miniature tag being considered by the Grant County PUD for the 2003 study weighs only 1.65 g (Herr, 2003b), which could be safely implanted in a fish of 82.5 g.

The nano-tags have longer battery-life (for a given sized tag) than the ones we have used in the past (Herr, 2003b). The typical tags we have used (with a burst interval of 2.5 seconds) lasted 18 days. A nano-tag of the same size will last 30 or 43 days, depending on whether the burst interval is set to 2 or 3 seconds. We conclude that studies using nano-tags will have sufficient battery-life for almost all projects under almost any conditions.

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# Appendix C.

# Submittal from Chuck Peven at Chelan County PUD

### Survival Workshop Questions 2003

1. Bias associated with particular mark-recapture methods and/or study design–
    a. Bias has been detected in studies where attempts have been made to estimate pool and dam survival. When using both radio and acoustic tags it has been found that dam survival is often overestimated while pool survival is underestimated. The cause of the bias is related to the area where post-release mortality is expressed. If there is any post release mortality associated with handling or tagging procedures then it will be expressed in and attributed to the pool portion of the estimate. In effect the "weak" fish are weeded out by the time they encounter the forebay arrays causing the dam estimate to be positively biased. This should be a non-issue in the paired release model since the weeding out effect should be expressed at similar levels in each group (Stevenson et al 2000, Skalski et. al 2003).

    b. In 2002, releases in the forebay of Rock Island and the tailrace of Rocky Reach were paired with Rock Island tailrace releases. Dam survival estimates derived from the Rock Island forebay releases were compared to survival estimates generated from the Rocky Reach tailrace releases. The estimates were significantly different. The Rock Island forebay releases also took longer to pass the project then did the fish released in the Rock Reach tailrace. It was also noted that the dam survival estimate, using the Rock Island forebay releases, was lower then both the acoustic and PIT tag Rock Island project survival estimates generated from paired-releases in the Rocky Reach and Rock Island tailraces (Skalski et. al 2003).

2. Criterion that needs to be met for new technologies (acoustic tags) to be accepted in "stand alone" survival studies.
    a. One of the obstacles for accepting acoustic tags in survival studies has been a concern about how representative the size range of the fish that can be tagged are compared to the size range of the population that is migrating. Typically, surgically implanted tags require fish that are on the upper size ranges for fish in a certain population, possibly biasing the results. The last couple of years Chelan has been comparing the survival estimates of acoustic tags and PIT tags to see if there has been a bias. To date, no differences have been seen. A post study analysis was also conducted in 2002 to determine if there was a difference in the survival estimates among different size ranges of the PIT tagged fish. No difference was seen. (Skalski et. al 2003).

b. Another concern in using a larger tag is the biological/behavioral effect that the tag has on a fish it is implanted in. Studies that Chelan has been involved in (either funded or conducted) have included travel time comparisons between PIT and acoustic tags (Steig et. al 2003), and a predator avoidance, swimming performance, and buoyancy compensation study on juvenile chinook salmon that have been surgically implanted with acoustic tags (Anglea et. al 2003). Travel times of the three species studied; juvenile chinook, steelhead, and sockeye; were not significantly different between PIT and acoustic tagged fish. In the second study, for all three tests, no measurable differences were found between tagged and untagged fish.

3. Extent that tag life limits the use of active tags for generating certain survival estimates.
    a. Tag life can become an issue when the tag life is shorter then the time needed for release groups to clear a detection grid. Chelan saw this in its' 2000 study when fish released in the Wells tailrace took too long to pass the RR and RI detection arrays. Survival results were biased low due to "tag death". In that year there was also an issue with tag quality that caused the tags to quit before they were supposed to (Skalski et. al 2001).

4. What informational needs are there that would ensure that surrogate species can be used to estimate survival.
    a. It would be important to know that the two species have similar migration timing and behavior as they reach a project. If these two criteria are met then it would seem plausible that one could act as a surrogate for another when trying to meet survival standards, especially if the one studied is generally thought of as having a lower survival then the other. If the one that survives at a lower rate meets a certain survival estimate then it would seem safe to assume that the other species would do as well or better, at least under normal water conditions for the area encompassed by the study.

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