The Status & Needs of the Columbia Basin PIT Tag Information System as Related to FCRPS BiOp RME Requirements

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1.0 Introduction

This document reviews the status of the Passive Integrated Transponder (PIT) tag detection network, the associated information system, and tagging efforts directed at monitoring performance indices, targets, and standards specified in the National Oceanographic and Atmospheric Administration (NOAA) 2008 Federal Columba River Power System (FCRPS) Biological Opinion (BiOp) and 2010 Adaptive Management Implementation Plan (AMIP). As such, the scope is restricted to anadromous salmonids within the geographic bounds of the FCRPS BiOp. More specifically, the geographic zone includes watersheds situated upstream from Bonneville Dam, and extends downstream from that site to the mouth of the Columbia River.

This document is the product of an FCRPS Action Agency (Bonneville Power Administration, Corps of Engineers, and Bureau of Reclamation) and NOAA Research, Monitoring and Evaluation (RM&E) Workgroup. It neither prescribes, nor prioritizes, specific actions; although, it does identify opportunities and alternatives for improving PIT tag-based information needed to address FCRPS BiOp requirements. Furthermore, it identifies assessments (evaluations) that should be performed in order to select among alternatives.

This document considers non-BiOp needs for PIT tag information as specified in the Fish and Wildlife Program, the Accords, and certain Habitat Conservation Plans. But it does not treat the objectives and issues of those programs in detail, except to the extent they relate to FCRPS BiOp requirements. This document does not address PIT tag monitoring needs in the Willamette River Basin. The BiOp specific to that basin and the associated regional RM&E planning forum will address those matters.

This is primarily a technical document that acknowledges there are finite limits to the number of fish that can be PIT-tagged; and that many legal and policy issues will need to be considered by PIT tag users before any of the alternative actions identified in this document can be implemented. Similarly, some uses of PIT tags (e.g., SAR estimates and hydropower system passage, etc.) are well defined and largely integrated into ongoing monitoring and research programs, while the region-wide vision for other uses of PIT tags (e.g., habitat and hatchery evaluations) are still being formulated.

As these newer programs become better defined (in terms of numbers of fish tagged, release and detection locations, precision of estimates), they are likely to affect ongoing research and monitoring efforts. Because of this, periodic assessments of PIT tag releases (numbers and location), detection sites, research needs and objectives, and interactions among projects, will need to occur in order to maximize the effectiveness and efficiency of the many regional PIT tag studies taking place in the Columbia River Basin.

Passive Integrated Transponder (PIT) tags are used in a broad array of research, monitoring and evaluation (RM&E) projects throughout the Columbia Basin. These projects are funded under a variety of different programs including studies requested or specified under the 2008 FCRPS BiOp, the NPCC Fish and Wildlife Program, the Fish Accords, various Habitat Conservation

Plans, the Corps-sponsored Anadromous Fish Evaluation Program, and state salmon and steelhead recovery efforts. Collectively, these programs use PIT-tagged salmonids in varying degrees to monitor the status of populations, evaluate the effectiveness of management actions, and resolve critical uncertainties under-pinning recovery strategies. As a whole, they also provide a variety of opportunistic evaluations as they migrate through the FCRPS.

In the region, the vast majority of tags are used for studies involving anadromous salmonids, but also to a more limited extent for resident fish species and lamprey. The network of detection sites in the Columbia Basin is vast, with over 150 stations in place. Several management questions and performance tracking needs are specified in the 2008 FCRPS BiOp, which may require altering the tagging effort and/or detection capabilities for juvenile and adult salmon (RM&E Recommendations Report, 2010).

http://www.salmonrecovery.gov/ResearchReportsPublications.aspx

Certain RM&E-related RPAs in the 2008 FCRPS BiOp rely on PIT-tagged fish to provide critical information. One (RPA 52.6) specifically calls for the development of an action plan:

> *"Develop an action plan for conducting hydrosystem status monitoring in ongoing collaboration with the State and Federal fishery agencies and Tribes. This will be done in coordination with status monitoring needs and strategies being developed for estuary/ocean, habitat, hatcheries, and harvest."*

The Action Agencies and NOAA consider the upcoming Implementation Plan to serve as this action plan.

The PIT tag is the primary tool capable of being shared among the various H-sectors, which can also integrate information across all life stages. For this reason the AA and NOAA want to foster better coordination and optimization of future tagging efforts, and the efficient, strategic emplacement of detection systems throughout the Columbia Basin. Importantly, this document can assist in informing the broader Regional Tagging and Marking Plan that has been recommended by the ISRP/ISAB (2009), consistent with RPA 52.6. That forum is underway and expects a plan to be in place in 2013.

Under the auspices of the FPC and CSS, the regional fishery agencies have established a process for coordinating tagging efforts (stocks and abundance) within the Snake and Columbia basins. The federal agencies intend to participate in that process to ensure BiOp needs continue to be adequately and efficiently met.

In summary, the purpose of this document is to ensure that the FCRPS BiOp RPAs requiring PIT tag-based information will be adequately addressed through the remainder of this decade. The primary objectives of this document are to:

- Align current and future PIT tag-related activities with RM&E RPAs requiring information from PIT-tagged anadromous salmonids.

- Identify opportunities for improving cross-H coordination, with respect to tagging effort and detector placement.
- Help to inform the NPCC Regional Marking Plan.
- Identify assessments directed at evaluating benefits, risks, and tradeoffs associated with various tagging schemes and PIT tag detection alternatives.
- Identify opportunities to improve coordination among federal and state and tribal fisheries agencies regarding future PIT tagging efforts and PIT tag detector needs.

2.0 Global Issues

2.1 PTAGIS

The PIT Tag Information System (PTAGIS) has been in place for more than two decades. The database system catalogues each tagged salmonid released and detected at various sites throughout the basin. A variety of attributes are specified for each fish/release group (e.g., tagging agency, tag coordinator, species/race of salmonid, etc.). Data attributes stored in the PTAGIS database are defined in the "PIT Tag Specification Document."[1] The system has evolved over the years as use of the tag has expanded.

The PTAGIS information system is undergoing major improvements. The development team is engaged in a large-scale upgrade of the PIT tag database, including web-based and field software systems, which will replace the existing production systems in late 2013. The infrastructure enhancements will strengthen the integrity and continuity of the established PTAGIS dataset, which contain tens of millions of rows of data. The data model and associated metadata are identical between the new systems for comparison purposes, and input from legacy field systems will be supported in the new server as well as all of the standard PTAGIS web-based reports.

A second generation beta-version of the new information system was released in October 2012. The content management system allows the team to more effectively manage end users, roles and published content (news, documentation, images, diagrams etc.). More of these features and related content will be revealed in future releases. Discussion forums are being used to obtain user feedback and help refine the systems. It is intended that the website have intuitive navigation so users can more readily locate elements and features of the system. The *PIT Tag Specification Document* has been transformed into an indexed data dictionary. Other features and content will be added to guide the uninitiated.

The primary objective of the new database and web server is to combine productive management and development tools with the prevailing database and web system platform to deliver the necessary performance, scalability and availability to handle the increasing loads of PIT tag data for the foreseeable future in a cost-effective manner. The new database is updated nearly in real-time and employs a world-class web reporting/analysis server to provide new opportunities for exploring the PTAGIS dataset. Users can interact with millions of rows of data from a standard

[1] The PIT Tag Specification Document can be accessed at:
http://php.ptagis.org/wiki/index.php/2009_PIT_Tag_Specification_Document

web browser and overlay graphs, heat maps and other data visualization features. The server systems employ standard data extraction features supporting output formats compatible with popular modeling tools. The development team is collaborating with the PTAGIS staff to maintain established interrogation sites and expand capabilities to accommodate a more diverse array of sites at a larger scale.

Additionally, the new server system is intended to improve technical coordination and accommodate metadata storage needs for the community. A *Field Service Portal* feature is planned to enhance the stewardship of interrogation sites submitting data to PTAGIS where site stewards can log into the new website and update metadata associated with the site.

The PTAGIS program has been coordinating with BPA to distribute PIT tags to Fish and Wildlife Projects (FWP) for over a decade. The custom web application that supports the tag distribution process will eventually be migrated into the new server system and provide an opportunity to realign (and potentially integrate) the PTAGIS distribution process and data with the *PIT Tag Forecast Database* described herein. Also, the information system will leverage existing GIS expertise with features to extend the PTAGIS dataset for spatial reporting. For example, researchers will be able to ask questions such as 'how many detection sites are below this release site location', and view results on a map within their web browser. Future GIS development is scheduled after the foundation of the web and database servers is completed. Due to recent BPA budget cuts to the PTAGIS program, the timeline for implementing and deploying these features has been postponed.

The Basin-Wide Detector System – PTAGIS currently maps the location of individual detector sites throughout the Columbia Basin (http://beta.ptagis.org/sites/map-of-interrogation-sites). Those detector arrays are deployed at dams, in both juvenile bypass systems and adult fish ladders, at hatcheries and associated acclimation ponds, and at in-stream installations including weirs, traps and stream-bottom systems. The link provided accesses a PTAGIS web page where interactive maps reside. New detectors come on line periodically as RM&E needs dictate. As noted above, properties and features associated with the mapping of detection sites should improve with the re-design of the PTAGIS information system.

2.2 PIT Tag Forecast Database

In order to accomplish some of the objectives specified herein, the Action Agencies (AA), NOAA and the NPCC determined that a means to forecast future tagging effort would be instructive and should be established. Ideally, the forecast should extend well into the next decade. To move this forward, these agencies formed a sub-group that specified attributes to be included in a database that can inventory and forecast future tagging efforts. Currently, PTAGIS can provide some of the desired information but only for current tagging efforts, not those planned for the out-years into the next decade. So, in December 2009 a template for a new PIT tag forecast-inventory was constructed and distributed to all agencies to populate. By June 2010, agencies and tribes using PIT tags had provided updated information, albeit in some cases incomplete. The database housing the forecast - inventory currently resides at the Columbia Basin Research website, until a permanent location for it can be determined

(http://www.cbr.washington.edu/pitsummary). The database includes a variety of important parameters including but not limited to; species, population, release location, projected sample size, life stage, etc.
Importantly, for the Forecast Database to be useful it needs to be updated periodically and in a systematic manner. Associating it with PTAGIS is an obvious option that is being explored. The AA and NOAA are discussing options with PSMFC staff, and may prioritize this work within future PSMFC contracts. Ultimately the information input to the forecast-inventory comes from the agencies conducting RM&E projects requiring PIT tags. To be useful, all parties employing PIT tags for RM&E projects directed at anadromous salmonids must participate.

2.3 General PIT Tag Technology Advancements

Technological advancements will be occurring over the next 2-5 years that will help improve survival estimates by increasing detection efficiencies and expanding the locations where PIT tag detection systems can be installed.

The standard 12.3 mm sized PIT tags were improved significantly over the past decade, and we will see more incremental improvement in them over the next few years. The current 9 mm tag (manufactured by RFID Solutions) was an improvement over the previous model produced by Destron. In the corner-collector detection system at Bonneville Dam, 54% of the tagged fish were detected relative to <1% for the Destron tag. A prototype for the new PIT tag transceiver being developed for the spillway-based detection system was tested in the corner-collector detection system in 2011; the result was a 10 percentage point increase in detection of the standard 12.3 mm SST-1 tags (87% compared to 77%). PSMFC will be installing this new ogee transceiver in the corner-collector detection system for the 2013 outmigration season. The Corps is exploring the use of this ogee transceiver to design vertical airfoil designed antennas at the entrance of an RSW or in front of the entrance of the corner collector at Bonneville Dam. This ogee transceiver will also be installed into a spillway-based system at Lower Granite Dam in 2014.

The new multiplexing transceiver (IS1001) initially developed by Destron and finished under Biomark's leadership in 2012 is now starting to be evaluated. NOAA Fisheries is installing a new detection system consisting of 12 antennas at the JD1 site on the John Day River in 2013. NOAA Fisheries is also evaluating how to use this new transceiver to improve the design for detecting adult salmonids near pile dikes in the estuary. It takes a year or two to learn how to best utilize a new transceiver after it has been developed. When more is known, a new antenna will be designed for the trawl system in the estuary and for larger rivers. We anticipate that there will be other applications (e.g., in the estuary, hatchery, and habitat-related) that we cannot imagine at this time.

A low-powered PIT tag detection system based on a board developed by Allflex Corporation and now manufactured by Biomark will enable antennas to be placed in remote locations in small streams with a small footprint that is not possible with the new IS1001 multiplexing transceiver.

2.4 Effects of Tags on Host Fish

Since the advent of the miniaturized PIT tag in the late 1980s, investigators have increasingly adopted the tool to estimate key performance indices for juvenile and adult anadromous salmonids in the Columbia Basin. PIT tags have demonstrated their utility in estimating a variety of important parameters including: smolt and adult survival, various migration indices including passage timing, smolt travel time and abundance. Additionally, the enduring properties of the tags from implantation in juveniles through the returning adult stage enable analysts to estimate survival through much of the salmonid life cycle. This is often expressed as the smolt to adult return rate (SAR). For such estimates to accurately represent survival over much of the life history, investigators must be assured that the tag and tagging process have no deleterious effects on survival and that the tag remains implanted and functional throughout the life history of the subject.

NOAA investigators first examined this assumption in the early 1990s as use of the tag expanded. Prentice et al. (1993) tagged juvenile coho salmon and reported a PIT tag loss of only 1% during the first 8 months post-tagging. As part of that same investigation, Prentice et al. (1994) used a double-tag study design to estimate SAR and determine the potential for PIT tag loss in coho salmon returning to spawn. They found that tag loss was minimal, except during the late stages of maturation just prior to spawning, when tag loss was pronounced at 59% for females, and 13% for males.

Some recent studies suggest that absolute values of SAR derived from PIT-tagged fish may be biased low, compared to the general untagged population (Knudsen et al. 2009; Copeland and Johnson 2007; Williams et al. 2005). Knudsen et al. (2009) implanted juvenile hatchery spring Chinook salmon in the upper Yakima River with PIT- and coded wire (in snout) tags in a double-tag study. The purpose was to test the assumptions that PIT tags do not fail, are not expelled, or negatively affect survival, behavior, or growth after release through the returning adult stage. They found that on average tag loss was 2.0% in juveniles prior to release, and 18.4% for fish returning 6 months to 4 years after release. Their analyses indicate that the majority of PIT tag loss had occurred within the first 6 months post-release. Smolt-to-adult survival (SAR) of PIT-tagged fish was significantly lower than that of non-PIT-tagged (NPT) fish. On average, the SARs estimate based on PIT-tagged fish underestimated the corresponding SARs estimated using CWT fish by 25.0%. After correcting for tag loss, they estimated that over all study years PIT tag-induced effects averaged 10.3%, with a maximum of 33.3% estimated. Results from this study are generally consistent with two other investigations that reported anadromous salmonids PIT-tagged as juveniles return at lower rates than non-tagged counterparts (Williams et al. 2005; Copeland and Johnson 2007).

However, there is an important cautionary note that may qualify some of these estimates. At the January 2011 PIT tag Workshop there were presentations and discussions regarding estimates of tag effects on host fish, and how they may be confounded with detection efficiency effects. Some investigators suggested that the detection efficiency when scanning returning adults may have been lower than presumed in some of these cited studies, and thereby may account for some of the discrepancy in SAR estimates. This is of particular concern since different types of hand-held devices were used in various studies.

These observations have raised concerns regarding bias associated with SAR estimates based on anadromous salmonids tagged as juveniles. The ISRP/ISAB tagging report (2009) recommended studies should be conducted to better determine the rate and extent of tag shedding or loss, as well as behavioral effects associated with tagging host fish. This topic was highlighted in discussions with the PIT Tag Steering Committee at the PIT Tag Workshop, held in January 2011. Indeed the fishery agencies are currently conducting a study directed at quantifying tag effects and disentangling the factors of tag loss, and tag induced mortality while presumably accounting for differential tag detection efficiency among treatment groups. This study is being staged at Carson National Fish Hatchery, with the first return data for spring Chinook being realized in 2012.

NOAA, the Action Agencies, and others have expressed concerns regarding the potential negative effects of handling and PIT-tagging populations of ESA-listed species, particularly wild populations collected and tagged in the field. The scope and magnitude of PIT tag use for RM&E purposes in the Columbia Basin has expanded dramatically in recent years. From 2005-2009 the total number of fish implanted with PIT tags has ranged from about 800,000 to over 3 million annually. The most dramatic increases have occurred in recent years. Based on information currently in the PIT Tag Forecast Database (input in 2010), the projections for 2011-2015 indicate that numbers of fish will level off at about 900,000 to 1,000,000 annually by 2012 across all species. Each year NOAA has to issue "take-permits" to agencies conducting studies on ESA-listed species. This involves balancing reasonable RM&E tagging needs against the potential negative effects of handling and tagging listed populations. BPA believes that, going forward, particular attention must be paid to the need to tag wild fish when population levels are low, when research benefits may be outweighed by potential adverse impacts. In these cases, a pause in wild fish tagging may be advisable on a temporary basis until abundance and productivity improve.

2.5 Management Questions/Objectives

The motivation for conducting particular RM&E activities and the associated PIT tagging activities is ultimately driven by the need to inform mitigation management decisions. The Action Agencies rely on clearly stated management questions to assist in focusing RM&E actions. Fundamentally:

1. Well-articulated management questions, goals or needs assist in formulating clear objectives;
2. The objectives in turn identify appropriate performance measures/estimates to be generated, using PIT tag data; and
3. Those specified performance measures and estimates dictate the required analytical framework, and associated precision and required number of tagged fish.

In some cases RM&E needs are not expressed in as explicit a manner as described here, and improvement efforts are underway to sharpen the focus to ensure useful results, such as moving to a programmatic approach for tributary and estuary habitat effectiveness work. Furthermore, some programs will be examined in the future through review processes such as the Columbia River Hatchery Effects Evaluation Team (CRHEET), which reviews hatchery programs and is described later in this document. In that program, details regarding required performance measures and analytical frameworks are yet to be developed. In contrast, much of the hydrosystem RM&E as prescribed in the FCRPS BiOp and FWP is quite specific and explicit in terms of expressing detailed objectives, performance measures and analytical approaches.

The analytical methods are specified in the BiOp, and are referenced where appropriate. Precision levels associated with performance indices, fish responses, or hypotheses tested need to be prescribed in individual study plans in order to estimate the number of fish to be tagged. Thus, desired precision often forms a critical criterion dictating the magnitude of the tagging effort and location and nature of key detection sites.

Other criteria may enter into the process as well. Compromises or tradeoffs between a management agency's perceived information needs (e.g., BiOp RPAs) and practical/logistical considerations often come into play. Practical considerations include fish availability, the comfort level of implanting potentially large numbers of fish (particularly wild fish) with a foreign device, cost, etc. Resolving these issues involves constructive dialog between managers and analysts.

2.6 RM&E Objectives and Associated Performance Measures

The FCRPS BiOp provides a comprehensive list of RM&E objectives (RPAs), which rely on PIT tag data. The RPAs are comprehensive and align with FWP objectives, including many of those expressed under the Smolt Monitoring Program. Some RM&E efforts such as the Comprehensive Survival Study (CSS) sponsored under the FWP have hydro-related components that support this plan. Consistent with previous AA nomenclature, these various RM&E objectives can be organized according to the following RM&E categories, which are typically applied across all H-categories. These include Habitat and Hatchery Effectiveness Monitoring programs that are also being developed using PIT tags and detection systems:

- Action Effectiveness Monitoring (AEM) – These projects are typically short-term (several years), and occur once or periodically. The objective is to evaluate the effectiveness of specific localized actions, or periodically check the enduring performance of a particular suite of actions. Given the periodic nature it is more difficult to predict with assurance the frequency and scope of future tagging efforts.
- Critical Uncertainly Research (CUR) – Projects in this category investigate fundamental hypotheses and assumptions underpinning system operations and recovery strategies. Examples of CUR studies include; transportation studies and early life history of Snake River fall Chinook.
- Status Monitoring (SM) – Projects involving long-term (decades) of consistent monitoring of key performance measures are classified as SM projects, e.g., the smolt

monitoring program including CSS, NOAA's annual system survival monitoring for smolts and adult salmonids. These types of studies lend themselves to long-term planning with respect to tagging and detection needs.

3.0 Hydrosystem PIT Tag RM&E

3.1 Key Hydro-Related Management Questions

There are several forums where Hydro-related management issues have been articulated. These include the 2008 FCRPS Biological Opinion, the NPCC Fish and Wildlife Program, and the Anadromous Fish Evaluation Program (AFEP). Briefly, with respect to anadromous salmonids the common management issues can be distilled as follows:

- Are salmon and steelhead meeting juvenile and adult hydro system passage performance standards and targets?
- What is the effect of changes in fish arrival timing and transportation on post-Bonneville mortality?
- Under what conditions does in-river passage provide greater smolt-to-adult return rates than transport?
- The near-shore Ocean (plume), estuary, and lower Columbia River below Bonneville Dam are included here as areas impacted in part, to the development and operation of the FCRPS.

At present, many of the hydro-related performance indices are generated using PIT-tagged fish released upstream from the FCRPS. Many of these fish are used to evaluate other actions, (e.g., habitat or hatchery actions). Reliance on these fish requires some assurance that representative populations will continue to be tagged in sufficient numbers to provide meaningful hydro-system performance measures into the future.

3.2 FCRPS RM&E Objectives and Associated Performance Measures

In early 2010, the AA, NOAA and NPCC produced a report "Recommendations for implementing Research, Monitoring and Evaluation for the 2008 NOAA Fisheries FCRPS BiOp." Some of those recommendations involved the use of PIT tags, and identified topics that are addressed herein. This plan periodically refers to that Recommendations Report:

http://www.salmonrecovery.gov/Files/BiologicalOpinions/RME%20RPA%20Assessment%20Report%20June%202009%20Draft%20_4_.pdf

The following is a list of PIT tag related items contained in the 2008 FCRPS Biological Opinion's Reasonable and Prudent Alternative (incorporated into the 2010 FCRPS Supplemental Biological Opinion).

Status Monitoring (SM)

- Planning

  RPA 52.6 – Develop a Regional action plan for conducting hydro-system monitoring.
- Juvenile System Survival

  RPA 52.2 – Monitor and evaluate in-river and system survival of juvenile salmonids through the FCRPS.

  RPA 52.4 – Increase the Upper Columbia PIT-tagging effort for spring Chinook and steelhead.

  RPA 52.5 – Assess the feasibility of PIT-tagging juvenile Snake River sockeye salmon for FCRPS survival monitoring.
- Adult System Survival

  RPA 52.3 – Monitor and evaluate adult salmonid system survival upstream through the FCRPS.

  RPA 52.7 – Examine and resolve observed incongruities between conversion rates of Upper Columbia River and Snake River steelhead and spring Chinook. Develop and implement a monitoring plan to address this.

  RPA 54.11 – Install and maintain PIT tag detectors in fish ladders at key dams in the FCRPS and evaluate adult survival (conversion rates).
- Juvenile Migration Characteristics

  RPAs 53.1, 53.2, and 53.3 – Monitor and estimate abundance, timing, and condition of smolts passing index dams.

Action Effectiveness Monitoring (AEM)

RPA 55.7 – Investigate the feasibility of developing PIT tag detectors for spillways and turbines.

RPA 55.9 – Assess the feasibility of developing PIT tag detectors for use in natal streams and tributaries, or other locations, as appropriate to support more comprehensive and integrated All-H monitoring designs and assessments of straying rates.

Critical Uncertainty Research (CUR)

RPA 54.7 – Monitor and evaluate the effects of environmental conditions affecting juvenile fish survival.

RPA 55.1 – Investigate and quantify delayed differential effects (D-value) associated with the transportation of smolts in the FCRPS as needed.

RPA 55.2 – Investigate the post-Bonneville mortality effect of changes in fish arrival timing and transportation to below Bonneville Dam.

RPA 55.4 – Investigate, describe, and quantify key characteristics of the early life history of Snake River Fall Chinook salmon in the mainstem Snake, Columbia, and Clearwater rivers.

RPAs 67, 68 and 69 – Investigate bird predation in the lower river and estuary (67, 68) and inland (69).

Most of the information used to address these RPAs is generated by projects funded under AFEP and the FWP. In addition, other programs also employ PIT-tagged fish for hydro-related and other types of investigations throughout the Columbia Basin. Some are conducted under the auspices of the HCPs, or the Accords. Some of these include studies of adult conversion rates through the upper Columbia (Colville Tribe), and smolt survival monitoring at Wells Project (Douglas HCP). The mixture of these studies can change through time, since many are periodic in nature. The periodic nature of these projects limits the horizon for long-term prediction and planning of PIT tag needs. Even so, agencies have provided their forecast as to the magnitude of future tagging activities, which have been included in the PIT Tag Forecast Database.

3.3 Species/ESU

The BiOp RPAs call for RM&E actions that focus on ESA-listed anadromous salmonids (in some cases unlisted populations are used as surrogates). It is important to note that the detection system was designed for monitoring anadromous salmonids, but provides detection opportunity for other species. This plan does not alter that intent. Moreover, the FCRPS agencies do not assume full responsibility for Columbia Basin RM&E across all H's. In many cases, these are collaborative or complementary efforts with other agencies and entities.

3.4 Applications for PIT-Tagged Anadromous Salmonids in the Hydrosystem

3.4.1 Action Effectiveness Monitoring

Action effectiveness monitoring involves projects that are typically short-term (up to several years), and occur periodically as the need arises. The objective is to evaluate the effectiveness of specific localized actions, or periodically check the enduring performance of a particular suite of actions. Many studies sponsored under AFEP fall into this category. All experimental designs are reviewed by the SRWG annually. Sample sizes vary considerably across projects depending on the power of the tests, or precision targets prescribed by the SRWG. The complex of this class of studies changes annually.

Although the AEM category was designated by NOAA and the AA during the development of the BiOp and associated RM&E activities, AEM-type studies are conducted under other programs as well, e.g., FWP and HCPs, but are not directly referred to as such.

3.4.2 Critical Uncertainty Research

Research projects that fall into this category focus on resolving key issues relative to improving system-wide passage strategies for anadromous salmonids. In the Hydro realm, two classes of ongoing studies fall into this category; Snake River fall Chinook studies and transportation evaluations. These projects span many years, even decades. Future tagging needs are usually predictable, and often planned for 3-5 year windows.

Fall Chinook ELHS & Transportation Study – Since the collaboration proposal for fall Chinook studies was released in 2007, the study design for a comprehensive early life history and passage strategy study has been under the auspices of the regional Fall Chinook Planning Team. That experimental design specified PIT-tagging approximately 600,000 to 700,000 juvenile Snake

River fall Chinook annually for five years (not necessarily consecutively). Details regarding the study and the broader fall Chinook program can be viewed at:

http://www.fpc.org/documents/fallchinook_planningteam_documents.html

The extent and duration of future tagging activities are uncertain. However, if the results of these studies result in changes to dam or transport operations, it is likely that additional studies will be required to evaluate the new operations.

Transport Evaluations Spring Migrants – Transportation evaluation studies have been conducted for nearly three decades, involving spring-migrating stream-type Chinook and steelhead. In recent years, studies have primarily relied on fish that are PIT-tagged upstream from Snake River dams. Most of these fish are tagged under the SMP, CSS or NOAA wild fish tagging programs. To the degree those programs continue tagging juveniles, transport evaluations could be conducted well into the future. However, fish need to be tagged in large enough quantities to yield useful transportation indices, and diversion of select tagged fish at collector dams needs to be intentionally implemented.

Proposed Assessment: NOAA and the AA should review the status of these two research programs (fall Chinook & transportation) and describe in general terms the state of knowledge, e.g. lessons learned. Then identify the future course of study needed to adequately address any related management issues in the BiOp that are still outstanding and require resolution.

3.4.3 Status Monitoring – Juveniles

The need for annual estimates of smolt survival through the FCRPS are articulated in the Supplemental Comprehensive Analysis of the 2008 FCRPS BiOp (incorporated into the 2010 FCRPS Supplemental Biological Opinion).

To provide context for these discussions, we have catalogued the key PIT tag detection facilities within the mainstem Snake-Columbia River system that provide data for hydro-system RM&E in Table 1.

Table 1. PIT detector sites that provide data for hydro-related RM&E; Existing (E), Proposed or Planned (P), and a blank indicates none in place or planned. SFO = Surface Flow Bypass, e.g., RSW, Bonneville Corner Collector.

Site	Smolt Bypass	SFO	Ladder	Other/Comment
Snake River				
Lower Granite	E	P	E	Install and test the RSW detector at Lower Granite for 2014
Little Goose	E			
Lower Monumental	E			
Ice Harbor	E		E	
Mid-Low Columbia				
McNary	E		E	
John Day	E			
The Dalles			P	A ladder system is being designed for installation in 2015
Bonneville	E	E	E	
Trawl				The current Trawl Program samples juveniles independent of dams
Upper Columbia				
Wells			E	
Rocky Reach	E		E	
Rock Island	E (Minor)		E	Small sample fraction of downstream migrants
Wanapum				
Priest Rapids			E	
Other				
Harvest Sampling				CRITFC started sampling in fall 2010 to improve conversion rate estimates
Tributary-Stream Bottom				Systems are now in the Deschutes, John Day, and Yakima rivers

Objectives **–** Both the FCRPS BiOp (RPAs) and the FWP (through the SMP and CSS) direct the region to maintain a historical time series of survival indices and migration characteristics (e.g., smolt travel time, migration timing, abundance indices) to track the overall effects of the collective reconfiguration and operation of the FCRPS and Upper Columbia River. To accomplish this, index stocks are PIT-tagged and monitored as they migrate through the system.

Additionally, the COMPASS model relies on system survival estimates to calibrate the model. Thus, continuing the acquisition of these estimates contributes to the updating and refinement of the model, which is used to assess alternative operational proposals and to periodically evaluate FCRPS passage performance during "Check-in years".

Key Performance Measures – Include smolt survival, migration timing, and travel time and abundance indices as obtained at established index sites within the system. Analytical procedures are described in appendices to the 2008 FCRPS BiOp and in the SMP and CSS study plans and reports. Survival estimates are based on the longstanding Cormack Jolly Seber (CJS) model using the single release format, which has been adopted by the region. Results are reported annually by the NOAA Science Center and the FPC.

Population Coverage – BiOp performance measures of system survival are reported at the ESU level for steelhead and yearling stream-type Chinook salmon, and are reported for wild stocks when sample sizes are adequate, and for wild and hatchery stocks combined, if necessary. Estimates for individual major population groups (MPGs) can be calculated in some cases, but precision estimates are typically too broad for NOAA to rely on the survival estimates as useful performance measures. The BiOp does not specify that particular populations or hatcheries need to be tagged each year.

The longstanding wild fish tagging projects of NOAA and the State of Idaho are expected to continue through the term of the current BiOp, subject to adaptive management over time or any reductions indicated in the interests of conservation where population abundance and productivity may be a concern. In general, the AA and NOAA rely on the admixture of tagged populations from other projects like CSS, the SMP, and assorted hatchery and habitat studies to supply fish that move through the FCRPS and are ultimately used for smolt survival monitoring. These programs also have a long time horizon.

Recently, the COMPASS modeling effort has focused on calibrating the model with wild PIT-tagged fish when they are available in adequate numbers. Comparisons of the COMPASS predicted survival rates of wild in-river listed fish to the actual survival of PIT-tagged wild in-river fish through the FCRPS is a significant element of juvenile performance evaluations (see annual FCRPS BIOP Progress Reports). The COMPASS Group analyses have revealed differences in wild and hatchery fish survival for some Snake River ESUs. Models have been calibrated opportunistically, using fish at hand that have been tagged for other purposes. Therefore, that team would like to see more wild fish represented in the PIT-tagged population. We expect this topic to be discussed between the modeling group and Policy-level managers. As noted previously, the desire for increased collection and tagging of wild ESA-listed fish in tributaries, the likely effectiveness of proposed collection facilities, and the potential risks to the ESU of the increased handling and tagging would need to be considered by the managers and accepted by NOAA before being permitted under ESA.

SMP and CSS tagged fish are also used to estimate key migration indices, including passage timing, travel time and abundance indices at index dams in the Snake River, and upper and lower Columbia Rivers. The mix and proportion of species and MPGs tagged in the future may change. In the future, sockeye tagging in the Snake may eventually fall under the auspices of CSS and/or the SMP, as could the anticipated expanded population coverage in the upper Columbia River.

Sample Sizes (N), Precision Targets – Many studies have specific precision requirements which are affected by the number of tagged fish released, the survival of those fish, and the number of subsequent detections. For example, sample sizes for the SMP and CSS are prescribed in the study plans. They are generally based on historical precedent to provide consistency over the years. Recently there has been an effort to increase steelhead tagging and expand effort in the upper Columbia. In addition, the USACE has funded 4 years of PIT-tagging of sockeye to provide a pilot transport evaluation, and accompanying collection efficiencies and reach and system survival estimates. The intent of this evaluation was to gather reach survival and collection efficiency information such that a larger scale transport evaluation could be conducted once the new Springfield Sockeye Hatchery is in full production (one million smolts per year).

As noted, BiOp survival status monitoring relies on hatchery and wild fish tagged for other purposes, e.g., the CSS, SMP, and assorted hatchery and habitat evaluations. No specific sample sizes are prescribed in the relevant RPAs or associated text describing analyses. A general guideline, as articulated in the BiOp RM&E Work Group, is to maintain and consider improved precision estimates consistent with the historical time series that dates back to at least 1997. However, historical precision tends to be quite variable, thereby not providing a clear standard (http://www.nwr.noaa.gov/Salmon-Hydropower/Columbia-Snake-Basin/upload/fish-psg-juvenile.pdf). Furthermore, most of the variability in precision is associated with estimates in the lower river from McNary Dam to Bonneville Dam. This raises the question of whether additional precision is truly a worthwhile undertaking from the standpoint of fundamental management decisions and needs.

Increasing precision estimates, especially in the lower Columbia River, would increase the accuracy of hydrosystem and life-cycle models, increase manager's ability to compare survival and behavior of different MGPs or ESUs/DPSs, and enhance the ability of managers to relate environmental and behavioral factors to juvenile survival and perhaps adult returns. Increasing the precision of survival estimates could involve either increasing detection capability at strategic locations, or increasing the numbers of tagged fish in the system. The costs associated with such actions need to be balanced against perceived gains in data quality and the certitude of resultant management decisions. These are largely policy issues that are beyond the scope of this technical document. Realistically, these types of improvements would have to be re-prioritized within existing RME programs.

One means to evaluate the tradeoffs between increased detection capabilities and tagging effort, is to conduct a power analysis. One such approach is presented in Appendix C. This example examined existing estimates of smolt survival estimates from 2005-2009. Over those years, the mean standard error (SE) for LGR-MCN smolt survival estimates was approximately 0.01 and 0.02 for Chinook and steelhead, respectively. These estimates are based on the composite wild and hatchery populations. The corresponding SE's for the lower Columbia River (MCN-BON) were much broader were broader at 0.043 and 0.096 for the same species, respectively. Thus, in order to achieve the similar precision levels in the lower Columbia River, a 4-5 fold improvement in precision would be required. This would require a 1.5-2.5 fold increase in the detection probabilities at MCN, BON, and the estuary PIT trawl, collectively.

Alternatively, similar precision levels could also be achieved by tagging more fish. However, the required increase in the number of tagged fish (and associated long-term costs to the implementing agencies) would be considerable. For Chinook, the numbers of fish tagged would need to increase by approximately 6- to 16-fold, and 9- to 16-fold for steelhead. Given recent heightened concerns regarding long-term tag effects on host fish, it is unlikely the region will embrace increasing tagging to this extent. In fact, a cogent argument can be made to reduce tagging from current levels, given these concerns. Improving detection probability at strategic sites in the FCRPS may be a more practical and acceptable long-term strategy.

Proposed Assessments:

1. *Determine the extent to which proposed detector installations or alternative tagging strategies can improve the precision of system survival estimates, and provide rationale for how such improvements will affect management decisions regarding system survival.*

   Conceivably, NOAA could use the COMPASS model to explore the effects of different detector configurations at select sites (dams or trawl), or numbers of tagged fish entering the FCRPS from different watersheds. This exercise can depict changes in survival estimates and associated precision, using the different strategies.

2. *Assess the suitability of the populations and numbers of fish being PIT-tagged in the region, in meeting BiOp needs.*

   The NOAA-led COMPASS group has recommended that more wild fish be tagged to better calibrate the model. NOAA and the AA have discussed whether the complement of populations and numbers of fish being tagged now, and into the future, are suitable to provide a representative profile for the various ESUs. These issues remain largely unresolved. NOAA and the AA should, in consultation with the COMPASS model group and TRT, formulate a rationale for either maintaining the status quo in terms of population coverage, or altering that course in some clearly defined manner. Furthermore, this assessment should address sample size needs for each population unit, and identify the relevance in terms of specific management actions and decisions. Importantly, this assessment should consider tradeoffs between the quality of resultant monitoring and risks associated with the capture and tagging of ESA-listed fish.

3.4.4 Status Monitoring – Adults

Objectives – Both the 2008 FCRPS BiOp (RPAs) and the FWP (through the SMP and CSS) direct the region to maintain a historical time series of adult passage survival indices. These indices of survival are for adult salmonids migrating upstream, and are intended to monitor for any changes relative to previous years, or changes in system operations. The monitoring is opportunistic in that it relies on known-origin adults, PIT-tagged as juveniles, returning to the system to make the calculations. To accomplish this, index stocks are PIT-tagged and monitored as they migrate through the system. The ISRP/ISAB tagging report (2009) recommended further development of prototype instream PIT tag detectors in key tributaries to monitor both adult fish and smolt movements to better understand migration behavior and timing, and the fate of juvenile and adult migrants both before and after dam passage and to spawning grounds.

Key Performance Measures – There are two types of adult passage performance measures that can be reported as calculated from PIT tag data; conversion rates which rely only on observed detections at dams, and survival indices that include corrections for straying and harvest. Survival indices are the most instructive in terms of addressing BiOp objectives, and the analytical methods are described in an appendix to the 2008 BiOp. The BiOp relies on the survival indices as the primary performance measure for adult migrants through the FCRPS.

Population Coverage – BiOp performance indices of survival are typically calculated at the ESU level, and can be reported for hatchery and wild stocks for in-river and transported fish, separately and combined. Estimates for individual MPGs are typically not practical, given small numbers of returning adults, particularly for populations that were originally tagged as juveniles in small numbers, or tagged as parr earlier in their life history. However, the tagging of returning adults, in particular steelhead at BON, PRA, GRA and Chinook at GRA, allow the development of spawning escapement estimates for populations with in-stream PIT detection infrastructure below spawning areas (e.g., Entiat, Wenatchee, SF Salmon, Lemhi, Upper Grande Ronde, Imnaha, and Lolo).

Sample Size (N), Precision Targets – In the BiOp a minimum sample size of 30 individuals per population unit/ESU is the goal for generating acceptable annual estimates of adult passage survival. It is expected that this number will be met or exceeded for Snake River ESUs based on current levels of juvenile tagging as predicted in the current version of the PIT Tag Forecast Database. Some increase in tagging for Upper Columbia ESUs may be needed. Mid- and Lower Columbia ESUs rely on upstream ESUs to serve as surrogate groups. Annual estimates of upstream passage survival are approximations. Annual straying rates are not known and any adjustments for such are currently based on generic estimates obtained in previous years using radio telemetry data. Harvest rates in key reaches upstream of Bonneville Dam are reported annually, however, the applicability of these estimates (provided by U.S. vs. Oregon Technical Advisory Committee) to hydro conversion rate estimates using PIT-tagged fish is disputed by some co-managers. Further analysis and discussion will be necessary to reach consensus on this issue. The AA and NOAA would like to explore a programmatic approach to improving the accuracy as well as the efficiency of survival indices by acquiring annual estimates for straying and improved harvest removals (of the PIT-tagged fish) where feasible. Toward this end, PIT tag detection systems could be deployed at strategic locations, e.g., major tributaries, select dams, and harvest landing sites. The lower Columbia River is critical in this regard since it has many cool-water tributaries that can attract migrants destined elsewhere, and substantial fisheries that remove undocumented numbers of PIT-tagged fish that are staged there.

3.4.5 Additional Adult Detection Needs

Ladder Detectors – Unaccountable loss of adult salmonids has been most obvious in the BON to MCN reach. But the limited adult PIT detectors (MCN, BON) provide poor spatial resolution, and thus guidance for solving the problem. The placement of PIT detectors in the ladders at The Dalles Dam would assist in identifying the specific reservoir where the unaccountable loss of tagged adults occurs, and would help in bounding a narrower river segment where fish removal or straying is most pronounced; a temporary system was installed in 2013 and permanent system is being designed for The Dalles in 2015. Results from the Dalles will be used to assess the need for detectors at John Day in the future. Installations have also been proposed for dams on the Snake River, at Little Goose and Lower Monumental dams; although the need for detectors at those ladders sites is not currently viewed as critical.

Tributary Monitoring for Mainstem Straying Evaluations – The vast majority of fish that wander or stray into tributaries do so into five rivers in the Bonneville, The Dalles, and John Day reservoirs; the Deschutes, John Day, White Salmon, Wind, and Klickitat rivers. Monitoring near the mouths of these five key tributaries in the lower Columbia provides the potential to estimate turnoff and straying rates through the FCRPS. This is important for improving the accuracy of adult passage survival estimates. For tributary systems to be effective at determining which fish actually remained in the tributary, upstream and downstream detection rates across the seasonal changes of water flow and depth must be determined. Based on input from NOAA, a vision for future installations is summarized here. Some of these are planned or proposed. Others present opportunities. A programmatic perspective and prioritization, as always, will have to be discussed at both the technical and policy levels.

Currently:

- The in-stream detection system in the John Day River will be extended to span the entire river in 2013 now that the new multiplexing transceiver is available. This would augment the systems upstream which are associated with the ISEMP monitoring effort (more on this topic in a later section).
- Additionally, there are detectors deployed on the Wind River, Umatilla River, and White Creek.
- The Klickitat River had a detection system installed in 2011(Lyle Falls). An additional site will be installed (Castile Falls) in the future.

Future:

- The feasibility of deploying detectors in the lower Deschutes River is still being ascertained. However, it is tractable to install detectors in the fish ladder at Warm Springs NFH, and perhaps add one or more readers at the Sherars Falls trap.
- As part of their BPA proposal, NOAA is proposing to install a detection system at the entrance to Drano Lake.
- In the Little White Salmon River, there are several candidate sites for detection systems.
- Additional detectors could be emplaced in the Wind River.

Maps identifying the locations of PIT tag detectors can be accessed and viewed at: (http://www.ptoccentral.org/testing/gmaps/os_map.html).

Harvest Sampling – In order to produce more accurate estimates of PIT tag based adult passage survival, the removal of PIT-tagged adults by harvest actions should be estimated. This requires monitoring of river-based fisheries. This does not yet occur in a systematic fashion and so remains a gap for monitoring of adult passage survival in the mainstem Columbia River. Later in this plan, the scheme for sampling fish in the various fisheries is described as part of the "Harvest" section of this planning document.

3.5 Guidelines and Future Considerations

Some of the proposed actions identified in this plan are based on the successful demonstration of prototype applications, or construction of accepted and planned PIT detection facilities. Some of these technologies, e.g. spillway detectors, may or may not prove feasible because of the level of performance required, and/or the cost of implementation and maintenance of such facilities. The feasibility of producing effective, large-scale PIT tag detectors that can be installed in spillbays or RSWs is currently being evaluated. Technically, it appears feasible to construct and install devices for testing (Downing pers. comm.). However, the actual detection capabilities need to be established through field tests of prototypes. We recommend that field testing of a spillway detection system occur as soon as practicable.

The leading candidate for possible installation and testing of a spillway-based detection system, if Corps funding allows, is Lower Granite Dam in 2014. The approach being designed is to install antennas into two trenches that are dug across the ogee face. The Corps is also investigating installing antennas at the entrance to the RSW that hang vertically and will move when debris hits them. Before installing both systems, the Corps will need to assess whether or not they will not interfere with one another. Required modifications to the spillway, including cutting channels in concrete to hold the antenna are likely to require at least one year lead time after the project is approved for design and planning of the modifications. Other actions, even if feasible, may not be prioritized.

Limitations regarding the ability or desirability to capture and tag targeted populations of listed wild fish may also affect the feasibility of increasing tagging efforts to attain desired precision or population coverage. These issues should be considered when devising a long-term strategy to provide important broad-based monitoring of population status and the effectiveness of salmonid management programs, while limiting the handling of wild fish.

Detection Systems – Existing and potential PIT tag detector systems at mainstem dams on the Snake and Columbia River are cataloged in Table 1. Data from these systems are the basis of estimating metrics used to monitor Hydrosystem survival indices and migration characteristics. Following are assessments or recommendations to better inform the design, and location of additional detection systems in the FCRPS. The order of listing here does not imply prioritization or a decision to proceed.

Proposed Assessments and Next Steps

Adult Salmonids

- Install PIT detectors in fish ladders at TDA by 2015. This will assist in identifying the reservoir(s) where unaccountable loss of PIT-tagged adult fish is most pronounced in the Bonneville to McNary reach.
- Install or expand in-stream detectors at strategic tributaries in the Lower Columbia River, where unaccountable loss is highest. These detectors have the potential to directly estimate the percentage of non-spawning fish that enter tributaries and never leave (strays and tributary harvested fish). Selection of detector sites should complement those being proposed for population status monitoring (Section 7).

- Implement the proposed harvest sampling effort in Zone 6 (for both tribal and recreational fisheries) and possibly on the Snake River to quantify the harvest removal of PIT-tagged fish.

Juvenile Salmonids

There are a number of possible options for increasing the detection probability of PIT-tagged smolts and to increase juvenile precision of survival estimates in the FCRPS. Deciding the most appropriate course of action often involves assessing tradeoffs, or quantifying the magnitude of benefit per unit effort or cost. We highlight some of these key issues and identify assessments that should be conducted to make an informed decision.

- *Assess the magnitude of benefits associated with either increasing the numbers of tagged fish released versus improving detection probability at key sites in the FCRPS.* Increasing the PIT trawl effort could improve the quality (precision) of smolt survival estimates for all ESUs being PIT-tagged in the basin, especially through the Lower Columbia (MCN-BON). A preliminary power analysis (Appendix C) points to this action as an effective means to improve precision of smolt survival estimates, especially through the lower Columbia River. Additionally, an increased trawl effort would likely benefit PIT tag survival estimates for Willamette, Clackamas, Cowlitz, and Lewis rivers.
- *Assess the nature and magnitude of benefits associated with the installation of spillway detection systems.* Installation of detection systems at prioritized spillway locations is another means to improve precision of smolt survival estimates. Additionally, this would afford the capability to detect the "Co" class of PIT-tagged fish, now evading detection at the Snake River dams.
- *Assess the nature and magnitude of benefits associated with PIT-tagging representative populations in the Upper Columbia at the same scale currently employed by CSS for the Snake River ESUs.* This assessment could take the form of a pilot study. The Action Agencies, the PUDs or NOAA could PIT tag and monitor FCRPS survival for several years (3-5 years) for select UCR populations. If smolt survival estimates through the lower Columbia differ for Snake and UC origin fish, then adopt long-term tagging of UC ESUs. Consider using this same strategy for Mid-Columbia ESUs.
- *Assess the benefits of a reconfigured PIT tag detection system in the FCRPS.* Following the installation of select new PIT tag detection systems, track changes in detection probabilities and associated precision levels for survival indices. This will ensure sample sizes are suitable to adequately estimate required monitoring metrics. In general, determine if precision is adequate with the expanded PIT detection system. The most fundamental step is the region agreeing on the precision criteria and the target. Once this is clearly established we recommend stepping through the following decision logic.
    - If precision does not meet an agreed upon target, then consider relaxing the target, in the context of what is really required for meaningful management decisions.
    - If precision exceeds the target:
        - Reduce the quantity of fish tagged in the Snake and/or Upper Columbia for the species, if warranted.

- Assess the extent of tagging proposed region-wide across all H-sectors. In conjunction with other H-programs, ensure the proposed scale of long-term PIT-tagging for hydro-related status monitoring is efficient, adequate, and uses the minimum number of wild fish taking into account conservation needs (but no more than levels currently specified under the SMP and CSS). We envision that the PIT Tag Forecast Database will be instructive in this regard.

4.0 Estuary PIT Tag RM&E

This section describes the use of PIT tag technology in studies of juvenile and adult salmon and steelhead in the lower Columbia River and estuary (LCRE). A summary table of PIT applications by study is included at the end of the section.

4.1 Key Estuary-Related Management Concerns

Applications of PIT tag technology in the LCRE are part of the federal RM&E effort because of LCRE ecosystem restoration efforts as offsite mitigation for the hydrosystem and linkages between LCRE conditions and dam operations upstream. Key management concerns involving PIT technology application in the LCRE, as expressed in the BiOp, include:

1. Determine system-wide survivals through the lower Snake and Columbia River hydrosystem;
2. Determine the effectiveness of the juvenile fish transportation system; and
3. Determine whether offsite habitat actions in the LCRE improve juvenile salmonid performance, and which actions are most effective at addressing limiting factors preventing achievement of habitat, fish, or wildlife performance objectives.

4.2 RM&E Objectives and Associated Performance Measures

PIT tags are used as a primary tool in estuary investigations of juvenile and adult salmon and steelhead. Besides purposeful tagging to meet study objectives, studies in the LCRE take advantage of the fact that over 90% of the over 2 million PIT-tagged fish are released into the Columbia River Basin each year at locations upstream of the LCRE. PIT data support nine RPAs in the 2008 FCRPS BiOp and two NPCC Fish and Wildlife Program strategies.

<u>2008 FCRPS BiOp</u>

- **RPA Action 52.2 – “**Monitor and evaluate juvenile salmonid in-river and system survival through the FCRPS, including estimates of differential post-Bonneville survival of transported fish relative to in-river fish (D-value) as needed.”
- **RPA Action 52.3 – “**Monitor and evaluate adult salmonid system survival upstream through the FCRPS.”
- **RPA Action 54.6 – “**Monitor and evaluate the effectiveness of the juvenile fish transportation program and modifications to operations.”

- **RPA 59.4** – "Evaluate migration through and use of a subset of various shallow-water habitats from Bonneville Dam to the mouth toward understanding specific habitat use and relative importance to juvenile salmonids."
- **RPA 60.2** – "Evaluate the effects of selected individual habitat restoration actions at project sites relative to reference sites and evaluate post-restoration trajectories based on project-specific goals and objectives."
- **RPA 61.1** – "Continue work to define the ecological importance of the tidal freshwater, estuary, plume, and nearshore ocean environments to the viability and recovery of listed salmonid populations in the Columbia River Basin."
- **RPA 61.3 –** "Investigate the importance of early life history of salmon populations in tidal fresh water of the lower Columbia River."
- **RPA 69** – Marine Mammal Predation. "Monitor the effectiveness of deterrent actions (e.g., exclusion gates, acoustics, harassment and other measures) and their timing of application on spring runs of anadromous fish passing Bonneville Dam."

Fish and Wildlife Program Strategies

The most recent FWP and amendments were issued in November 2009 (NPCC 2009). PIT technology has application to the following FWP's "Estuary Strategies" (p. 32), which are consistent with FCRPS BiOp RPAs.

- Establish "Long-term effectiveness monitoring for various types of habitat restoration projects in the estuary."
- Conduct "Continued evaluation of salmon and steelhead migration and survival rates in the lower Columbia River, the estuary, and the marine environment."

4.3 Species/ESUs

Studies using PIT tags as a primary tool provide specific presence, residence time, and migration history, i.e., migrant within the river or transportation around the hydropower system, for fish of known origin. Researchers provide specific data by species, run, and rear-type (natural or hatchery source). The goal of PIT tag related studies investigating habitat use is to describe species-level presence and individual residence time in LCRE habitats by fish of known origin. For example, NMFS performs studies to tag and release lower Columbia River fall Chinook salmon. They are also using genetic stock identification methods to target adult salmon from the Middle and Upper Columbia and Snake River ESU groups.

4.4 Applications for PIT-Tagged Anadromous Salmonids in the Estuary

Studies using PIT tag technology to evaluate survival and timing of juvenile salmonids in the LCRE generally utilize the 2 million PIT-tagged fish released at known sites and sources well upstream of the LCRE. These studies delineate results on the basis of known species, runs, and rear-types only possible using PIT-tagged fish of known source as defined in PTAGIS. The following material describes various PIT studies in the LCRE.

Transportation, Adult Passage, and Marine Mammal Predation Studies

In RPA 52.2, PIT trawl data provides basic timing, residence (or lack thereof), and relative survival of transported and fish detected passing Bonneville Dam on the same dates. NMFS's proposed mobile separation by code (MSBC) system would provide samples of fish from known source and migration history to help understand temporal differences in these outmigrants and factors effecting 'D' just prior to ocean entry and after they co-mingle in the estuary.

There are two current research projects aimed at monitoring adult salmon and steelhead (RPA 52.3): passive detection on a Pile Dike Antenna and NMFS's adult study. Nearly 100% of all PIT-tagged adults are detected passing upstream at Bonneville Dam and a significant portion are detected passing upstream at Willamette Falls, another important ESU. Thus, passive and active estuary research is currently addressing this action item.

Evaluation of the fish transportation program (RPA 54.6) was the original goal for trawling for PIT tags in the estuary, beginning in 1995. After Bonneville Dam was wired for PIT tag detection of juveniles beginning in 1996, the comparison of transported fish to fish that had remained in the river for migration became possible and continues. The emphasis of the trawling study gradually changed from transportation evaluation to emphasize collecting data downstream from Bonneville Dam required for completing the reach survival estimates of the FCRPS to Bonneville Dam tailrace. Comparison of paired groups based on date at Bonneville Dam allows evaluation of SARs for groups (transport or no) entering the ocean at similar times. Increased tagging of sockeye salmon in recent years has allowed similar transportation to inriver migration evaluation using PIT tag data collected in the estuary.

Juvenile Salmon Ecology and Action Effectiveness Studies

PIT tag technology is used for Status and Trends (RPA 59), Action Effectiveness Monitoring (RPA 60), and Critical Uncertainties Research (RPA 61). For example, PIT tag technology is being used to address the critical uncertainty of whether juvenile salmon populations emanating from upstream locales will migrate into shallow, tidal wetlands (EST-P-10-01). Other research is being considered concerning passage of upriver tagged-fish through culverts connecting the mainstem Columbia River with shallow water embayments and wetlands (BPA 2003-007-00). Two AFEP funded studies, Salmon Benefits (EST-P-09-1) and Multi-Scale Action Effectiveness Research (EST-P-11-01), intentionally tagged and released fish in strategic locations to address specific research questions about restoration action effectiveness.

In the AFEP study EST-P-10-01, NMFS has conducted research (2006, 2008, 2012) in which they intentionally tagged and released juvenile Chinook salmon for the purposes of measuring residence time and growth. These studies also involve taking a subset of the tagged fish and strategically releasing them for estimates of detection efficiency of PIT arrays when they are newly deployed in a particular location.

For adult salmon investigation, NMFS has been conducting research to resolve critical uncertainties in estuarine survival since the spring of 2010. This adult survival study utilizes PIT tag technology as a primary means of estimating survival, estuary residence, and run and passage timing for upriver spring/summer Chinook salmon stocks. Researchers tag fish representatively over the spring run and utilize genetic stock identification methods to target study fish from the Upper and Middle Columbia and Snake Rivers. Estimates of survival to Bonneville dam are very precise as detection efficiency at this location is typically greater than 98%.

Sampling Methods and PIT Data

Sample sizes or precision targets for habitat-use studies are typically not specified and not usually applicable for the elements of those LCRE studies using PIT tag based information, because statistical comparisons are not study objectives. While some investigations rely on capturing and purposefully tagging and releasing groups of fish, others rely on opportunistic detections of fish from other studies. This research does not make large demands on the PIT tag program. The one exception is the avian predator study conducted by NMFS for the USACE Portland District (AVS-P-08-01 and 02). In this study, between 9,000 and 18,000 juvenile salmon are PIT-tagged annually and released at strategic locations in the estuary, with subsequent detection efforts targeting the bird colonies in the lower estuary. Analysis of avian predation data, like trawl data, is fully dependent on PTAGIS for breakout by species, run, and rear-type.

The design of detection systems depends on the research questions at hand. When fixed PIT arrays are necessary, such as for passage rates at a culvert, the study is dependent on locations where the arrays can be successfully deployed and maintained to collect data to address specific objectives, usually at a very local level. Channel widths and depths, structures, and salinity are among the factors of concern when designing PIT tag based studies in the LCRE. Strategies for deploying detection systems include:

1. Fixed arrays in tidal channels known to provide rearing habitat for juvenile salmon, but small enough to effectively interrogate the entire cross-section.
2. Fixed arrays near culverts and tide gates connecting off-channel areas to the main channel.
3. Hand-scanning PIT detector to detect PIT tags in seined or captured fish.
4. Mobile PIT trawl system to concentrate and guide fish through an antenna. This system is restricted to the thalweg, with potential to divert a sample of known source and history fish for hands-on examination to monitor fish condition in the estuary. It is a passive collection and detection system where the cod end of the trawl is open and the fish pass-through PIT antenna arrays deployed there.
5. Fixed arrays on pile dikes adjacent to the thalweg targeting returning adults to evaluate arrival timing in the estuary and survival (re-detection) of fish of known source migrating pass interrogation sites at Bonneville Dam or the Sullivan Plant at Willamette Falls.

Table 2 contains information about the investigations in the LCRE using PIT technology. The performance indicators derived from the PIT tag data include entrance propensity, passage rates, passage timing, residence times, survival rates, and predation impacts. Some of the detection efforts are relatively long-term, such as the trawl study and surveys of bird colonies in the estuary. The tidal channel study on Russian Island is an example of a successful application of PIT technology to help evaluate habitat use in the estuary.

Since most of the estuary detection systems are considered to be temporary installations, PTAGIS currently does not have designate permanent code for many of these sites. Although some detection site data are reported to PTAGIS (trawl (site code "TWX"; pile dike (site code PD7))) and avian predation studies (data listed in mortality files), several individual projects also maintain their own database of PIT tag detections that they rely on for analyses.

4.5 Future Considerations

PIT Tag Detection Systems

For salmon habitat-use studies, NMFS currently has PIT detection arrays at four locations strategically placed in the lower estuary and tidal-fluvial reaches. However, before deploying more PIT detection arrays in the LCRE, managers need to determine what type of detections (which ESUs) and how many detections at each site will make installation of detection arrays worthwhile. A serious cost-benefit analysis would need to be performed. Such an analysis should be informed by existing data NMFS has on detection rates and species detected at different locales in the LCRE. It should also be recognized that additional work will likely have to be re-prioritized from ongoing estuary research.

In the meantime, improvement in detection capability in the LCRE could come from the expansion of site-specific studies in the estuary that require increased reliance on intentionally tagged fish released in the vicinity of localized studies areas. These obviously would involve the strategic deployment of detection arrays, which collectively would form a broader detection network. NOAA Fisheries and USACE are implementing such deployments at four tidal channel sites mentioned above (EST-P-10-01), and a pile dike site and trawl sampling on or near the thalweg as part of ongoing AFEP research (BPS-W-00-11).

Future research on fish diverted from a mobile separation by PIT code (MSBC) system behind the trawl near the head of the estuary delta could also provide fish for subsequent PIT- or acoustic-tagging for release at head of the estuary to supplement specific habitat, timing or behavior studies in the lower estuary and nearshore ocean. A prototype method to divert PIT-tagged fish from the trawl system to a sample tank for examination was demonstrated in 2010-11. The MSBC system allows comparison of stock specific and migration route specific (barge vs. inriver) of individual fish growth since tagging and makes possible physiological changes occurring after migration and comingling of various groups of fish in the estuary. Implementation of a full MSBC study would allow these evaluations through the migration season, nested within the known migration time periods for specific stocks of interest. The diverted fish would provide estimates of species composition, including density independent samples (unlike with purse seines) of untagged fish.

Based on information in the PIT Tag Forecast Database, we expect the region to continue PIT-tagging in excess of two million or more of fish annually in the Columbia Basin. It is advantageous to sample these fish as they move throughout the LCRE. This may require the deployment of additional detectors at strategic locations, when the contribution to specific study objectives is clear. These detector needs should be determined for individual studies. No estuary-wide PIT Tag detection system is envisioned at this time. However, a pile dike detection system (prototype in place 2011 and 2012) could be expanded to salt-water and at multiple sites to better cover movements within the estuary and associated vulnerabilities to pinnipeds.

PIT tag technology continues to evolve and technological changes are allowing for larger more robust antennas. Such developments will undoubtedly increase the applicability of PIT tag technology to studies in the estuary.

<u>Site-Specific Studies that Use PIT-Tagged Fish</u>

Site-specific studies using PIT-tagged fish are anticipated. NMFS's site-specific study (EST-P-10-01) using PIT-tagged fish is ongoing. The primary objectives are to measure general habitat use, residence time, and growth of juvenile Chinook salmon in specific habitats within the LCRE. The detections of up-river fish on fixed PIT antennas are important additional data. Action effectiveness studies (to be specified) will likely examine residence time and other measures at habitat restoration sites.

Since 2002, avian predation researchers have PIT-tagged primarily subyearling Chinook salmon at various hatcheries and net pens in the lower Columbia River (about 12,000 per year at 3 or 4 locations). A few groups of coho salmon and steelhead were also tagged in some years. Representatives of these groups recovered on the bird colonies represented impacts on these fish relative to those emanating from the upper river and some were detected in off-channel habitat arrays as well. These are other examples of specific estuary studies that benefitted from the strategic releases of PIT-tagged fish and deployment of PIT tag detectors.

The need for PIT detectors is developed at the individual project level; at this time, there is no programmatic strategy for the LCRE with respect to PIT tag investigations or an accompanying detector system. The University of Washington is currently (fall 2012) developing a general statistical plan for application of PIT technologies to specific programmatic research questions in the LCRE.

Table 2. PIT Research in the Lower Columbia River and Estuary.

Project No.	Short Title	Research Agency(s)	Funding Agency/ Program	Project Status	Project Purpose	PIT Antenna Location(s)	Fed to PTAGIS	Performance Indicator	Estuary Application Category
EST-P-09-01	Salmon Benefits	PNNL/ USFWS/ UW	USACE AFEP	2010; no other PIT research planned	Estimate entrance propensity for off-channel wetlands	6 -antenna arrays at Cottonwood Island and vicinity (rkm 115); 2010 only	Yes	Entrance propensity; passage rates; passage timing; residence time	Tidal channels
EST-P-10-01	Tidal Fluvial	NMFS	USACE AFEP	Ongoing; yearly since 2008 (usually March thru September)	Measure habitat use and performance of juvenile Chinook salmon in shallow water estuarine habitats. Travel times and migration pathways of diverse stocks and life history types that enter off-channel habitats	Tidal channel on Russian Island in Cathlamet Bay (rkm 36, started in 2008); Woody Island (rkm 47, started 2011); Wallace Island (rkm 80, started 2011); lower Suavie Island (rkm 141, started 2012)	Yes (?)	Residence time, growth rates. Presence of upriver ESUs; travel times and residence times of upriver ESUs	Tidal channels
EST-P-11-01 (merged with EST-P-05-07)	Multi-Scale AER	USFWS with PNNL/ ODFW/ UW/ NMFS	USACE AFEP	Ongoing; yearly since 2007; various locations	Assess fish passage and behavior at retro-fitted tide gates	PIT arrays at the JBH Nat'l Wildlife Refuge (rkm 60); Tenasillahee Island (rkm 56, 2007 and 2008)	Yes (?)	Passage rates; passage timing; residence time	Tide gates
BPS-W-00-11	PIT Trawl	NMFS	USACE AFEP	Ongoing annually since 2000	Detect PIT-tagged fish in main channel LCRE to allow estimation	PIT detection arrays in cod end of a large trawl (rkm 61-83)	Yes	Passage timing; survival estimates; fish condition; stock composition;	PIT Trawl

Project No.	Short Title	Research Agency(s)	Funding Agency/ Program	Project Status	Project Purpose	PIT Antenna Location(s)	Fed to PTAGIS	Performance Indicator	Estuary Application Category
					of reach survival to BON+PIT diversion sampler			migration history (barged vs. in-river)	
2003-007-00	Ecosystem Monitoring	LCREP/ NMFS	BPA F&WP	Deployed in 2011 and 2012	Determine fish residence times in shallow, tidal habitats	Paired-antenna arrays at Campbell Slough in Ridgefield National Wildlife Refuge (ca. 1.4 km from mainstem at rkm 145)	Yes (?)	Passage rates; passage timing; residence time	Tidal channels
2003-011-00	Habitat Restoration	LCREP/ NMFS	BPA F&WP	Preparations in 2012	Assess fish passage and behavior at culverts connecting off-channel and main channel habitats; AEM for restoration actions improving fish access	Paired antenna arrays upstream and downstream of culvert at Oneonta/Horsetail Falls (rkm 222)	Yes (?)	Passage rates; passage timing; residence time	Culverts
	Bird colony PIT detections	NMFS	AFEP	Ongoing	Predation impacts	Mobile PIT at the bird colonies on islands in the lower estuary	Yes		Predation
PDA	Pile structures	NMFS	---	Pilot study	Fish movement patterns at pile structures; arrival timing, survival and timing of adults to Bon or	Integrated within pile structures	Yes	Presence, residence time; movements; survival	Pile structures

Project No.	Short Title	Research Agency(s)	Funding Agency/ Program	Project Status	Project Purpose	PIT Antenna Location(s)	Fed to PTAGIS	Performance Indicator	Estuary Application Category
					Willamette Falls				
	Adult survival to BON	NMFS	---	Ongoing since 2010 pending funding	Survival, residence, run and passage timing, and natural mort./predation impacts of adult salmon in the LCRE	BON	yes	Survival; residence; run and passage timing; and natural mortality/predation impacts	Adult migration
	Predator study -= tag NPM	ODFW	BPA	Ongoing	Predation impacts	Various locations	Yes		Predation
MSBC	Mobile separation by code	NMFS	BPA	Suspended	Passively separate fish concentrated by the estuary trawl to a sample tank	Estuary trawl	Yes	Presence, growth (following tagging), physiological condition	Migration

Project No.	Short Title	Research Agency(s)	Funding Agency/ Program	Project Status	Project Purpose	PIT Antenna Location(s)	Uploaded to PTAGIS?	Performance Indicator	Estuary Application Category
EST-P-05-07	Julia Butler Hanson	USFWS	USACE AFEP	Ongoing	Assess fish passage and behavior at retro-fitted tide gates	Paired-antenna arrays at the JBH Nat'l Wildlife Refuge (rkm 60)	Yes(?)	Passage rates; passage timing; residence time	Tide gates
EST-P-09-01	Salmon Benefits	PNNL/ USFWS/UW	USACE AFEP	Ongoing 2010; no PIT research planned for 2011	Estimate entrance propensity for off-channel wetlands	6 paired-antenna arrays at Cottonwood Island and vicinity (rkm 115)	Yes	Entrance propensity; passage rates; passage timing; residence time	Tidal channels
EST-P-10-01	Tidal Fluvial	NMFS	USACE AFEP	Ongoing 2010 and 2011	Determine fish residence times in shallow, tidal habitats	TBD	TBD	TBD	TBD
EST-P-11-01	Tidal Freshwater Research	PNNL/ ODFW/ UW/NMFS	USACE AFEP	No PIT during 2010; under discussion for 2011	Perform action effectiveness research	None at this time	n/a	n/a	n/a
BPS-W-00-11	PIT Trawl	NMFS	USACE AFEP	Ongoing annually since 2000	Detect PIT-tagged fish in the main channel LCRE to allow estimation of reach survival to BON+PIT diversion sampler	PIT detection arrays in cod end of a large trawl (rkm 61-83)	Yes	Passage timing; survival estimates; fish condition	PIT Trawl
2003-007-00	Ecosystem Monitoring	LCREP/ NMFS	BPA F&WP	Planned for 2011	Determine fish residence times in shallow, tidal habitats	Paired-antenna arrays at Campbell Slough in Ridgefield National Wildlife Refuge (ca. 1.4 km from mainstem at rkm 145)	Yes(?)	Passage rates; passage timing; residence time	Tidal channels
2003-011-00	Habitat Restoration	LCREP/ NMFS	BPA F&WP	Planned for 2011	Assess fish passage and behavior at culverts connecting off-channel and main channel habitats; AEM for restoration actions improving fish access	Paired antenna arrays upstream and downstream of culvert at Oneonta/Horsetail Falls (rkm 222)	Yes(?)	Passage rates; passage timing; residence time	Culverts
	Bird colony PIT detections	NOAA	AFEP	Ongoing	Predation impacts	Mobile PIT at the bird colonies on islands in the lower estuary	Yes		Predation
	Regan McNatt	NOAA	NOAA	Ongoing	Juvenile salmon ecology	Tidal channel on Russian Island in Cathlamet Bay	Yes(?)	Residence time	Tidal channels
	Predator study = tag NPM	ODFW	BPA	Ongoing	Predation impacts	Various locations	Yes		Predation

5.0 Harvest PIT Tag RM&E

5.1 Key Harvest-Related Management Questions

The FCRPS BiOp specified two management issues that address the impacts and effectiveness of harvest activities in the Columbia River Basin:

- What is the effect of acquiring more accurate and precise in-river harvest estimates on the resultant estimates of straying and adult passage survival?
- Can selective fisheries targeting hatchery fish or healthy populations reduce impacts on ESA-listed populations?

5.2 RM&E Objectives and Associated Performance Measures

To address these management questions, the FCRPS BiOp identifies a total of five Reasonable and Prudent Alternatives. However, only two BPA projects (2008-502-00 and 2008-105-00) utilize PIT-tagged fish to address the management questions. Furthermore, those projects do not call for additional fish to be PIT-tagged specifically for those investigations. Instead, they rely on fish previously tagged under the auspices of ongoing research projects within the region. The harvest-related RPAs from the FCRPS BiOp are listed here. Only three (62.1, 62.2, and 62.3) involve the use of PIT-tagged fish in analyses.

Status Monitoring (SM)

RPA 62.1 – Evaluate the feasibility of obtaining PIT tag recoveries between Bonneville and McNary dams (Zone 6) to determine whether recoveries can help refine estimates of in-river harvest rates and stray rates used to assess adult survival rates. For FY 2009, focus on a pilot to test the feasibility of PIT tag recoveries of harvested fish in this reach (spring, summer, and fall Chinook salmon and summer steelhead).

RPA 62.4 – Support coded-wire tagging and coded-wire tag recovery operations that inform survival, straying, and harvest rates of hatchery fish by stock, rearing facility, release treatment, and location.

RPA 62.5 – Investigate the feasibility of genetic stock identification monitoring techniques.

Action Effectiveness Monitoring (AEM)

RPA 62.2 – Evaluate methods to develop or expand use of selective fishing methods and gear.

RPA 62.3 – Evaluate post-release mortality rates for selected fisheries.

Non-BPA Related Projects

Harvest monitoring is generally not a responsibility of the FCRPS and the AAs. While in some cases the projects described above are jointly called for or supported in forums other than the BiOp or its associated addendums (i.e., NPCC Fish and Wildlife Program; the COE's AFEP process; or HCPs), there are no other management directives to assess harvest management questions, using PIT tags as the research or monitoring tool. Even so, one study funded by BPA under the FWP (Project 2008-105-00) uses some PIT tag data acquired for non-ESA listed species (sockeye and summer Chinook).

5.3 Species/ESU

With regard to population specificity, results from harvest RM&E projects will likely be reported at the species level and perhaps for individual ESUs if suitable numbers of tag recoveries are realized. Given the scope of the projects described herein, data will be acquired for both ESA-listed and unlisted anadromous salmonid species.

5.4 Applications for PIT-Tagged Anadromous Salmonids Relative to Harvest

Of the five RPAs identified above, three involve two research projects that will rely on PIT tag recoveries, and neither of those projects calls for additional fish to be PIT-tagged. They are opportunistic analyses relying on observations of fish PIT-tagged for other purposes that enter fisheries. The following summarizes the RPA projects that will utilize PIT tag recoveries to some extent.

5.4.1 Status Monitoring

Reasonable and Prudent Alternative 62.1 – This RPA will rely on fish PIT-tagged under the auspices of other research projects to improve the monitoring and catch sampling of the Zone 6 tribal fisheries. According to the study proposal (BPA Project No. 2008-502-00) all species entering the fishery that have been PIT-tagged appear to be subject to sampling. There are four general harvest segments within the Zone 6 tribal fishery; a platform fishery, a ceremonial and subsistence gill net fishery, a commercial gill net fishery, and a setline fishery that targets white sturgeon and shad. Currently, catch is assessed using creel surveys, commercial buying records, and aerial surveys of gill nets. However, while extensive, current efforts to assess overall catch and stock composition of these fisheries is incomplete. As such, the Columbia River Inter-Tribal Fish Commission is expanding efforts to increase sample rates and employ additional data collection methods. These efforts will provide fisheries managers with more accurate information regarding overall catch, as well as a more refined estimate of stock specific harvest, by ESU where possible. This work was initiated in 2009 and will be funded through 2017.

5.4.2 Action Effectiveness Monitoring

Reasonable and Prudent Alternatives 62.2 and 62.3 – These RPAs will be addressed in part by BPA Project 2008-105-00, which is being conducted by the Colville Confederated Tribes, and is entitled "Selective Harvest Gear Deployment." The Colville Tribal fisheries focuses on hatchery summer Chinook and sockeye as they stage within the Columbia River prior to ascending the Okanogan River to spawn. As such, it is the desire of the Colville Tribe to release other species (i.e., spring Chinook, summer steelhead, and wild summer Chinook) back into the river unharmed.

The objective of this research is to test a variety of capture methods to collect broodstock, as well as harvest target species from the naturally spawning population for tribal use. A total of 12 different capture methods were initially tested, and have at this point been narrowed to the three most plausible methods; beach seining, purse seining, and tangle nets. These three alternatives have been selected for further evaluation due to the high Catch per Unit Effort (CPUE) associated with each method. While the CPUE for all three methods is high, both purse and beach seining have a post-release mortality of less than 1%, whereas post-release mortality for tangle nets is about 20%. While no fish will be PIT-tagged specifically for this evaluation, PIT tag recoveries will be utilized in this assessment. In addition to assessing the capture methods described above, the Tribe will also evaluate a temporary demonstration weir on the Okanogan River intended to supplement harvest and broodstock collection.

While the efforts described above will presently rely on fish previously PIT-tagged for other purposes, it is possible that additional fish will be PIT-tagged in the future in conjunction with this research. Project funding was initiated in 2008 and will continue until 2017.

Key Performance Measures – With regard to harvest RM&E, neither the FCRPS BiOp nor the FWP specifically identify preferred or required biological or environmental performance measures.

5.4 Future Considerations

Currently there is no intention to expand the status monitoring and AEM efforts using PIT-tagged fish beyond those described in the projects described herein. These RM&E efforts are planned through 2017. We note that the SM performed under project will help inform and improve the accuracy of adult passage survival monitoring though the FCRPS (see Section 3). However, we expect that the implementation of tagging strategies that better represent entire ESUs/DPSs (or MPGs) would generally provide more useful information (differences in stock run timing, improved methods for estimating adult abundance at key locations like Bonneville Dam, alternative methods for evaluating management assumptions, etc.) for hatchery managers (both within and post-season).

6.0 Hatchery PIT Tag RM&E

Hatchery programs in the Columbia Basin have three general management purposes; supporting harvest, reducing extinction risk, and supporting population rebuilding. Often a single program has multiple purposes. Hatchery RM&E is necessary to assess the effectiveness of these programs in meeting their goals, and to understand the critical uncertainties regarding target and non-target populations.

PIT tags are a key tool in assessing hatchery program effects and success. PIT tags have enabled managers and funding agencies to acquire more detailed information regarding the effects of hatchery programs. Tagged fish have been used to estimate migration timing, life stage-specific survival, and other hatchery program-specific information. The expansion of the detection network throughout the FCRPS and into select tributaries has improved the spatial resolution of various performance indices.

It is important to note that not all of the management questions and objectives identified herein rely on PIT tag based information. However, PIT tags could potentially be used to address many or all of the questions and objectives. Other marking methods are also candidates, and once a basin-wide programmatic approach is developed (see CRHEET below), the region will most likely have a firmer understanding of the exact roles that PIT-tagged fish will contribute.

6.1 Key Hatchery-Related Management Questions

To understand the effectiveness of hatchery programs, certain management questions must be answered. The FCRPS BiOp defined these management questions as:

- Are hatchery improvement programs and actions achieving the expected biological performance targets (that are currently defined within each program's RM&E plan)?
- What is the proportion and origin of hatchery fish within naturally spawning salmon and steelhead populations?
- How can hatchery management minimize potential adverse effects of artificial production on listed wild fish, thereby contributing to a reduction in extinction risk for affected natural populations?
- How can properly designed intervention programs using artificial production make the most effective contribution to recovery of listed populations?
- What is the reproductive success of hatchery fish spawning in the wild relative to the reproductive success of wild fish?

6.2 RM&E Objectives and Associated Performance Measures

To address these questions, the FCRPS BiOp identified a number of RM&E objectives that fell into one of two strategic categories; Action Effectiveness Monitoring, and Critical Uncertainty Research. Along these lines, the BiOp established the following hatchery management directives, or objectives, that would require RM&E actions:

- Establish safety-net programs to reduce extinction risk for target ESU populations of Snake River Sockeye Salmon, Snake River Spring/Summer Chinook Salmon, Mid-Columbia River Steelhead, Lower Columbia River Steelhead, and Columbia River Chum Salmon.
- Establish conservation hatchery programs to increase abundance of target ESU populations of Snake River Spring/Summer Chinook Salmon, Snake River Fall Chinook Salmon, and Upper Columbia Steelhead, thereby reducing the time to recovery.
- Implement high-priority hatchery reform actions that are considered major limiting factors by NMFS, which will improve abundance, productivity, diversity, and/or spatial structure of target populations.
- In the future, implement additional hatchery reforms identified through the Columbia River Hatchery Scientific Review Group's review process. Furthermore, in conjunction

with Best Management Practices (BMPs) at FCRPS hatchery facilities, improve abundance, productivity, diversity, and/or spatial structure of target populations, depending on the nature of the reform.

Additionally NOAA and other stakeholders are concerned about potential density-dependent effects of hatchery programs through ecological interactions. The following is offered as an additional general guideline or objective for hatchery mangers:

- The reduction of ecological interactions between hatchery- and natural-origin fish during critical life stages improves abundance, productivity, spatial structure and diversity of the target (and potentially non-target) population.

The strategies and actions developed for hatcheries in the FCRPS BiOp are broad and not well defined. The actions therefore are not as easily categorized, as those described in the hydro section of this Plan. However, RPAs offer more specificity and direction in terms of needed RM&E:

Action Effectiveness Monitoring (AEM)

RPA 63.1 – Determine the effect that safety-net and conservation hatchery programs have on the viability and recovery of the targeted populations of salmon and steelhead.

RPA 63.2 – Determine the effect that implemented hatchery reform actions have on the recovery of targeted salmon and steelhead populations.

Critical Uncertainty Research (CUR)

RPAs 64 and 65 – Estimate the relative reproductive success of hatchery-origin salmon and steelhead compared to reproductive success of their natural-origin counterparts.

RPA 63.2 – Determine if hatchery reforms reduce the deleterious effects of artificial production on listed populations, thereby contributing to a reduction of extinction risk for the affected natural populations.

RPA 64.2 – Determine if properly designed intervention programs using artificial production make a net positive contribution to recovery of listed populations.

6.3 Species/ESU

The BiOp RPAs call for RM&E actions that focus strictly on ESA-listed anadromous salmonids. However, under the FWP, management needs and prescriptions are not limited to listed populations, and include both listed and unlisted salmonid populations. For hatchery related RM&E, non-listed species could interact and potentially affect listed species, so it is important that non-listed species be considered in hatchery RM&E.

6.4 Hatchery Applications for PIT-Tagged Anadromous Salmonids

6.4.1 Action Effectiveness Monitoring

For hatchery programs, determining whether specific changes or "reforms" are having the desired effect, Action Effectiveness Monitoring is required. However, to determine effects, long-term status and trend monitoring is required, especially if the results are determined through the VSP parameters.

6.4.2 Critical Uncertainty Research

The two key critical uncertainties for hatchery programs are relative reproductive success and density dependent effects from ecological interactions.

6.4.3 Status Monitoring

Most information that is needed to determine whether hatchery programs are impacting VSP parameters require long-term status and trend monitoring of natural populations, which is discussed in Section 7.

Objectives – It is important to understand the direct linkage between the hatchery strategies, objectives, and actions. This will assist managers in defining and coordinating tagging needs. Table 3 summarizes how these categories intertwine and Table 4 shows in greater detail how PIT tags are used within hatchery monitoring studies.

Key Performance Measures – For evaluating hatchery programs, much of the information that is used to assess population viability can also be used for hatchery assessment. For example, estimates of adult returns, spawner escapement, spawner origin, etc. are all key metrics that are necessary to assess the success of a hatchery program. In Table 4, a list of RM&E performance measures and associated indicators where PIT tags can be used are identified. Again, as stated above, PIT tags may not be the only tool used to assess some of these performance measures. There are also other performance measures and indicators for hatchery RM&E that do not appear within this table.

Population Coverage – While a comprehensive Columbia Basin-wide programmatic approach for hatchery RME does not yet exist, all hatcheries need some level of monitoring. For AEM and SM, the CRHEET will consider the development of such a programmatic approach (see below). Agency projections of PIT tag releases and detection arrays are catalogued in the PIT Tag Forecast Database.

Table 3. Strategies, management questions, objectives, actions and RPA association for hatchery monitoring utilizing PIT tags.

Strategies	Management questions	Objectives	Actions	RPA Associations and Use of PIT tags
Monitor Hatchery Effectiveness	Are hatchery improvement programs and actions achieving the expected biological performance targets?	Safety-net programs reduce extinction risk for target populations in Snake River Sockeye Salmon, Snake River Spring/Summer Chinook Salmon, Mid-Columbia River Steelhead, Lower Columbia River Steelhead, and Columbia River Chum Salmon ESUs. Conservation hatchery programs increase abundance of target populations in Snake River Spring/Summer Chinook Salmon, Snake River Fall Chinook Salmon, and Upper Columbia Steelhead ESUs, thereby reducing the time to recovery.	Determine the effect that safety-net and conservation hatchery programs have on the viability and recovery of the targeted populations of salmon and steelhead. Determine if hatchery reforms reduce the deleterious effects of artificial production on listed populations, thereby contributing to a reduction of extinction risk for the affected natural populations. Determine if properly designed intervention programs using artificial production make a net positive contribution to recovery of listed populations	**RPA 63.1** ● Population trend monitoring by origin ● Spatial structure of HOS ● Stray rates **RPA 63.2** ● Natural origin population trend monitoring ● pHOS ● Stray rates ● Spatial structure of HOS ● Various adult management measures **RPA 64.2** - Same as 63.1
		Reduction of ecological interactions between hatchery- and natural-origin fish during critical life stages improves abundance, productivity, spatial structure and diversity of the target (and potentially non-target) population		**RPA 63.2** - Same as above and in addition: ● Residualism rates ● Rearing area use of non-migrating HOF ● Growth rate of NOF and HOF juveniles ● Pre-spawning staging ● Pre-spawning mortality
	Can hatchery reforms reduce the deleterious effects of artificial production on listed populations, thereby contributing to a reduction in extinction risk for affected natural populations?	High-priority hatchery reform actions (i.e., those needed to address hatchery programs) that are considered major limiting factors by NMFS, result in improved abundance, productivity, diversity, and/or spatial structure of target populations.	Determine the effect that implemented hatchery reform actions have on the recovery of targeted salmon and steelhead populations. Determine if hatchery reforms reduce the deleterious effects of artificial production on listed populations, thereby contributing to a reduction of extinction risk for the affected natural populations.	**RPA 63.2** - see above

Table 3. Continued.

Strategies	Management questions	Objectives	Actions	RPA Associations and Use of PIT tags
Monitor Hatchery Effectiveness	Can properly designed intervention programs using artificial production make a net positive contribution to recovery of listed populations?	Safety-net programs reduce extinction risk for target populations in Snake River Sockeye Salmon, Snake River Spring/Summer Chinook Salmon, Mid-Columbia River Steelhead, Lower Columbia River Steelhead, and Columbia River Chum Salmon ESUs. Conservation hatchery programs increase abundance of target populations in Snake River Spring/Summer Chinook Salmon, Snake River Fall Chinook Salmon, and Upper Columbia Steelhead ESUs, thereby reducing the time to recovery.	Determine the effect that safety-net and conservation hatchery programs have on the viability and recovery of the targeted populations of salmon and steelhead. Determine if hatchery reforms reduce the deleterious effects of artificial production on listed populations, thereby contributing to a reduction of extinction risk for the affected natural populations. Determine if properly designed intervention programs using artificial production make a net positive contribution to recovery of listed populations.	**RPAs 63.1, 63.2, and 64.2** - see above
Investigate hatchery critical uncertainties	What is the reproductive success of hatchery fish spawning in the wild relative to the reproductive success of wild fish?	High-priority hatchery reform actions (i.e., those needed to address hatchery programs) that are considered major limiting factors by NMFS, result in improved abundance, productivity, diversity, and/or spatial structure of target populations.	Estimate the relative reproductive success of hatchery-origin salmon and steelhead compared to reproductive success of their natural-origin counterparts.	**RPAs 64 and 65** ● PIT tags are an essential tool for identification of individual fish for pedigree studies (see AHSWG 2008 for study design considerations)
	What is the proportion and origin of hatchery fish within naturally spawning salmon and steelhead populations?	Future implementation of additional hatchery reforms identified through Columbia River Hatchery Scientific Review Group's hatchery review process, combined with use of best management practices (BMPs) at FCRPS hatchery facilities, improve abundance, productivity, diversity, and/or spatial structure of target populations, depending on the nature of the reform.	Determine if hatchery reforms reduce the deleterious effects of artificial production on listed populations, thereby contributing to a reduction of extinction risk for the affected natural populations.	**RPA 63.2** - see above

Table 4. Relationship between performance measures and the possible use of PIT tags for hatchery RM&E studies.

Performance Measure	Indicator	Suggested Protocol/Comment	Analytical Method/Definition
Abundance	Spawner Abundance	PIT tag detections from remote detectors or sampling stations at weirs.	Total number of adults that spawned within the population boundary in a single spawning season.
	Juvenile Emigrant Abundance	PIT tags may be needed to assess trap efficiency, or for other recapture needs.	Estimates of the total number of fry, parr, or smolts emigrating from tributary streams.
Productivity	Progeny-per-parent Ratio	Calculated for naturally spawning fish and hatchery fish separately as the brood year ratio of return adult escapement to parent escapement.	Adult to adult ratio of the abundance of returning adults to the abundance of parents for that brood year. May be calculated for 1) escapement, and 2) spawners. May be calculated for naturally spawning fish and hatchery fish separately.
	Smolt-to-Adult Return Rate (SAR)	Smolt abundance estimated using observations of PIT-tagged juveniles at smolt monitoring sites (weirs, dams) divided by adult returns back to the monitoring site (weirs, dams) using adult PIT-tag observations.	The number of adult returns from a given brood year returning to a point (stream mouth, weir) divided by the number of smolts that left this point 1-5 years prior. Calculated for wild and hatchery origin conventional and captive brood fish separately.
Diversity	Hatchery Fraction (spawning ground)	1) Number of hatchery carcasses divided by the total number of known-origin carcasses sampled. Uses carcasses above and below weirs, 2) Uses weir data to determine number of fish released above weir and calculated as in 1 above, and 3) Use 2 above and carcasses above and below weir. PIT tag detections from remote detectors or sampling stations at weirs.	Percent of fish in the population or on the spawning ground that-originated from a hatchery.
Spatial structure	Stray Rate (percentage)	Carcass surveys of spawning grounds looking for marks or tags or taking scale and tissue samples for DNA analysis. PIT tag detections from remote detectors or sampling stations at weirs.	Estimate of the number and percent of hatchery-origin fish on the spawning grounds, as the percent within MPG, and percent out of ESU.
	Spawner Spatial Distribution	Can be derived by compilation of multiple data sets. Remote PIT tag detection could be key for steelhead.	Target GPS redd locations or reach specific summaries, with information from carcass recoveries to identify hatchery-origin vs. natural-origin spawners across spawning areas within populations.
	PNI (Hatchery fraction on spawning grounds and natural-origin fraction in broodstock)	PIT tags are usually one of the only tools available to determine origin for steelhead on the spawning grounds.	Estimated by the proportion of natural origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery origin fish in the natural spawning escapement (pHOS). The ratio pNOB/(pHOS+pNOB) is the Proportion of Natural Influence (PNI).
	Adult Run-timing	Determined by collecting data on time of first arrival at specified point. May be determined from a onetime observation, or repeated series of observations (e.g., as for test fishery or harvest based estimates of run timing for particular stocks of salmon in the mainstem).	Beginning (10^{th} percentile), peak (mode), and end (90^{th} percentile) time for migration time of hatchery- and natural origin fish.

Table 4. Continued.

Performance Measure	Indicator	Suggested Protocol/Comment	Analytical Method/Definition
Spatial structure	Spawn-timing	Determined from observations of spawning activity and numbers on spawning grounds. May be determined from observations of live adults engaged in spawning activities, redd counts, or carcass surveys. PIT tags are usually one of the only tools available to determine origin for steelhead on the spawning grounds.	Beginning (10^{th} percentile), peak (mode), and end (90^{th} percentile) time for spawning time of hatchery- and natural origin fish.
	Relative Reproductive Success (RRS) (Parentage)	Use a pedigree analysis. See Galbreath et al. (2008). PIT tags are used to identify individual fish.	The relative production of offspring by a particular genotype. Parentage analyses using multilocus genotypes are used to assess reproductive success, mating patterns, kinship, and fitness in natural populations and are gaining widespread use with the development of highly polymorphic
Productivity	Residualism rates	Calculated by dividing the estimated number of residualized fish compared to the estimated number of fish released. Remote PIT tag detection may assist in understanding this indicator.	Number of fish failing to migrate after release (steelhead)
	Precocious rate	Calculated from the estimated number of fish that appear to have matured prematurely divided by the total number of fish in the release group. Remote PIT tag detection may assist in understanding this indicator.	Number of fish failing to migrate after release (Chinook)
Productivity (this is in relationship to ecological interactions)	Habitat use by Hatchery produced fish	PIT tags may be used, but study designs have not been developed.	The number of hatchery-origin fish using a specific habitat type after release.
	Number of fish consumed by Hatchery produced fish		The number of fish observed or estimated to be consumed hatchery-origin fish after release.
	Number of Hatchery and Naturally produced fish consumed (by all predators)		The estimated number of hatchery- and natural origin fish consumed by predators within the observation area.
	Distribution overlap		If hatchery- and natural-origin fish are occupying the same area, determine if they compete for space or food.
	Premature emigration rate (displacement rates)		The number of fish present after a hatchery release divided by the number of fish present prior to a hatchery release.
	Growth rate of Naturally produced fish		Derived from the average size of fish at time x divided by the average size of fish at time x+1. Growth in natural environment over time.
	Habitat use by Naturally produced fish prior to and after Hatchery release		The number of natural origin fish using a specific habitat type.
	Density of fish in holding areas and on spawning grounds		Spawner density (by origin). The number of fish divided by the holding area for holding density and the number of fish on spawning areas divided by that area for spawner density
	Pre-spawning mortality		In relationship to escapement of hatchery- and natural origin fish
	Residualism rates		See above
	Precocious rate		See above

Sample Sizes (N), Precision Targets – Without a basin-wide study design for hatchery RM&E, the exact number of PIT tags that will be used is difficult to determine. Sample size, or the number of PIT tags necessary to obtain the information required to assess the performance measures, is currently dependent on the goals and objectives of individual hatchery programs. In each case, the managers of the hatchery program should apply a power analysis and decide what level of precision is needed to satisfactorily answer the monitoring questions. As the region moves forward with defining a basin-wide hatchery evaluation program (see CRHEET below), a clearer understanding of tagging and detection needs should emerge. Even so, the region has projections for the general magnitude of tagging into the next decade as reflected in the PIT Tag Forecast Database. Those projections have been provided by all parties engaging in tagging activities in the Columbia Basin, including those supported by, AFEP, FWP, NOAA, the states, tribes and HCPs.

Proposed Assessment - In an effort to better inform the upcoming IP, the Hatchery RME Work Group should conduct a power analysis to help focus sample size needs for envisioned hatchery evaluations. It would be instructive to select a suite of key performance indices and demonstrate how precision around those estimates varies with sample size. This will help investigators visualize and appreciate the tradeoffs between tagging effort and quality of estimated parameters. This would assist in the design of future hatchery studies.

Detection Sites – Every hatchery using PIT tags for evaluations should have an efficient detection system for tabulating returns. Recent presentations at the January 2011 PIT Tag Workshop highlighted some of the deficiencies associated with using a hand wand to scan adult fish. The list of stream-based detection systems cataloged in Table 5 also provide critical information regarding tributary use of hatchery fish as juveniles and adults. Stream-based detection needs beyond those described in Table 5 have not been identified by the authors of the Hatchery Section of this plan.

The AA should work with hatchery managers to survey hatcheries they fund and evaluate and document the status of their PIT tag detectors as well as the fish interrogation and data-logging protocols being used.

Table 5. Location of existing and potential PIT tag detection sites throughout the Snake and Columbia River basins.

Domain	Watershed	Potential	Existing (Code)
Mid-Columbia	Deschutes	Mouth of Deschutes	Warm Springs Hatchery (WSH) Round Butte Dam upper Deschutes(RDF)
Mid-Columbia	Yakima	Mouth of Swauk N, W, MF Teanaway Easton Mouth of Satus Mouth of Toppenish Mouth of Naches	Prosser dam (PRO)(PR2) Rosa Dam (ROZ) Roza Fishway (RZF) Chandler facility Cle Elum Dam Bypass (CLE) Easton Accl. Pond (ESJ) Jack Cr Accl. Pond (JCL) Clark Flat Accl. Pond (CFJ) Taneum Creek (TAN) Lower Teanaway River (LMT)
Mid-Columbia	Hood	Mouth of Hood River Mouth of West Fork	
Mid-Columbia	Rock Creek WA		Rock Cr rkm 5 (RCL) Rock Cr rkm 14 (RCS)
Mid-Columbia	Little White Salmon		L. White Salmon Hat (LWL)
Mid-Columbia	Klickitat	Lyle Falls Castile Falls	Lower White Cr (WHC)
Mid-Columbia	Wind		Shipherd Falls Ladder (SFL) Carson Hatchery Adult (CAL) Trout Cr (TRC) Panther Creek
Mid-Columbia	Fifteen Mile Creek Hood	Mouth of Fifteen Mile	Fifteen mile at Ramsey Cr Fifteen mile at Eightmile Cr Eightmile Cr at Fivemile Cr
Mid-Columbia	John Day		Bridge Creek at ODOT Bridge Creek, at Painted Hills Bridge Cr at USGS gage Bridge Cr at Gable Cr. Upper SF John Day Middle SF John day Lower SF John Day MF John Day John Day McDonald Ferry (JD1)

Domain	Watershed	Potential	Existing (Code)
Snake	Clearwater	2 Lolo Creek 2 SF Clearwater 2 Lower Joseph Cr Lochsa	Clearwater River Trap (CLJ) Mouth of SF Clearwater Dworshak Hatchery Adult (DWL) Big Bear Cr Clearwater (KHS) Sweetwater Cr mouth (SWT) Joseph Creek km 3 (JOC) Lapwai Cr near mouth (LAP) Secesh at Zena Cr Ranch (ZEN) Fish Cr Lochsa Potlatch R near Helmer (HLM) Potlatch R near Juliaetta (JUL)
Snake	Grande Ronde	2 in Lower GR	GR Accl. Pond (GRP) Catherine Cr. Accl. Pond (CCP)
Snake	Salmon	EF of the South Fork	Lower Lemhi R (LLR) Lemhi River weir (LRW) Lemhi R weir juv. (LWJ) Hayden Cr Lemhi (HYC) Kenney Cr. Lemhi (KEN) EFSF at Parks (ESS) Big Timber Cr. Lemhi (BTC) Canyon Cr. Lemhi (CAC)
Snake	SF Salmon		SF Salmon at Krassel Cr (KRS) Salmon R Juv. trap (SAJ) SF Salmon Guard Station Br (SFG) SF Salmon Satellite Knox Br. (STR)
Snake	Upper Salmon	Upper Salmon at Shoup	Valley Cr Downstream (VC2) Valley Cr Upstream (VC1) Sawtooth Hatchery (STL)
Snake	MF Salmon		Big Creek at Taylor Ranch (TAY)
Snake	Little Salmon		Rapid River hatchery Pond (RPJ)
Snake Snake	Walla Walla		Oasis Rd Bridge (ORB) Garden City Diversion Burlingame Dam (BGM) Mill Cr Diversion Dam (MCD) Yellowhawk Creek (YHC) Nursery Bridge Dam (NBA) Kiwanis Camp Mill Cr (KCB) Bear Creek (WW2) Harris Park (WW1) Roosevelt St Bridge Mill Cr (RSB)
Snake	Touchet		Touchet at Lowden Dam (LWD)
Snake	Imnaha	Cow Cr. Imnaha (COC) Big Sheep Creek	Lower Imnaha km 7 (IR1) Lower Imnaha km 10 (IR2) Upper Imnaha km 41 (IR3) Big Sheep Cr ISA km 6 (BSC)

Domain	Watershed	Potential	Existing (Code)
Snake	Wallowa		Lostine R Accl. Pond (LOP)8989o
Snake	Umatilla		3 Mile Falls dam (TMF) Umatilla USFWS (UM1) Maxwell Canal (MWC) Feed Diversion Dam (FDD)
Snake	Tucannon	Highway 12 Rkm 22 Marengo Rkm 32 Mouth of Cummings Cr	Lower Tucannon (LTR) Tucannon RR Bridge (TRB)
Snake	Asotin		Upper Asotin Cr (ASB) Lower Asotin (ASA) Charlie Creek (CCA) NF Asotin
Snake	Main Snake	Ice Harbor	2 Lower Granite Dam (GRA, GRJ) 2 Lower Monumental (LM2, LMJ) 2 Little Goose dam (GOJ, GO2) Ice Harbor Dam Combined (ICH)
Mainstem Columbia	Main Columbia	Dalles Dam John Day adult ladders	3 McNary Dam (MC1, MC2, MCJ)) John Day Dam Juv. (JDJ) Priest Rapids Adult (PRA) 2 Rocky Reach (RRF, RRJ) Rock Island adult (RIA) Bonneville Adult (BO1, BO2, BO3, BO4)) Bonneville PH2 Juv. (B2J) Bonneville PH2 Adult (BCC) Wells dam adult (WEA) Chief Joseph Dam
Upper Columbia	Wenatchee	Chewaukum Chumstick Icicle Mission	Lower Wenatchee (LWE) Middle Wenatchee (MWE) Upper Wenatchee (UWE) Little Wenatchee (LWN) Lower Chiwawa R (CHL) Chiwawa Accl. Pond (CHP) Upper Chiwawa R (CHU) Tumwater Dam Adult (TUF) White River (WTL) Lower Nason Cr (NAL) Upper Nason Cr (NAU) Peshastin Cr. (PES) Rolfing Accl. Pond (RFP) Butcher Cr Accl. Pond (BCP) Beaver Cr Accl. Pond (BVP) Coulter Cr. Accl. Pond (CLP)
Upper Columbia	Methow		Lower Methow at Pateros (LMR) Beaver Creek (BVC) Beaver Creek Upper (BVCA2)

Domain	Watershed	Potential	Existing (Code)
			Chewuck R above Winthrop (CRW) Eight Mile Cr. (EMC) Libby Creek (LBC) Methow Twisp (MRT) Methow Winthrop (MRW) Methow side channels (MSC) Lower Twisp R (TWR) Wolf Cr (WFC) Winthrop Hatchery Spring Cr (SCL)
Upper Columbia	Okanogan		Mouth of Okanogan Okanogan channel at VDS3 (OKC) Zosel Dam (ZSL)
Upper Columbia	Entiat		Lower Entiat (ENL) Middle Entiat (ENM) Mad R. Entiat (MAD) Upper Entiat at USFS (EFS) Middle Entiat at Riverwood (ENS) Entiat at Mad R (ENA)
Lower Columbia	Abernathy Creek		Farmers Bridge (AB2) Lower Abernathy (AB3) USFWS Tech. Center (AB1)
Lower Columbia	Willamette River		Sullivan Dam (SUJ) Willamette Falls Fishway (WFF) Leaburg Dam bypass (LEA)
Lower Columbia	Mainstem Columbia		Cottonwood Island (CIC)

6.5 Future Considerations

As discussed above, there is no basin-wide effort in place to conduct a coordinated hatchery RM&E assessment with PIT tags. The potential value of this type of hatchery RM&E coordination has been recognized for some time. An important step in this direction was the development of standardized monitoring measures for hatchery programs by the Collaborative System-Wide Monitoring and Evaluation Project (CSMEP 2004). Subsequent to this effort, the most recent relevant effort was the work of the Ad Hoc Supplementation Work Group (AHSWG 2008). Responding in large part to a critique of supplementation monitoring by scientific review panels (ISRP and ISAB 2005), the AHSWG (2008) reviewed supplementation projects in the Columbia basin and made recommendations on how to move forward with basin-wide coordination.

<u>Columbia River Hatchery Effects Evaluation Team (CRHEET)</u>

Responding to the AHSWG recommendations and amended language in the FCRPS Supplemental BiOp, NOAA Fisheries and BPA have proposed the formation of a technical workgroup to coordinate hatchery RM&E programs in the Columbia basin. The workgroup will review hatchery RME and develop a more streamlined and standardized programmatic approach to hatchery RME within current budget expectations. Specific products of the workgroup will be recommendations for streamlined basin-wide study designs, analytical methods, and monitoring measures to facilitate this research. This workgroup will be called the Columbia River Hatchery Effects Evaluation Team (CRHEET).

Summary of Proposed Assessments

In the future, and perhaps related to CRHEET, the Hatchery RME Work Group should conduct a power analysis to help focus sample size needs for envisioned hatchery evaluations.

In the near future, the AA should work with hatchery managers to survey hatcheries they fund and evaluate and document the status of their PIT tag detectors as well as the fish interrogation and data-logging protocols. This will be performed under the auspices of the Hatchery RME Work Group.

7.0 Habitat RM&E and Population Status Monitoring

This section addresses two general categories for PIT tag-based information for anadromous salmonids; status and trends monitoring of natural populations, and habitat RM&E directed at status and trends monitoring as well as action effectiveness monitoring. These topics are combined in this section because of the clear temporal and spatial overlap.

Population RM&E

Population monitoring programs in the Columbia Basin support management questions regarding the status of listed species:

- What is the status and trend of selected populations?
- What is the status and trend of the MPGs?
- What is the status and trend of the listed species, i.e., the ESUs/DPSs?

Listed species include both wild and hatchery fish. Often a single monitoring program has multiple purposes, including habitat action effectiveness, harvest monitoring, etc. However, the basic indicators are the same – abundance and productivity of salmonid populations on an annual basis. Although the AAs conduct a substantial amount of population status RME, this is not an exclusive responsibility of the FCRPS.

Tributary Habitat RM&E

Tributary habitat status, trends and effectiveness monitoring programs in the Columbia Basin have two general management purposes: monitoring the status and trends of habitat quality and quantity, and assessing the biological effects of habitat management actions. A single monitoring program can have multiple purposes, but the basic framework is the same – tracking indicators of stream habitat quality and quantity through time and space as a function of habitat management action strategies and other landscape-level covariates. Again, habitat RME is not the exclusive responsibility of the AAs, and there are multiple funding agencies in the basin.

PIT tags are an important tool in generating basic population monitoring data and relating these population process features to stream habitat quality and quantity. PIT tags have been used in population monitoring programs for almost two decades and have enabled managers and funding agencies to get more precise information on origin, distribution, survival, and timing – all components of population estimates of abundance and productivity. Not all population monitoring programs use PIT tags. For example, spawning ground surveys estimate spawning escapement (adults) based on live fish, carcass counts, and redd enumeration. Smolt traps are often used for population estimates of juvenile outmigrants. However, some key population monitoring indicators such as parr-to-smolt survival, migration timing and pre-spawn mortality for steelhead and Chinook salmon, and adult steelhead enumeration in some locations, lend themselves very well to the application of PIT tags.

PIT tags have specific benefits over other monitoring methods for RPA requirements and tasks associated with fish population and habitat monitoring and evaluation in the tributary environment. PIT tags can be used to determine abundance, survival and movement, and indirectly allow the development of trends in fish condition. Other monitoring methods can be used to generate these attributes, but for some species, age/size classes and geographies, PIT tags may be a more efficient tool. For example, the ability to identify individual juvenile and adult fish and associate their rearing and spawning with specific watersheds or stream reaches allows the comparison of fish performance measures across gradients of habitat condition. PIT tags also allow the enumeration of fish at times or life stages that are not observable by other means. Ongoing programmatic reviews of status and trend monitoring will examine this issue, and will explore possible efficiencies and savings.

7.1 ESU/MPG/Population Status and Tributary Habitat-Related Management Questions

The FCRPS agencies and others support monitoring of Viable Salmonid Populations (VSP) indicators are for all ESUs, as well as key populations per Major Population Group (MPG). Again, this is a basin wide responsibility and not the exclusive responsibility of the AAs. The AAs have worked with the region to identify the locations where they fund status monitoring.

- What is the abundance, productivity, and spatial distribution of ESA listed populations for the FCRPS?
- Are tributary habitat actions achieving the expected biological and environmental performance targets?
- What are the relationships between tributary habitat actions and fish survival or productivity increases, and which actions are most effective?
- What are the limiting factors or threats preventing the achievement of desired habitat or fish performance objectives?

7.2 RM&E Objectives and Associated Performance Measures

The RPAs in the FCRPS BiOp are meant to help focus and answer these habitat-related questions.

Reasonable and Prudent Alternatives

The strategies and actions developed in the FCRPS process are broad and not as detailed as those in the hydro portion of the BiOp. Thus, the actions are not as easily categorized. The following strategies and actions were developed in the FCRPS BiOp process to help address the management questions. Not all of these RPAs require PIT tag-based information, but we include the entire suite to provide context.

Status Monitoring (SM)

RPA 50.1 – Implement and maintain the Columbia River Basin passive integrated transponder (PIT)-Tag Information System (annually).

RPA 50.2 – Monitor adult returns at mainstem hydroelectric dams using both visual counts and the PIT tag detection system (see Hydrosystem section; annually).

RPA 50.3 – Monitor juvenile fish migrations at mainstem hydroelectric dams using smolt monitoring and the PIT tag detection system (see Hydrosystem section; annually).

RPA 50.4 – Fund status and trend monitoring as a component of the pilot studies in the Wenatchee, Methow, and Entiat river basins in the Upper Columbia River, the Lemhi and South Fork Salmon river basins, and the John Day River Basin to further advance the methods and information needed for assessing the status of fish populations. (Initiate in FY 2007-2009 Project Funding, review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions).

RPA 50.5 – Provide additional status monitoring to ensure a majority of Snake River B Run steelhead populations are being monitored for population productivity and abundance (Initiate by FY 2009, then annually).

RPA 50.6 – Review and modify existing Action Agencies' fish population status monitoring projects to improve their compliance with regional standards and protocols, and ensure they are prioritized and effectively focused on critical performance measures and populations (Initiate in FY 2008, develop proposed modification in FY 2009, and implement modifications in FY 2010).

RPA 50.8 – Report available information on population viability metrics in annual and comprehensive evaluation reports (Initiate in FY 2008).

RPA 51.1 – Support the coordination, data management, and annual synthesis of fish population metrics through Regional Data Repositories and reports (Annually).

Action Effectiveness Monitoring (AEM)

RPA 56.1 – Implement research in select areas of the pilot study basins (Wenatchee, Methow and Entiat river basins in the Upper Columbia River, the Lemhi and South Fork Salmon river basins, and the John Day River Basin) to quantify the relationships between habitat conditions and fish productivity (limiting factors) to improve the development and parameterization of models used in the planning and implementation of habitat projects. These studies will be coordinated with the influence of hatchery programs in these habitat areas. Review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions.

RPA 57.1 – Action effectiveness pilot studies in the Entiat River Basin to study treatments to improve channel complexity and fish productivity (Initiate in FY 2007- 2009 Projects, review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions).

RPA 57.2 – Pilot study in the Lemhi River Basin to study treatments to reduce entrainment and provide better fish passage flow conditions (Initiate in FY 2007-2009 Projects, review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions).

RPA 57.3 – Action effectiveness pilot studies in Bridge Creek of the John Day River Basin to study treatments of channel incision and its effects on passage, channel complexity, and consequentially fish productivity (Initiate in FY 2007-2009 Projects, review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions).

RPA 57.4 – Project and watershed level assessments of habitat, habitat restoration and fish productivity in the Wenatchee, Methow and John Day basins (Initiate in FY 2007-2009 Projects, review and modify annually to ensure that these projects continue to provide a means of evaluating the effectiveness of tributary mitigation actions).

RPA 57.5 – Action Agencies will convene a regional technical group to develop an initial set of relationships in FY 2008, then annually convene the group to expand and refine models relating habitat actions to ecosystem function and salmon survival by incorporating research and monitoring results and other relevant information (Initiate in FY 2008).

7.3 Species/ESU

Ideally all ESUs should have established Viable Salmonid Population (VSP) indicators. At this time VSP indicators are being developed for select ESUs as described herein.

7.4 Applications for PIT-Tagged Anadromous Salmonids in Population Status and Trends and Tributary Habitat

7.4.1 Analysis of Current uses of PIT Tags for Population and Tributary Habitat Objectives

Methods

An analysis of the current uses of PIT tags in the Columbia Basin was conducted using a list of projects provided to the BiOp Workgroups by the Bonneville Power Administration, and is titled *"RPA Associations Report and ISRP Review"*. This is a list of projects slated to move forward and will be reviewed by the ISRP prior to funding. Eventually, PIT tag data from these projects will be integrated into the PTAGIS database. Each project was examined to determine the status of PIT tag use (i.e., whether they were proposing or currently using PIT tags), and the purpose of using PIT tags. Although the length of PIT tag research outlined in most proposals was generally on the order of three years, this exercise only evaluated the tags proposed for use in 2011 in order to provide a short-term assessment of PIT tag use. Out of 149 projects reviewed, 66 projects identified PIT tags as the research tool for all or part of their monitoring program. The use of PIT tags in the Columbia Basin is extensive with 44% of all of the fish and wildlife agency proposals utilizing PIT tags to answer their monitoring questions.

ESUs and DPSs involved include Snake River Spring Chinook salmon, Snake River Fall Chinook salmon, Snake River Sockeye, Upper Columbia Spring Chinook salmon, Upper Columbia Steelhead, Mid-Columbia Spring Chinook salmon, Mid-Columbia Steelhead, Mid-Columbia coho, Lower Columbia Fall Chinook salmon, and Lower Columbia Steelhead. As noted earlier, these species are either the focus of the FCRPS BiOp, or are ESA-listed.

Uses of PIT tags in terms of population and tributary habitat monitoring include: predator control information for pikeminnows, terns and cormorants; hydropower survival estimates; kelt reconditioning; tributary VSP abundance, productivity, and distribution; B-run steelhead determinations; hatchery supplementation program effectiveness; and habitat restoration action effectiveness.

Remote PIT Tag Arrays

The PIT tag detection network in the Columbia-Snake Basin is now expansive, extending well beyond the mainstem dams. The current remote[2] PIT tag arrays are being proposed for expansion in many watersheds and will soon have capabilities that exceed the use of CWT in answering tributary habitat and population questions. There are approximately 155 existing remote PIT Tag detection sites and another 37 either under construction or proposed in existing proposals (Table 5). Please note that Table 5 is not a complete list of remote detectors within the Columbia Basin, and requires additional input from current researchers to be completed. These detectors are deployed in a variety of forms including weirs, traps, stream bottoms, or dams beyond the mainstem FCRPS. Some are permanent installations and others are temporary sites that may not have designated location codes in PTAGIS. Future consideration of how these PIT tag arrays may reduce, or eliminate the need for other studies involving fish status should be explored.

Summary of PIT Tag Use

Lower Columbia River

There are currently two projects that use PIT tags in the Lower Columbia. One tags hatchery fish in both Oregon and Washington for later detection in the Columbia estuary bird colonies. The other study is a reproductive success study for steelhead is being conducted in Abernathy Creek, where both hatchery smolts and wild parr are being tagged.

Upper Columbia River

PIT tag arrays are in deployed in the Wenatchee and Entiat rivers as part of the ISEMP, and there are also arrays in the Methow River. Arrays are also proposed for the Okanogan River, which will provide detection for all major rivers in the upper Columbia. PIT tag data are primarily used to answer VSP and habitat effectiveness questions, but they are also used to parse out upstream migrating adult populations at Priest Rapids Dam, and assist with hatchery effectiveness RM&E.

[2] We designate an array as remote when it is constructed independently of existing cross-stream structures.

Mid-Columbia River

PIT tag arrays are deployed in all major tributaries of the John Day River as part the ISEMP, and also IMWs research. The Yakima River has existing PIT tag arrays, but they are not able to detect a specific TRT population because the location of the arrays combined more than one population, so more arrays are proposed to correct this problem. Modifications at Lyle and Castile falls including PIT tag arrays will allow better enumeration and distribution information for the Klickitat River. Rock Creek, (Washington shore), and Fifteen Mile (Oregon shore), will provide improved information as a result of added detection capability, as well as the Deschutes River.

Snake River

A large number of PIT tags are being used in the Snake River Basin, which are being monitored by an extensive system of detection arrays. Various projects (ISEMP and IMW) within the Lemhi, SF Salmon, Grande Ronde, and Potlatch basins, as well as other sites have improved detection coverage. Reasonable and Prudent Alternative requirements for B-run steelhead have also increased the number of detection sites; and coupled with increased tagging should provide some insight as to the characteristics of B-run steelhead in the Clearwater and Salmon river basins, and their abundance and distribution within those basins. There are also numerous supplementation programs in the Snake being evaluated with PIT tags associated with hatchery evaluations. Lower Snake PIT-tagging is associated with habitat restoration effectiveness monitoring, identifying straying from other tributaries and basic VSP monitoring.

Appendix Tables D-1, D-2, and D-3 provide a breakdown of PIT tag numbers for hatchery juveniles, wild juveniles, run-of-river juveniles, and wild adults that are either proposed through the Categorical Review Process or listed in PTAGIS for the example year 2011. This is not a comprehensive compilation of all PIT-tagged fish released in the basin. Additional fish were tagged under AFEP and various HCPs. The wild juveniles are a combined number of both parr and smolts tagged in tributaries. These numbers should be considered a minimum estimate since many projects had not yet identified the exact number of PIT tags to be used until a statistical power analysis had been completed; but overall, this tabulation depicts the magnitude of fish tagged in a recent representative year.

7.4.2 Current Status of PIT Tag Detection to Support Population and Tributary Habitat Objectives

PIT tag detection systems are being installed in tributary environments across the Columbia River basin. However, there has been no systematic evaluation of their location, nor standardization of their design and maintenance to meet regional needs. PTAGIS currently receives data from many, but not all of these sites. In fact, no single comprehensive list of the sites, their location, configuration and capacity exists, primarily because not all sites have been implemented by FCRPS BiOp parties or to addresses RPA objectives. However, the aggregate suite of PIT tag detection sites across the Columbia River basin certainly is beneficial to Population and Tributary Habitat objectives of the FCRPS BiOp and should be evaluated for spatial-temporal gaps and redundancies. Table 5 is an initial attempt to compile PIT tag detection infrastructure across the basin. The accompanying data from which the table was constructed forms the basis for an evaluation of the system's capacity, though it was not designed to meet that need because the data were not generated through a single, rigorous standard.

7.4.3 RPA Basis for use of PIT Tags

It is important to understand the relationship between the management questions, strategies, objectives and actions. In addition, Appendix Table D-4 shows the association between the management questions, etc., and the appropriate RPA.

7.4.4 How Management Questions can be Addressed by Application of PIT Tags

The use of PIT tags has many applications. Appendix Table D-5 summarizes some of the metrics that are associated with population and tributary habitat monitoring and some of the associated issues or considerations that need to be addressed.

A programmatic approach to the application of PIT tags, both deployment and detection, is necessary for the region to be addressing management questions at the scale of the Columbia River basin efficiently and effectively. A programmatic approach will need to consider what populations are currently, or plan to be, the focus of natural origin fish tagging programs, how many fish or what life stage are to be tagged, and are these tagging rates and locations supported by power calculations? Similarly, locating additional detection infrastructure, beyond what is currently in place, needs to be specified in terms of the ability to answer programmatic questions.

7.4.5 Requirements Guidelines for Managing Data from the Application of PIT Tags to Fish Natural Origin Fish in Tributary Environments

<u>Study Design and Analysis Topics</u>

The expanded use of PIT tag technology in the Columbia River Basin for small stream studies has resulted in an expansion of the functional requirements for a central data management system to support these studies. In this section, based on input from ISEMP researchers (C.E. Jordan, S. Rentmeester, N. Bouwes et al.), we summarize current research topics utilizing PIT tag technology and existing data storage needs, identify methodological needs for the community and suggest a suite of metadata that should be recorded when using PIT tag technology.

The fisheries research community utilizes PIT tag technology for a range of research objectives, including estimating fish populations, studying fish survival and mortality, movement and life history patterns, and fish response to environmental condition. These research objectives are addressed at a wide range of spatial scales, such as investigating species-species interactions and resulting movement patterns (reach scale) (Taiexiera et al. 2007) to population estimates that may utilize several PIT tag arrays across an entire basin (Connolly et al. 2008). Furthermore, PIT tag technology is utilized to answer questions over short and long time frames, such as diel movement patterns (Johnson et al. 2009) and migratory events (Zabel et al. 2005). The application of PIT tag technology to a variety of disciplines requires detailed tracking of equipment set up, sampling designs, and study objectives in order to maintain the integrity and versatility of collected data.

One of the first uses of PIT tag technology was to estimate fish abundance and passage through Columbia River dams. This concept has expanded to small stream studies and PIT tags are now used to estimate population densities within streams and basins. Detections can also be used to verify presence/absence of fish for distribution estimates. Population estimates from PIT tag technology have been used for population monitoring, run-size forecasting, harvest allocation and monitoring, genetic stock identification, hatchery evaluation, and setting benchmarks for recovery actions and mitigation.

Fish survival can be determined with PIT tag technology through a variety of methods, including tracking recaptured individuals within seasons or years (e.g. Brakensiek and Hankin 2007), tracking tag detections in predators, or by analyzing the spatial patterns of detection. Survival estimates are often input variables to life history models (e.g. SHIRAZ), mark-recapture models, and models estimating overall populations. PIT tag technology has been used for calculating delayed mortality, hooking mortality, predator indexing and consumption rates, viability and sustainability studies, estuary use and survival, and ocean use and survival (list compiled by PNAMP Tagging and Telemetry workgroup 2008).

PIT tags are useful for detecting fish movements because a large number of fish can be easily tagged as individuals and tracked over time (Gries and Letcher 2002). Tracking fish movement may be important for evaluating fish use of habitat units as thermal refugia, barrier passage (Aarestrup et al. 2003) or behavioral conditions such as migration due to species' interactions (Taiexiera et al. 2007). Research objectives focusing on fish movement are spatially scale dependent. Small-scale studies track fish movement patterns within sites or arrays and require metadata about array positions within streams, detection order between arrays and antenna positions within arrays. Community composition studies are another example of small-scale movement studies that require detailed information on individuals from multiple species tracked at the habitat unit or reach scale. Fish movement studies that take place at larger spatial scales, such as tracking ocean migration timing and routes, determining stray locations and rates and outlining species distributions, focus on collecting information about the capture histories of individuals at sites, rather than detections at individual arrays or antennas. Examples of important attributes for these studies include site location and the timing of detection within the year.

The ability to track fish as individuals provides an excellent opportunity to gain information on fish response to environmental variables. PIT tag technology has been used for evaluating habitat productivity, microhabitat use, habitat action effectiveness monitoring, and watershed condition. These studies commonly use individual fish density, growth rate, and migration directionality as response metrics for the question of interest. Additionally, these studies track information about the antenna and array positions relative to the environmental variables of interest.

Data Collection Protocols

Data Collection Protocols and Methodology

In ecological investigations, data collection protocols are created or modified for three specific reasons: evolution of research or management questions, advances in measurement technology, and spatial variation across the landscape. Unlike small-scale, question specific data collection efforts, regional-scale research, monitoring and evaluation programs must contend with the complexity of protocol variation. In a regional-scale RM&E program, research and management questions will evolve, measurement technology will advance during the life of the program, and the data collection landscape will display significant variation. As a result, a regional data management systems aimed at supporting RM&E efforts must have the ability to track details about data collection protocols and tie metadata about data collection protocols to the observation data. The metadata must describe rules of inclusion for all observed entities (e.g. fish greater than 60 mm in length) and include a data dictionary of observed attributes and the validation rules for those attributes.

The expanded use of PIT tags for small stream studies is an example of new protocols being developed as a result of advances in measurement technology. While some recent studies have made significant progress in testing equipment and protocols for use of PIT tags in small stream studies - estimating antenna efficiencies (Connolly et al. 2008) and tag detection rates (Horton et al. 2007) - much of the methodology has not been formalized or well documented. To advance the use of PIT tag technology in small streams and to guide development of data management applications in support of these studies, it is critical for the research community to formalize and document methodology associated with site establishment, quality assurance procedures for antenna efficiencies and array detection probabilities, data dictionaries of both required and optional attributes, and descriptions of metric calculation and data summarization procedures. Delay in formalizing and documenting protocols will limit development of data management applications. The development of formal protocols should be tasked to the PIT tag research community.

Despite the need for standardization of protocols, development of prototype data management applications can move forward. We suggest that there is a common set of attributes collected by all researchers utilizing PIT tag technology, regardless of the management topic being addressed or methodology used to collect data. These are 'core' attributes about the equipment (e.g., type of antenna, detection resolution) and detection events (e.g., time of detection, tag code). We have also described natural groupings of studies utilizing PIT tag technology. These groups were described earlier as population estimate, fish movement, survival, and environmental response studies. Additional attributes that are pertinent to these sub-groups are called 'auxiliary' attributes, as they are not required by all studies utilizing PIT tag technology.

Current Metadata

Within the PTAGIS system, a well-defined set of validation rules are enforced for each of the three survey types. These validation rules were established to ensure consistency of a long-term dataset focusing on fish survival within the Columbia River hydrologic system. The validation rules define which attributes are required and acceptable values or ranges for each attribute. This has been an effective data management approach to support survival studies and management decisions related to fish survival. Researchers have expressed a need for greater flexibility in the list of attributes tracked for individual data collection events. Designing a data management system with the ability to ensure long-term data consistency of a primary dataset and to support multiple or flexible validation environments requires careful design considerations and thorough documentation regarding the validation environments. Currently PTAGIS is being updated to address metadata issues.

Metadata and Database Architecture

Site-Level Metadata

Identifying the specific location of fish detections is an essential metadata component, and is required to support data discovery, summarization, and analysis. Spatial location can be expressed in many formats and at multiple scales. For example a location can be expressed as a distance from the mouth of a river, as a distance from a tributary junction, or as a latitude and longitude. Similarly, data could be discovered and summarized by sub-basin, watershed, stream, site, or other spatial scale. Historically, these types of spatial analyses were difficult due to limited processing power and analytical procedures. However, with the rapid advancement of geographic information systems (GIS) and computer processing power, these types of spatial searches and analyses are routine for modern database systems.

In order to support a wide range of spatial searching and analysis capabilities, two pieces of spatial data need to be stored as metadata in the database. First, latitude and longitude for each site needs to be recorded and stored. Additionally, a location on a stream network should be stored as a secondary piece of spatial metadata. Locating a site on a stream network supports a full range of network analysis including identification of upstream or downstream sites, stream distance between sites, and estimates of stream flow or other stream characteristics at the site. During the past twenty years, data practitioners in the Pacific Northwest typically expressed location on a stream network as the distance from the mouth of a river and significant effort was spent maintaining GIS layers of these routes and the distances along routes. While this approach has supported past analysis requirements in the region, ESRI (the world leader in geographic information systems) has pursued a slightly different approach to locating sites on networks. Instead of locating sites relative to the mouth of rivers, the new approach is to locate sites relative to the nearest downstream network junction (tributary junction). Developers of the National Hydrologic Dataset Plus and the Arc Hydro application have both followed this newer approach to network locations.

By storing the latitude and longitude and a stream network location as metadata, a database application connected to a GIS can support a wide range of spatial functionality for the end user. An updated user-interface should allow users to discover, summarize and download data at multiple spatial scales including ESU boundaries, population boundaries, sub-population boundaries, 4^{th} field sub-basin, 5^{th} field watershed, 6^{th} field sub-watershed, and stream. The user-interface should also allow users to discover sites that are located upstream or downstream of a selected site and to report stream distance between sites.

Antenna and Array Metadata

Small stream studies rely on detection of fish at multiple arrays within a site, to determine direction of movement and to evaluate site-level detection probability. For the purpose of this document, antennas are individual coils connected to and identified by the data logger. Arrays span the entire width of a stream channel and can contain one or more antennas. To support these analyses, metadata about antenna and arrays must be maintained within the database for individual sites. Metadata should include which arrays an individual antenna belongs to and the direction (upstream or downstream) and distance between arrays, where distance is measured along the thalweg. This basic metadata will allow determination of within site movement and site-level detection probability. Additionally, a site diagram depicting location of arrays and antennas is valuable metadata and should be stored in the database.

Sample Units within Sites

Frequently small stream studies address questions about intra-site variation in movement patterns, fish densities, or fish behavior. These studies look for variation at spatial scales finer than the site and require that sample units or habitat units within a site be delineated and tracked. Field methods used to delineate and measure within site sample units or habitat units are highly variable and complex, and therefore, managing data about the characteristics of these units may be beyond the scope of a central PIT Tag data management system.

Measurements of the habitat unit's physical characteristics may need to be maintained in an independent database and linked through the unit identifier field. However, the ability to assign tagged fish to a sample unit or habitat unit and maintain the unit identifier as an attribute of the fish is critical for many small stream studies. This functionality can be supported by adding an optional sample unit field to the database. Documentation for individual protocols should define the sample unit attribute as required, optional, or not applicable. Data capture applications will need to enforce this validation rule for individual protocols.

Pre-Processing and Data Summary

Raw interrogation data contains large volumes of data where each record represents a single observation of an individual fish. A series of processing steps must be performed to transform these data into information that can be used to support management decisions. For the purpose of this discussion, we organize the process into steps that assure data quality, steps that calculate derived attributes, and steps that calculate metrics from or summarize the data. Each of these topics will be discussed separately.

Derived Attributes

Derived attributes are additional characteristics of a detection event that can only be calculated by evaluating other detection events for an individual fish. Examples of derived attributes include the first and last time an individual was observed at a site or an array, the direction of movement between detections, the time elapsed between detections of an individual, and the length of time an individual was observed at one array without being detected at other arrays. Each of these analyses requires data from multiple detection events to determine a value for an individual detection event. Processes that perform these types of analysis require computer programming to perform logic evaluations or iterative loops. Programming these analyses is typically very challenging for the average computer user. However, local experts may duplicate effort in writing independent code to perform these processes. A central repository should support these analyses and maintain a process for regularly updating the list of derived attributes that can be calculated.

Calculated Metrics and Data Summaries

Reports of calculated metrics and derived summaries can be organized into four broad categories – detection probability; movement; counts by origin, species, or life stage; and presences/absence of individuals. Within each broad category, individual reports created by defining the inclusion criteria, variables to aggregate by, and the output statistic. We start by describing the categories in more detail and then describing input parameters.

Detection probability describes the portion of fish known to have passed a site, array, or antenna that were actually detected by that site, array, or antenna. The ability to determine that a fish passed an antenna, even if the antenna did not detect that fish, requires knowing both the release origin of the fish and a detection of that fish at a facility downstream of the given antenna. If a fish was released upstream of an antenna and was later detected at a facility downstream of the antenna, then it is assumed the fish passed the antenna regardless of whether it was actually detected by that antenna. Determining detection probability for a given site, array, or antenna requires selecting all fish that were released upstream and were later detected at the given antenna or downstream of the given antenna. Detection probability is calculated as the count of fish detected at the given antenna divided by the count of fish detected at or downstream of the given antenna.

Many management and research questions require data on movement of fish between sites and between arrays within a site. To determine direction and distance of movement, the relative location of sites to each other and arrays within sites must be documented as metadata within the database (see Metadata section). Reports that describe movement will either report all activity of individual fish during a specified time period or will summarize the percent of fish moving downstream, moving upstream, or holding for a given site and time period.

The most common reports are variations of the count of fish that passed a site or array during a specified time period. In addition to specifying the time period, the counts may be specified or grouped by release location, origin, species, or life stage of the fish. Counts-of-fish is a broadly used report and a web based interface should allow users to select values for a range of input parameters. The parameters include detection location and release location expressed as one of a range of spatial scales (array, site, stream, or watershed), date range, agency or project that released the fish, origin, species, and life stage.

Presence or absence of individual fish at a site or array during a given time interval is input data needed to run mark-recapture models. The time interval is determined by the management or research question being asked and may be annual, seasonal, quarterly, monthly, or other equally spaced temporal bins (e.g. 61 day intervals). The output lists all individuals released during a specified time interval and location as rows in the report and the temporal intervals are listed as columns. For each temporal interval a value of true is reported if the individual was detected by any antenna during the temporal interval. A value of false is reported if the individual was not detected by any antenna in the network. This output file is the input for most mark-recapture models.

The description above describes broad categories of reports. To increase flexibility and utility of a data reporting application, it is useful to view the broad categories described above as the basic structure or model for the analysis. Each of these models has a variety of input parameters that modify the results. The input parameters can be grouped as the inclusion criteria for source data, variables to aggregate the output by, and the output statistics or metrics. The inclusion criteria should include the temporal range, spatial location, organizational or programmatic criteria, and type of detections (e.g. all detections, movement only, first or last detection, holding only). The variables by which to aggregate the output by include release and detection location (sub basin, watershed, stream, site, or array), fish species, origin, and life stage.

Proposed Assessments:

1. Assess and evaluate the data analysis methodologies currently in use for sufficiency in addressing FCRPS BiOp Population and Tributary Habitat objectives given proposed or existing PIT tag data collection infrastructure.
2. Assess and evaluate the magnitude of the tagging effort (numbers of tags by life-stage, origin and watershed) related to FCRPS BiOp Population and Tributary Habitat objectives. Furthermore, develop a programmatic approach to streamline and improve multiple uses and efficiencies.
3. Assess PIT tag detection infrastructure modifications or additions (numbers and locations of antenna arrays, capacity and data flow) related to this programmatic approach, and reprioritize to address any deficiencies in the existing detector network.

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Appendix A

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This report is a BiOp RM&E Workgroup product with multiple AA and NOAA staff input, but the following were lead authors for different sections.

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Appendix B

Appendix B. A Preliminary tabulation of numbers of ESA-Listed fish PIT-tagged during the period of 2005-2009 from PTAGIS database tag files.

Chinook

Lower Columbia

Run	Rear type	2009	2008	2007	2006	2005
	Hatchery	14,722	28,544	12,335	6,503	7,628
	Wild	0	176	1	99	7
	Unknown	668	2	15	28	393
Lower Columbia Total:		15,390	28,722	12,351	6,630	8,028

Snake River

Run	Rear type	2009	2008	2007	2006	2005
Spring/Summer	Hatchery	360,628	501,585	64,318	318,899	295,680
Fall	Hatchery	600,659	1,115,508	48,453	504,366	205,192
Unknown	Hatchery	131,410	343,985	121,958	231,005	52,510
Spring/Summer	Unknown	1,915	0	162	0	2
Fall	Unknown	12,987	8,986	19,828	8,297	8,878
Unknown	Unknown	7,719	24,672	29,698	5,771	10
Spring/Summer	Wild	127,779	106,847	87,791	85,463	98,477
Fall	Wild	1,001	1,140	2,021	1,676	1,879
Unknown	Wild	41,740	80,256	41,750	40,900	40,971
Total Spring		490,322	608,432	152,271	404,362	394,159
Total Fall		614,647	1,125,634	70,302	514,339	215,949
Total Unknown		180,869	448,913	193,406	277,676	93,491
Snake River Grand Total:		1,285,838	2,182,979	415,979	1,196,377	703,599

Upper Columbia

Run	Rear type	2009	2008	2007	2006	2005
Spring/Summer	Hatchery	84,675	90,088	58,036	37,478	119,659
Unknown	Hatchery	4,199	10,378	3,390	1,625	0
Spring/Summer	Unknown	3,270	668	83	0	2,898
Unknown	Unknown	3	10,990	4,467	5,624	4,286
Spring/summer	Wild	27,306	62,536	23,247	16,373	4,695
Unknown	Wild	1,848	13,038	496	739	1,794
Upper-Columbia Total:		121,301	187,698	89,719	61,839	133,332

Willamette

Run	Rear type	2009	2008	2007	2006	2005
	Hatchery	18,200	11,194	2,728	2,386	12,127
	Unknown	0	0	0	2	0
	Wild	16,025	59,776	16,242	13,479	1,134
Willamette Total:		34,225	70,970	18,970	15,867	13,261

Other Listed Species

Lower Columbia Coho

Rear Type	2009	2008	2007	2006	2005
Hatchery	6,127	4,224	2	27	1,025
Unknown	0	0	0	128	41
Wild	2,338	6,806	3,382	2,158	1,948
Lower Columbia Total:	8,465	11,030	3,384	2,313	3,014

Snake River Sockeye

Rear Type	2009	2008	2007	2006	2005
Hatchery	67,307	5,957	4,944	5,583	6,667
Wild	699	945	921	885	1,372
Snake River Sockeye Total:	68,006	6,902	5,865	6,468	8,039

Lower Columbia Steelhead

Rear Type	2009	2008	2007	2006	2005
Hatchery	1,225	2,468	1,220	6,883	7,150
Unknown	0	216	1	29	3
Wild	1,339	2,288	1,061	1,631	1,587
Lower Columbia Steelhead Total:	2,564	4,972	2,282	8,543	8,740

Middle Columbia Steelhead

Rear Type	2009	2008	2007	2006	2005
Hatchery	52,704	53,644	59,250	36,438	26,121
Unknown	4,192	3,755	91	62	6
Wild	29,880	42,037	20,419	15,447	22,087
Mid-Columbia Steelhead Total:	86,776	99,436	79,760	51,947	48,214

Snake River Steelhead

Rear Type	2009	2008	2007	2006	2005
Hatchery	301,924	330,383	131,616	143,352	73,343
Unknown	3,367	7,346	1,195	330	3,643
Wild	73,753	141,606	74,652	73,814	64,271
Snake River Steelhead Total:	379,044	479,335	207,463	217,496	141,257

Upper Columbia Steelhead

Rear Type	2009	2008	2007	2006	2005
Hatchery	76,080	115,543	38,968	57,996	380,465
Unknown	7,607	9,960	4	5	41
Wild	14,391	34,756	12,179	9,857	6,522
Upper Columbia Steelhead Total:	98,078	160,259	51,151	67,858	387,028

Willamette Steelhead

Rear Type	2009	2008	2007	2006	2005
Hatchery	2,003	4,684	1,582	0	0
Unknown	1	0	0	0	
Wild	0	4	0	1	
Willamette Steelhead Total:	2,004	4,688	1,582	1	0

	2009	2008	2007	2006	2005
Total Chinook	1,456,754	2,470,369	537,019	1,280,713	858,220
Total Steelhead	568,466	748,690	342,238	345,845	585,239
Total Sockeye	68,006	6,902	5,865	6,468	8,039
Total Coho	8,465	11,030	3,384	2,313	3,014
Total ESU listed Fish by Year:	2,101,691	3,236,991	888,506	1,635,339	1,454,512

Note: Total numbers of adults and juveniles tagged. All fish tagged from an area where a listed ESU exists were presumed to be listed fish.

Appendix C

Appendix C. Power analyses for precision bounding smolt survival estimates.

To: Regional PIT tagging work group
From: Charlie Paulsen
Subj: Increasing precision of lower river reach survival estimates
Date: 8/17/2010

When the group met last fall, we discussed both ongoing PIT tagging programs (CSS, transport studies, etc.) and potential changes to those programs, such as CSS plans to increase tagging of hatchery steelhead. Among possible future efforts, NOAA noted that lower river (McNary to John Day and Bonneville, MCN-JDA-BON) reach survival estimates for Snake spring-summer Chinook and steelhead have had much lower precision than Snake (Lower Granite, LGR-MCN) estimates, and that increasing the precision of lower river reach survivals would enable better regression and simulation modeling of both ongoing smolt survival and the effects of future management actions on listed stocks.

Here, I use the NOAA comments as a starting point for a simple power analysis. The analysis is a first-round attempt to investigate how one might change smolt release numbers and detection probabilities in the lower river to make estimates MCN-BON reach survival as precise as those from LGR to MCN. The motivation is two-fold. The primary reason to do this is to help kick off discussion on future goals for regional PIT-tagging, and so advance the conversation begun last fall. A secondary motivation is simply to investigate whether or not the straw-man goal of making lower river estimates much more precise is plausible, at least on paper. It might, for example, require increasing tagging efforts by a factor of 10, or increasing detection probabilities to something approaching one for every lower river project.

The analysis explores three options for increasing MCN-BON precision. The first is simply tagging more smolts, the second is increasing detection rates at BON, and the third is increasing detection in the estuary trawl. Methods to increase the number of fish tagged are obvious, but obviously depend on logistical constraints and concerns regarding tagging effects. Increasing detection rates at BON could in principle be achieved by changes in project operation (more turbine flow, less spill), and/or via potential spillway detection. Changing project operations might encounter policy and legal constraints, while spillway detection is presently undergoing proof-of-concept testing similar to the work that preceded detection in the Bonneville corner collector. Increasing detection in the estuary would require one or more additional trawl systems, increased effort with available equipment, and/or increased detection in the trawl apparatus. While none of the three options appear impossible, they may all face serious practical constraints, a subject beyond the bounds of this straw-man analysis.

Table 1. Summary statistics, 2005-2009. Snake (LGR-MCN) standard deviations are about 1% for Chinook and 2% for steelhead.

1.A - Chinook

Variable	Minimum	Maximum	Mean
Number Detected at MCN	35,820	89,094	63,021
Number Detected at BON	2,811	11,083	6,913
Number Detected at Trawl	658	3,009	1,636
BON Detection Rate	0.116	0.183	0.154
Survival Rate - MCN to BON	0.517	0.784	0.687
Std. Dev. of Survival Rate	0.030	0.060	0.043
Trawl Detection Rate	0.025	0.045	0.035

1.B - Steelhead

Variable	Minimum	Maximum	Mean
Number Detected at MCN	5,710	21,335	11,141
Number Detected at BON	143	3,215	1,363
Number Detected at Trawl	119	600	263
BON Detection Rate	0.059	0.269	0.169
Survival Rate - MCN to BON	0.325	0.861	0.618
Std. Dev. of Survival Rate	0.053	0.161	0.096
Trawl Detection Rate	0.018	0.055	0.039

Any comparative analysis requires a baseline for the comparison, and this one is no exception. Table 1 displays summary statistics for Snake River yearling Chinook and steelhead, hatchery and wild origin combined, for the years 2005-2009. Survival rates are estimated on an annual basis for each species (i.e., a single release group for each species and year). Note that the release numbers are lower than those in, for example, the annual NOAA passage reports, for several reasons. First, any fish detected in a raceway, and potentially transported, is excluded from the analysis, even if the detection occurred before transport begins each spring. Second, it excludes any releases below LGR. Finally, I simply did not take the time to fine-tune the selection criteria. Despite this, the annual estimates of reach survival and its associated variance are within a few percentage points of the annual NOAA estimates for LGR-MCN (results not shown) and for MCN-BON, the focus herein.

Given a baseline, the next step is to decide what parameters to vary and the range for that variation. For this worked example, I chose to vary the number of smolts at MCN (via changes in number released), then proportion of smolts detected at BON, and the proportion detected in the trawl. In all three cases, I looked at varying the baseline by -50% (e.g., numbers decrease by half), no change, and 50, 100, and 150% increases in releases/detections. This results in 125 (5 cubed) possible future values for the precision of the survival estimate for each species. The precision "target" for Chinook is a standard deviation in MCN-BON survival of 1%, and 2% for steelhead in the same reach, approximately the precision of their respective LGR-MCN survival rates from 2005-2009. As can be seen from Table 1, the 2005-2009 standard errors are about 4-5% for Chinook and 9-10% for steelhead. The targets would therefore require increasing the precision of the 2005-2009 lower river estimates by a factor of 4 to 5 (from 4% to 1% for Chinook, and 10% to 2% for steelhead), a daunting prospect. Simulations were performed using each of the five years of baseline data, and the results were averaged over all five years.

Tables 2A and 2B display the subset of the 125 simulation per species that meet the pseudo-targets (complete results are in the attached spreadsheet). As one can readily see, substantial increases in both number of smolts tagged, Bonneville detection proportions, and trawl detection proportions will be needed to increase precision/decrease standard errors to the desired values.

As noted above, the practicality of these increases is unknown at this point, with the possible exception of increasing trawl effort. That said, the 2 – 2.5 multipliers on MCN and BON detection efficiency imply raising PIT tag detection rates from roughly 15-20% (see table 1 for BON rates, MCN are similar) to 40-50%. This in turn implies increasing spillway detection rates from zero (baseline) to perhaps 30-40%, or roughly half the 70-75% detection rate in the BON corner collector. Whether or not that is in fact possible is of course unknown at present.

One feature of the results that is not readily apparent from the tables is that the question of where to place detectors is not quite symmetric, in the sense that an X% increase in detection rates increases precision more if the increase occurs upstream rather than down. The reason for this is straightforward: an increase in an upstream detection rate (e.g., at MCN) will also increase the number of tagged smolts detected downstream (e.g., and BON and the trawl), while the reverse is not true: doubling detection rates in the trawl has no effect on the number detected upstream. The result, subtle but nonetheless real, is that if cost, feasibility, etc. are roughly equal, it is better to increase detection rates at upstream sites rather than those further down river. As a side note, giving priority to upstream sites would also result in a greater increase in the precision of Snake survival estimates.

In summary, the straw-man example described above is intended as a starting point for discussion of tradeoffs among efforts to "improve" regional PIT-tagging efforts, whatever that term may mean in practice. The illustrative results suggest that if spillway detection is feasible and detection rates are non-trivial, one can in fact substantially increase the precision of lower river reach survival estimates. The example covers only a subset of the ways on might attain this goal – John Day detections, for example, are ignored completely in the work discussed above – but the objective is to get researchers thinking and talking about where to go from here.

Table 2.A. Chinook simulations meeting precision "target".

Number at MCN Multiplier	Detection Multiplier		Mean MCN-BON Std. Error
	Bonneville	Trawl	
2.5	2.5	2.5	0.008
2.5	2.5	2.0	0.009
2.0	2.5	2.5	0.009
2.5	2.0	2.5	0.010
2.0	2.5	2.0	0.010
2.5	2.5	1.5	0.010
1.5	2.5	2.5	0.010
2.5	2.0	2.0	0.011
2.0	2.0	2.5	0.011
2.0	2.5	1.5	0.011
1.5	2.5	2.0	0.011
2.0	2.0	2.0	0.012
2.5	2.5	1.0	0.012
2.5	1.5	2.5	0.013
2.5	2.0	1.5	0.013
1.0	2.5	2.5	0.013
1.5	2.0	2.5	0.013
1.5	2.5	1.5	0.013
2.0	2.5	1.0	0.014
2.5	1.5	2.0	0.014
2.0	1.5	2.5	0.014
1.0	2.5	2.0	0.014
2.0	2.0	1.5	0.014
1.5	2.0	2.0	0.014

Table 2B. Steelhead simulations meeting precision "target".

Number at MCN Multiplier	Detection Multiplier		Mean MCN-BON Std. Error
	Bonneville	Trawl	
2.5	2.5	2.5	0.018
2.5	2.5	2.0	0.020
2.0	2.5	2.5	0.020
2.5	2.0	2.5	0.022
2.0	2.5	2.0	0.022
2.5	2.5	1.5	0.023
1.5	2.5	2.5	0.023

Appendix D

Appendix D. Planned PIT-Tagging efforts as planned for 2011, an example of a recent representative year (provided by Chris Jordan and colleagues at NOAA).

Appendix Table D-1. Columbia River Spring Chinook PIT Tags proposed use for 2011.

Domain	Watershed	Species	Hatchery Juveniles	Wild Juveniles	ROR Juveniles	Wild Adults	Total PIT Tags
Upper Columbia	Chiwawa	UC Spring Chinook	10,000				10,000
	Methow		30,000		3,000		33,000
TOTALS			**40,000**		**3,000**		**43,000**
Mid Columbia Tributaries	Deschutes	MC Spring Chinook		1,500			1,500
	Hood		37,000				37,000
	Klickitat		22,000	1,000			23,000
	Yakima				23,500		23,500
TOTALS			**59,000**	**2,500**	**23,500**	**0**	**85,000**
Snake River Tributaries	Clearwater Hatcheries	SR Spring Chinook	124,800				124,800
	Clearwater			750			750
	Snake			39,300	16,000	7,000	62,300
	Lemhi			7,000			7,000
	Lostine		12,600	1,200			13,800
	Johnson Cr		10,000	3,000			13,000
	Grande Ronde		2,000	5,000			7,000
	Walla Walla			11,800			11,800
	Catherine Cr		21,000				21,000
	Imnaha		21,000				21,000
	Pahsimeroi		21,400				21,400
	Rapid River		52,000				52,000
	Salmon		73,400	2,500			75,900
	SF Salmon			21,400			21,400
	Upper Salmon			1,200			1,200
	Umatilla		7,000	3,600			10,600
	Tucannon		25,000	3,000			28,300
Snake Mainstem	Little Goose Dam				6,036		6,036
	Lower Granite Dam			20,000	132,000		152,000
TOTALS			**370,200**	**119,750**	**154,036**	**7,000**	**650,986**

Appendix Table D-2. Steelhead PIT Tags proposed use for 2011.

Domain	Watershed	Species	Hatchery Juveniles	Wild Juveniles	ROR Juveniles	Wild Adults	Total PIT Tags
Upper Columbia	Methow	UC Steelhead	80,000	1,500		1,500	83,000
	Twisp		20,000				20,000
	Wenatchee		40,000				40,000
TOTALS			**140,000**	**1,500**		**1,500**	**143,000**
Mid Columbia Tributaries	John Day	MC Steelhead		5,912			5,912
	Deschutes			2,500			2,500
	Hood		9,500				9,500
	Klickitat		10,000	2,500			12,500
	Yakima			3,000			3,000
	Rock Cr			1,200			1,200
	Wind			3,000			3,000
TOTALS			**19,500**	**18,112**			**37,612**
Snake River Tributaries	SF Clearwater	SR Steelhead	5,000				5,000
	Clearwater Hatcheries		51,800				51,800
	Lolo		13,000				13,000
	Grande Ronde		35,400	5,750			41,150
	Umatilla		4,500	1,000			5,500
	Walla Walla			3,600			3,600
	Salmon		63,300				63,300
	SF Salmon			5,350			5,350
	Lemhi			10,500			10,500
	Imnaha			10,000			10,000
	Asotin			2,200			2,200
Snake Mainstem	Little Goose Dam				24,249	3,000	27,249
	Lower Granite Dam			16,000	8,249	7,000	31,249
	Snake			25,000			25,000
TOTAL			**173,000**	**79,400**	**32,498**	**10,000**	**294,898**
Lower Columbia Tributaries	Abernathy	Steelhead	1,500	3,000			4,500
TOTAL			**1,500**	**3,000**			**4,500**

Appendix Table D-3. Fall Chinook and Sockeye proposed use for 2011.

Domain	Watershed	Species	Hatchery Juveniles	Wild Juveniles	ROR Juveniles	Wild Adults	Total PIT Tags
Upper Columbia	Wenatchee	UC Sockeye	15,000				
Snake River Tributaries	Salmon	SR Sockeye					
TOTALS			**15,000**				**15,000**
Snake Mainstem	Clearwater	SR Fall Chinook	17,000	10,000			27,000
	Little Goose Dam				10,475		10,475
	Snake		110,600	8,000			118,600
TOTALS			**127,600**	**18,000**	**10,475**		**156,075**
Lower Columbia Tributaries	Kalama, Big Creek, Blind Slough	LC Fall Chinook	12,000				**12,000**
TOTALS			**12,000**				**12,000**

Appendix Table D-4. Strategies, management questions, objectives, actions, and RPA association for population and tributary habitat monitoring utilizing PIT tags.

Strategies	Management Questions	Objectives	Actions	RPA Association and Use of PIT tags

Monitor fish population status and trends	What is the abundance, productivity, and spatial distribution of ESA listed populations for the FCRPS?	Monitor adult returns at mainstem dams using both visual and PIT tag detections
		
		Install in-stream PIT tag detection systems in key tributary environments to complement existing monitoring and habitat management programs
			Monitor adult returns at mainstem dams using PIT tags
			
			To obtain useful estimates of life stage survival at the population or wild ESU level adequate numbers of naturally produced fish need to be PIT-tagged
				50.1 –
				• Data management of PIT tag data stream
				• Specific data management needs for tributary instream detection and random tributary tagging actions
				  ○ location (lat/lon)
				  ○ efficiency (real time) covariates
				  ○ tagging rationale metadata
				
				50.2 –
				• Application of PIT tags to adult enumeration, survival, transit in mainstem
				50.3 –
				• Application of PIT tags to juvenile enumeration, survival, transit in mainstem
				
				50.4 –
				• Application of PIT tags to specific tribs (UC)
				  ○ Estimation of steelhead origin and escapement
				    ○ tagged juveniles – sufficient returns, spatial

Strategies	Management Questions	Objectives	Actions	RPA Association and Use of PIT tags
				structure of detection o common tagging adults – sufficient tagging, spatial structure of detection o Improve estimation of smolt abundance o determining efficiency of smolt traps o instream arrays as outmigrant detectors, rearing phase tagging o Improve estimation of outmigration timing, life stage survival o instream arrays as outmigrant detectors o spatial structure/density of detection 50.5 – • Improve abundance estimation of B-run steelhead in Snake R. o LGR tagging of adults for population allocation o improve distribution of instream detection targeting B-run 50.6 – • Improve adult population estimation in selected watersheds, to meet data quality needs o tagged juveniles – sufficient returns, spatial structure of

Strategies	Management Questions	Objectives	Actions	RPA Association and Use of PIT tags
				detection ◦ common tagging adults – sufficient tagging, spatial structure of detection 50.8 & 51.1– • Regional reporting – indicators needed for management, integrate into data stream AMIP – • One population per MPG adult and juvenile abundance, life cycle based survival information, especially for populations that indicate climate change impacts gradient.
Investigate linkage between habitat quality and quantity and fish population processes in the tributary environment	Are tributary habitat actions achieving the expected biological and environmental performance targets? What are the relationships between tributary habitat actions and fish survival or productivity increases, and which actions are most effective?	Tag rearing juvenile salmonids in key tributary environments to support the evaluation of habitat quality and quantity assessments on fish population processes Monitor juvenile fish migration at mainstem dams using smolt monitoring and	To obtain useful estimates of life stage survival at the population or wild ESU level adequate numbers of naturally produced fish need to be PIT-tagged. Where possible action effectiveness research will	56.1 – • Pilot watershed IMWs, habitat contrast FW survival/abundance/growth/movement 57.1 – • Pilot watershed IMW in Entiat 57.2 – • Pilot watershed IMW in Lemhi 57.3 – • Pilot watershed IMW in Bridge Ck.

Strategies	Management Questions	Objectives	Actions	RPA Association and Use of PIT tags
	What are the limiting factors or threats preventing the achievement of desired habitat or fish performance objectives?	PIT tag detection systems	attempt to examine fish performance at the MPG scale using juvenile and adult PIT tag detection	(John Day) 57.4 – • Evaluate the impact of habitat actions in IMW watersheds 57.5 – • Modeling effort to support evaluation of FW fish population processes as determined by contrast in FW habitat Q/Q

Appendix Table D-5. Relationship between specific metric and questions for the use of PIT tags in population and tributary monitoring and considerations.

Metric or Question	Factor	Consideration or Issue
Juvenile survival Juvenile abundance	Stage specific	Location of detection infrastructure (Habitat Quality and Quantity (HQQ) gradient including restoration)
	Spatially explicit	
Adult abundance	Allocation of returning adults across groups of populations that share a common tagging point	Location of detection/tagging infrastructure
Adult spatial structure	Spatial grain of structure	Location of detection infrastructure
How will survival / abundance be estimated?	Mark/Recapture models specifically for PIT application	e.g. Barker Robust for survival specify tag rate, detect rate / N, precision
What are management applications of abundance / survival data?	Life cycle models	Survival measurements used in demographic models to predict population dynamics
	Mechanistic fish-habitat relationships	Location / density / movement Survival Growth rates (if HOF in addition to PIT) Relate fish response to habitat HQQ contrast
Limitations	Detection efficiency – needs to be known @ each PITDA	• Size limitations of tagging fish (No information from first 6 – 9 months) • Tag effects, tag shedding – how are these tag loses applied to survival/abundance estimates? • What rates would obscure the use of PIT tags for detection of survival/abundance differentiation?