PIT-Tag Effects on Hatchery Salmonids: Carson National Fish Hatchery Spring Chinook Salmon

Annual Report 2011 and Work Plan 2012

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Introduction

Coded-wire-tags (CWT) and passive integrated transponder (PIT) tags are used extensively throughout the Columbia River Basin to address a wide variety of management and research questions. A recent study by Knudsen et al. (2009) found that dual-tagged (CWT and PIT-tagged) hatchery spring Chinook salmon smolts released in the Yakima River had lower smolt-to-adult return rates (SARs) compared to CWT smolts, indicating that PIT-tags may impart a survival bias relative to smolts tagged with CWTs. Given the widespread use of CWT and PIT-tags, further evaluations of potential tag effects would be informative for quantifying the level of bias, if present, associated with each of these two tag types. Towards this end, we initiated the PIT-Tag Effects Study (PTES) at Carson National Fish Hatchery (NFH) with the marking of the brood year 2009 release. The objectives are 1) to determine the effects of PIT-tags on spring Chinook salmon SARs and 2) to determine PIT-tag loss rates throughout the complete salmon life-cycle.

Methods

Spring Chinook salmon from brood year 2009 was the first release from the four-year (brood years 2009-2012) PTES at Carson NFH. The study consist of three tag groups: 75,000 CWT-only fish, 15,000 PIT-tag-only fish, and 15,000 dual-tagged fish (PIT-tag and CWT). Sample sizes were attained by supplementing the current tagging levels at Carson NFH with an additional 50,000 CWT only fish and a dual-tagged group of 15,000 fish. The PTES proposal contains the general study design, including the methods used to select sample sizes (Appendix A).

Historically there have been 4 tag groups at the hatchery: 3 coded-wire-tag groups and a PIT-tag group that are part of ongoing stock assessments. The coded-wire-tag groups consist of 25,000 tags each (75,000 total) and are split between 3 types of rearing vessels (outside raceways, adult ponds, and earthen ponds), with a different tag code for each rearing vessel. The PIT-tag group consists of 15,000 PIT-tagged fish reared in the outside raceways. We chose to rear all PTES fish in the outside raceways to account for potential confounding factors associated with rearing vessels and to not alter the long term data set provided by the PIT-tag group. Historically, the PIT-tag group at the hatchery may have included some fish with CWTs. For the purposes of the PTES, starting in brood year 2009 we ensured that these fish did not also get a CWT and therefore made up the PIT-tag-only group. The existing 25,000 CWT fish that rear in the outside raceways were supplemented with an additional 50,000 CWTs and make up the CWT-only group. Lastly, we added a group of 15,000 fish which received both a PIT-tag and CWT. These fish were considered the dual-tagged group and were given a unique CWT code to identify these individuals from the other CWT groups. Tags consisted of 12mm full duplex PIT tags and 1.5mm decimal coded-wire-tags.

All spring Chinook salmon at Carson NFH were adipose fin marked from late-April to mid-May 2010 at approximately 120 fish/lb. Fish were then returned to the raceways and reared throughout the summer and fall. In mid-November 2010 the fish were CWT and PIT tagged at a size of approximately 35 fish/lb. After tagging the PTES fish were ponded in the outside raceways. The fish were released from the hatchery (rkm 28) to the Wind River on April 14th 2011. The tagging files for the PIT-tagged fish were uploaded to the PTAGIS database on November 9, 2010, and the tagging files for the CWT fish were uploaded to the RMIS database in winter 2011.

A sample of fish from each PTES group was held for 30 days in the hatchery building to assess initial tag retention rates. The dual tagged fish needed to be euthanized to determine both the PIT-tag and CWT retention rates. It was also determined that the CWT-only fish should be euthanized to not impart any bias that may be associated with the 30 day holding period. The PIT-tag-only fish were sampled for tag retention rates and the unique tag codes from these fish were removed from the PTES database which allowed the fish to be returned to the outside raceways and subsequently released. To euthanize as few fish as possible and still collect robust tag retention information, we estimated the expected precision (i.e., coefficient of variation = std. deviation/mean) that would be achieved for various assumed retention rates ranging from 0.90 to 0.99 and sample sizes ranging from 10 to 1000 (Figure 1). At sample sizes greater than ~200 fish, the improvement in precision is relatively small. Therefore, from these data we opted to hold ~300 fish from each PTES tag group for retention sampling to ensure a low coefficient of variation.

A PIT-tag detection array was installed in Tyee Springs between the Hatchery and the Wind River. The array consisted of 6 PIT-tag antennas, a multiplexing transceiver, and computer to log data. We installed this array in order to evaluate mortality that may be occurring between the time of tagging and release, and in order to improve the accuracy of subsequent survival estimates. For the 2009 brood year release, the in-pond mortalities were not scanned for PIT-tags and/or CWT and raceways were not checked for shed tags throughout the rearing period or after the release.

On June 7, 2011 all PIT tag codes were queried from the PTAGIS database and summarized to determine the number and location of detections and average travel time. We conducted an interrogation detail query using all PTES PIT-tag codes as a registered tag file in PTAGIS.

Results

Tagging occurred from November 8 to November 17, 2010. Total numbers of tagged fish, number of fish held for tag retention sampling, and percent of fish that retained their tags are reported (Table 1). No mortalities occurred of fish held for tag retention sampling. Overall, 100% of fish retained their PIT-tags and above 99.0% of all Carson NFH fish retained their CWTs.

Fish from PIT-tag-only and dual-tag groups were detected at a number of detection arrays during their out-migration to the Pacific Ocean. The PIT-tag detection array that was installed in the Tyee Springs release channel experienced equipment failures and subsequently detected only 37 unique PIT-tag codes. The Bonneville Dam detection arrays collectively detected 2,892 unique PIT-tag codes and the estuary trawl array at the mouth of the Columbia River detected 129 unique PIT-tag codes. Twenty-two unique PIT-tag codes were detected at both Bonneville Dam and the estuary trawl (Table 2). This equates to about 1% of the total PIT tagged fish being detected on their outward migration in the Columbia River. The PIT-tag-only and dual-tagged groups were detected at similar rates at each of the downstream detection arrays (Table 2). The two groups also displayed similar average travel times to Bonneville Dam and the estuary trawl array (Table 3) as well as similar estimated survival rates from release to Bonneville Dam and similar detection probabilities at Bonneville Dam (Table 4).

Discussion

In this first year of the PTES, we were successful in achieving the initial study objectives. We successfully tagged and released the target sample sizes for each of the three release groups and conducted tag retention sampling. Estimates of tag retention indicate that tag loss was negligible for all three groups. Following release, the PIT-tag-only and dual-tagged groups displayed similar recovery rates, travel times, survival rates and detection probabilities at downstream arrays. Due to equipment failure, we were unable to estimate survival from tagging until release. However, we have identified measures to reduce the likelihood of similar equipment failures occurring in upcoming study years. During Summer 2011, we will be conducting site visits to Carson NFH during inoculation and spawning periods to refine logistic issues associated with sampling returning adults. Initial adult returns from the 2011 releases will occur in 2012. PTES tasks for 2011-2012 are provided in Appendix B.

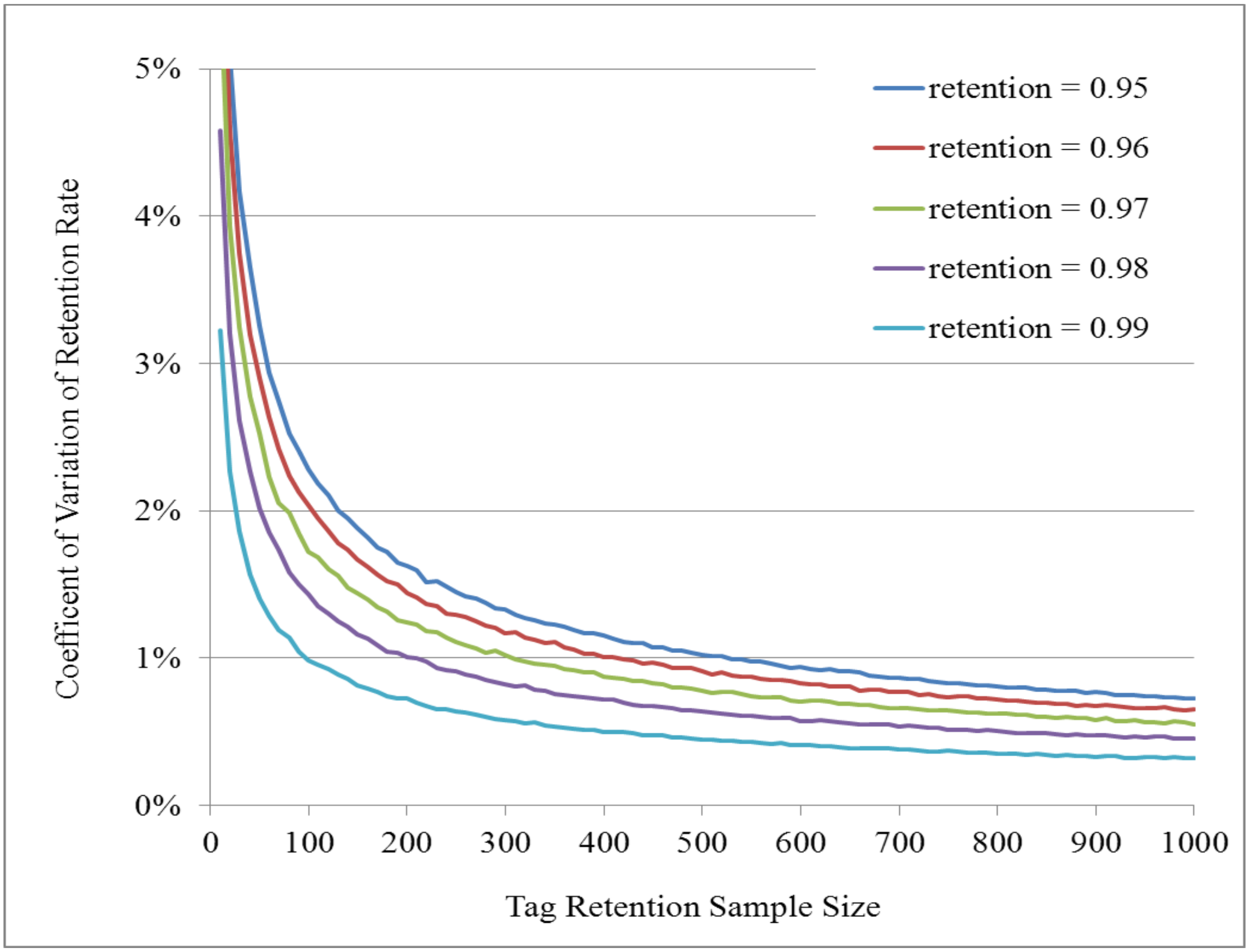

Figure 1. Precision of expected tag retention rates used to determine the sample size of fish held for tag retentions.

Table 1. Summary of tag group sizes and tag retention rates of brood year 2009 Carson National Fish Hatchery spring Chinook salmon. Tagging occurred from November 8 to November 17, 2010 and tag retentions were sampled on December 16, 2010.

	PTES tag groups			Other on-station tag groups	
	PIT-tag only	Dual-tagged PIT / CWT	CWT only outside raceways	CWT only earthen ponds	CWT only adult ponds
Unique CWT code	NA	05-53-58	05-45-68	05-48-29	05-48-30
Total tagged fish ponded	14,646	14,595	74,722	25,121	25,174
Sampled for tag retention	306	289 / 289	305	509	514
Tags not retained	0	0 / 1	1	1	1
Percentage	100	100 / 99.7	99.7	99.8	99.8

Table 2. Detection histories of brood year 2009 PIT-tagged juvenile spring Chinook salmon released from Carson National Fish Hatchery. All data was queried from the PTAGIS database on June 7, 2011 except Tyee Springs release channel information which is housed at the Columbia River Fisheries Program Office. Fish were released on April 14, 2011.

	PIT-tag only		Dual-tagged	
	Counts	Percent of Ponded	Counts	Percent of Ponded
Tagged fish ponded	14646	NA	14595	NA
Tyee Springs release channel	17	0.001	20	0.001
Bonneville Dam	1425	0.097	1467	0.101
Estuary trawl	60	0.004	69	0.005
Bonneville Dam and Estuary Trawl	9	0.001	13	0.001

Table 3. Average travel time in days (± 95% CI) of brood year 2009 PIT-tagged juvenile spring Chinook salmon released from Carson National Fish Hatchery. Fish were released on April 14, 2011.

	PIT-tag only	Dual-tagged
Carson NFH to Bonneville Dam	18.1 (± 0.6)	17.4 (± 0.6)
Bonneville Dam to trawl	7.4 (± 5.4)	14.8 (± 7.5)
Carson NFH to trawl	31.3 (± 1.2)	32.2 (± 1.2)

Table 4. Mark-recapture estimates of survival from release to Bonneville Dam (BON) and detection probability at Bonneville Dam of brood year 2009 PIT-tagged juvenile spring Chinook salmon released from Carson National Fish Hatchery. Standard errors are in parentheses.

	PIT-tag-only	Dual-tagged
Release-to-BON survival	0.65 (0.20)	0.53 (0.13)
BON	0.15 (0.05)	0.19 (0.05)

Appendix A.

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Study Proposal 3/1/2011

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Introduction

Both Coded-Wire Tags (CWT) and Passive Integrated Transponder (PIT) tags are used extensively throughout the Columbia River Basin to address a wide variety of management and research questions. A study by Knudsen et al. (2009) recently found that dual-tagged (CWT and PIT-tagged) hatchery spring Chinook salmon smolts released in the Yakima River had lower smolt-to-adult return rates (SARs) compared to CWT smolts, indicating that PIT-tags may impart a survival bias relative to smolts tagged with CWTs. Given the widespread use of CWT and PIT-tags, further evaluations of potential tag effects would be informative for quantifying the level of bias, if present, associated with each of these two tag types. Towards this end, we conducted sample size calculations to quantify the levels of tagging effort (number of tagged fish released) and study duration (years) that would be required to further evaluate CWT and PIT-tag effects on hatchery spring In addition to tagged fish, the number of untagged fish reared at the hatchery is enumerated annually during mass marking operations (i.e., adipose fin-clipping of all hatchery fish; Hand et al. 2010). Chinook salmon released from Carson National Fish Hatchery (NFH). Spring Chinook salmon from Carson NFH have been selected as an initial location for beginning this evaluation, but a more comprehensive evaluation would result from replicating the general experimental design with other hatcheries and species throughout the Columbia River Basin. Towards this end, we illustrate the general experimental design using Carson NFH as an example, recognizing that sample sizes could easily be modified for replicating the experiment with other locations or species.

General Study Design

The general study design is to release three groups of tagged fish: a number of fish are released with only CWTs, a number of fish are released with only a PIT-tag and a number of fish are dual-tagged, released with both a PIT-tag and a CWT (batch identification numbers for the two groups with CWTs must be different). All fish will be adipose fin marked.

To evaluate short-term tag retention and survival rates for the three groups of tagged fish, a subsample of approximately 300 fish per group is monitored in separate holding facilities. To evaluate mortality that may occur between tagging and hatchery release, a PIT-tag detection array will be installed at the hatchery release channel. Using standard Cormack-Jolly-Seber survival models and downstream detection capabilities at Bonneville Dam, the NOAA PIT-trawl and avian colony recoveries, juvenile reach survival rates will be estimated for the PIT-only and PIT+CWT groups. These survival rates will cover the period from tagging until hatchery release and from hatchery release to Bonneville Dam for these two groups.

Adults returning from these releases are examined for the presence of a CWT and/or PIT-tag and enumerated. Tag loss rates over the life-cycle are estimated by quantifying the number of adults from the dual-tagged group without a CWT (i.e., with a PIT-tag only) and the number of adults from the dual-tagged group without a PIT-tag (i.e., with a CWT only). Tagging effects on SARs are estimated by comparing the SARs for each of the three release groups. The PIT-tag effect is estimated by comparing the dual-tagged SAR to the CWT-only SAR. The CWT effect is estimated by comparing the dual-tagged SAR to the PIT-only SAR. For PIT-tagged groups, we will monitor PIT-tag loss between the time of hatchery return until spawning through periodic sampling of adults at the hatchery.

Study Design Simulation and Sample Size Calculation

Before initiating this PIT Tag Effects Study (PTES), we summarized historical SARs from the facility and species of interest to calculate sample sizes and the associated power to detect a difference (Tables 1 – 4). This will inform study duration and yield the maximum benefit from a limited amount of resources (i.e., tags, personnel, funds, etc.). When calculating sample sizes specific to Carson NFH spring Chinook salmon we assume future SARs will be similar to the brood year 2000 to 2004 average of 0.37% (Pastor 2010). With this information we examined the precision and power of the study design under the following conditions:

- Assumed dual-tagged SARs range from 0.1% to 0.5% over a four-year study,
- Assumed that the CWT-only SARs were 25% higher than the dual-tagged SARs (i.e., the assumed magnitude of the PIT-tag effect),
- Assumed that the PIT-only SARS were 5% higher than the dual-tagged SARs (i.e., the assumed magnitude of the CWT effect),
- Transformed SARs to total instantaneous mortality rates (Z) for statistical properties:
$$Z = -\log_e(SAR), \text{ and}$$
- Used inverse-variance weighted ANOVA approach instead of unweighted linear regression (zero-intercept) approach of Knudsen et al. (2009).

Table 1. Estimated power to detect a 25% increase in SARs of CWT-only group relative to dual-tagged smolts (i.e., PIT-tag effect) for a four-year study across a range of release levels.

Appendix A.

	Number in dual-tagged group and number in PIT-only group				
CWT	10,000	12,500	15,000	17,500	20,000
25,000	0.57	0.64	0.68	0.73	0.75
50,000	0.60	0.67	0.76	0.82	0.83
75,000	0.63	0.69	0.79	0.82	0.84
100,000	0.65	0.71	0.79	0.82	0.84

Table 2. Estimated power to detect a 5% increase in SARs of PIT-only group relative to dual-tagged smolts (i.e., CWT effect) for a 4-year study across a range of release levels.

	Number in dual-tagged group and number in PIT-only group				
CWT	10,000	12,500	15,000	17,500	20,000
25,000	0.11	0.13	0.14	0.12	0.13
50,000	0.11	0.12	0.12	0.14	0.15
75,000	0.11	0.12	0.14	0.13	0.13
100,000	0.12	0.11	0.14	0.13	0.13

Table 3. Coefficient of variation in the estimated PIT-tag effect for a four-year study across a range of release levels.

	Number in dual-tagged group and number in PIT-only group				
CWT	10,000	12,500	15,000	17,500	20,000
25,000	0.46	0.43	0.40	0.38	0.36
50,000	0.45	0.41	0.37	0.34	0.32
75,000	0.42	0.38	0.35	0.34	0.31
100,000	0.41	0.39	0.33	0.33	0.31

Table 4. Coefficient of variation in the estimated CWT effect for a four-year study across a range of release levels.

	Number in dual-tagged group and number in PIT-only group				
CWT	10,000	12,500	15,000	17,500	20,000
25,000	1.32	1.21	1.25	1.24	1.23
50,000	1.35	1.30	1.22	1.25	1.20
75,000	1.29	1.35	1.23	1.26	1.21
100,000	1.32	1.24	1.24	1.27	1.16

From these tables, samples sizes of 75,000 CWT-only fish, 15,000 PIT-tag-only fish, and 15,000 dual-tagged fish have been selected for the Carson NFH study. These sample sizes can be attained by supplementing the current marking levels at Carson NFH with an additional 50,000 CWT-only fish and a dual-tagged group of 15,000 fish.

Appendix A.

Juvenile Tag Retention and Release Sampling

To minimize bias of any PTES study there are logistical considerations that need to be addressed during the period of juvenile tagging and holding and during the period of adult return though spawning. How these considerations are addressed will vary at each facility according to infrastructure, ponding schedules, marking timelines and release dates. Using Carson NFH as an example, tagging of juvenile salmon occurs mid-November and the release occurs in mid-April. Fish tagged as part of the PTES will be randomly distributed throughout the raceways and reared with the rest of the production fish. Approximately 300 fish will be collected throughout the tagging period from each of the three groups, held in the hatch building for 30 days, and then sampled for tag retention of both CWTs and/or PIT tags. All fish held for tag retention will not be incorporated in the analysis of returning adults due to concerns that the 30 day holding period may result in some level of bias. Fish from the CWT-only group and the dual-tagged group will be euthanized and fish from the PIT-only group will be returned to the raceway for release and the PIT tag codes removed from the study's database. The dual-tagged group is euthanized to differentiate between CWT retention and PIT tag retention. The CWT only group is euthanized to remove those CWTs from the release group.

Following tagging, it is difficult to determine whether fish survive the period between tagging and hatchery release. Tags may fail, be shed in the raceway, or tagged fish may be removed by predators. To account for PIT-tag loss and mortality at the hatchery, a PIT array will be installed into the release channel at Carson NFH to detect PIT tags during the release. The release will take place over a 2 day period and we will attempt to detect as many tagged fish as possible leaving the hatchery. This information can be combined with subsequent PIT detections at Bonneville Dam, the NOAA PIT-trawl, avian colony detections and from returning adults to estimate the number of PIT tagged fish that successfully left the facility. An estimate of the number of PIT-tagged fish that successfully left the facility (for each of the PIT-only and dual-tagged groups) will be derived using the Cormack-Jolly-Seber model estimate of survival from tagging until detection at the Carson NFH release channel. These survival estimates will be compared to evaluate whether the PIT-only hatchery survival rate differs from the dual-tagged survival rate. Similar comparisons will be made for these two groups in terms of their survival to Bonneville Dam. After the release all raceways containing PIT tagged fish will be swept for shed tags and any tags found will be enumerated and removed from the dataset.

Sampling of Returning Adults

When sampling returning adults researchers will need to obtain as many opportunistic PIT detections as possible from when fish enter the hatchery to spawning. This is especially important with spring Chinook salmon which return to the hatchery and are held for a long period of time (2-4 months) prior to spawning relative to steelhead (1-4 weeks), for example. A PIT array installed in the adult ladder at Carson NFH will detect PIT-tagged adults as they enter the hatchery holding pond. Once a fish has entered the holding pond there are three more opportunities to detect PIT tags; during inoculation, surplusing, or spawning activities. Carson NFH collects brood stock throughout the run and excess fish are removed from the ponds and surplused. Fish held for brood stock are given an antibiotic injection (inoculation) and returned to the holding pond until spawned. Detecting PIT-tags at inoculation will be used to evaluate whether tags are shed over time as fish mature.

During surplus activities the fish are removed from the pond and donated to a Tribe or Food Bank. All fish will be sampled for presence of a CWT and/or PIT-tag before they leave the facility. Sex, length, scale samples, CWTs and PIT-tag code will be collected for all tagged fish. Spawning activities are more complicated in regards to collecting PIT-tag data. PIT-tags are injected into the body cavity of a fish. During spawning activities the body cavities of both female and male salmon are opened to collect eggs and tissue samples for fish health. During these activities a PIT-tag may be unknowingly removed from the fish. Therefore, immediately prior to spawning it is essential to sample individual fish for the presence of PIT-tags. When a PIT-tag is detected, we have two sampling options that need to be considered. One option would be to remove any PIT-tagged fish from the brood stock for subsequent sampling. If this option is selected, hatchery managers will need to plan accordingly and maintain a larger number of individuals in the brood stock to allow for the subsequent removal PIT-tagged individuals. The other option would be to allow the PIT-tagged fish to be spawned as usual if care is taken to uniquely identify PIT-tagged individuals (e.g., with a uniquely numbered external tag) prior to spawning. The external tags would cross-reference the individual PIT-tag codes, and would allow for standard handling during the spawning and biological sampling process. If a PIT-tag is lost during spawning, but the individual is uniquely tagged, it would be possible to combine the PIT-tag data with CWT, scale, length, and sex information that is not collected until after the fish is spawned.

Study Duration and Analysis

The study design requires four years of juvenile tagging, with adults returning 1-3 years following tagging. Thus, the total study duration will be seven years. We will develop a database to store the juvenile tagging data and the adult sampling data. The PIT-tagged individuals will be uploaded to the PTAGIS database and the CWT individuals will be uploaded to the RMIS database. Annual reports will be written to summarize juvenile tagging and detection history, along with adult return data as it is collected. A final report will be generated within a year of the final adult return year.

Appendix A.

References:

Knudsen, C.M., M.V. Johnston, S.L. Schroder, W.J. Bosch, D.E. Fast, and C.R. Strom. 2009. Effects of passive integrated transponder tags on smolt-to-adult recruit survival, growth, and behavior of hatchery spring Chinook salmon. North American Journal of Fisheries Management 29:658-669.

Pastor, S.M. 2010. Annual Stock Assessment – CWT. U.S. Fish and Wildlife Service Annual Report 2008. http://www.fws.gov/columbiariver/publications/mgr08.pdf

Appendix B. PIT-tag Effects Study work plan for 2011 – 2012.

Year	Month	Activity	Responsible Party*
		BROOD YEAR 2009	
2011	late-June	Complete Annual Report	HAT/WMT
2011	June - August	Site visits to incorporate PIT arrays into adult pond entrance/inoculation/spawning/and surplusing activities (always on Wednesday; alternating surplus and inoculations until beginning of August then switch to spawning activities.	HAT/FMP
2011	June - August	Test bio-sample program that incorporates digital PIT info to other bio data	HAT/FMP
2011	June-November	Build and test adult and bio-sampling PIT arrays	HAT
2011	June-November	Install adult and bio-sampling PIT arrays	HAT
		BROOD YEAR 2010	
2011	Spring	Juveniles adipose marked	FMP
2011	mid-November	Juveniles CWT and PIT tagged	FMP/HAT
2011	mid-November	Ponding numbers and PIT tag data reported to common drive	FMP
2011	mid-November	Juveniles held for tag retention	FMP/HAT
2011	mid-December	Juveniles checked for tag retention	HAT
2011	mid-December	Remove PIT tag codes of PIT tagged only fish from our database	FMP
2011	mid-December	Remove PIT tag codes of dual tagged fish from our database and PTAGIS. Subtract the number of the sacrificed CWT fish from the dual tagged and CWT only release numbers	FMP
2011-2012	November - April	Mortalities collected from ponds and checked for PIT tags and CWTs	Carson NFH/HAT/FMP
2011-2012	November - April	Remove in-pond mortality tag codes from our database and report to PTAGIS	FMP
2012	April	Install in-stream Tyee array for release	HAT
2012	mid-April	Juvenile release	Carson NFH
2012	April - June	Summarize out-migrations	HAT/WMT
2011-2012	November - April	Raceways scanned for shed PIT tags	HAT/FMP
2011-2012	November - April	Remove shed tag codes from our database and report to PTAGIS	FMP
2012	mid-May	remove in-stream Tyee array post release	HAT
2012	late-June	Complete Annual Report	HAT/WMT
2012	June - November	Install adult and bio-sampling PIT arrays	HAT
2012	June - August	Collect bio-data (age, sex, size) and tag codes of returning BY 2009 fish	HAT/FMP

*Hatchery Assessment Team -HAT, Water Management Team -WMT, and Fish Marking Program -FMP