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MEMORANDUM

TO: Tom Karrier, NPCC
Tony Grover, NPCC

Michele DeHart

FROM: Michele DeHart

DATE: November 18, 2009

RE: PIT tag effects

In response to your request the Fish Passage Center staff reviewed the subject journal article; 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. We offer the following comments and responses to your questions.

Our overall conclusions are:

- **Effects of PIT-tagging were extensively studied and documented by the NOAA Science Center during development of PIT-tag methodology. Prentice et al documented the loss of tags in adult females near spawning, and mortality and tag loss in juveniles directly after marking.**
- **The Knudsen article illustrates the potential for PIT tag effects, which has been documented in previous NOAA research;**
- **The results of the Knudsen study can not be applied to other river reaches or other populations of fish.**
- **We have some concerns about inconsistencies in the analysis that may have influenced the results; these should be resolved with the researchers.**
- **PIT tag detection efficiency may be less than 100% efficiency when hand wand readers are used (as was in the Knudsen study) to detect PIT tags in adult salmon or**

steelhead. Failure to account for detection inefficiency may have led to bias in study results or incorrect conclusions.

- **An important point from the study is that all researchers utilizing PIT tags (as well as any other marking method) should be aware of potential PIT tag effects and should address these effects in their analysis and conclusions.**
- **Handling and marking effects are recognized with all tagging methods. These cover a broad range of potential effects including, tag loss and effects on behavior and survival. The severity of effects can be expected to vary depending on tagging technique and handling environment.**

Impacts of PIT-tagging, acoustic tagging and coded wire tagging are documented in the literature

Fishery managers have raised concerns about potential PIT-tag effects since the early stages of PIT-tag development. The NOAA Science Center, under a group headed by Earl Prentice, conducted several years of research over 1986-1994 on PIT-tag retention and their effects on growth and survival of salmonids (Prentice et al. 1986, 1987, 1993, 1994).

Prentice et al. (1986) used laboratory studies to assess juvenile growth, juvenile survival, and adult tag retention, and field studies to assess juvenile survival and recovery rates. They concluded that PIT-tags did not affect growth or survival of juvenile fall Chinook and steelhead, and that tag retention was high for steelhead greater than 85 mm. Adult male Atlantic salmon retained all PIT-tags during hand stripping, while 17% of the adult females shed PIT-tags during hand stripping. In a field study examining survival from release in McNary Reservoir to McNary Dam, they concluded that PIT-tags did not significantly impair survival of juvenile migrant fall Chinook salmon compared to the survival of fish marked with freeze brands.

Prentice et al. (1987) used laboratory studies to assess juvenile growth, survival and tag retention, and field studies to assess juvenile survival and recovery rates. They concluded that tag retention was 99-100% in juvenile Chinook weighing 3 g or larger and that survival was usually greater than 99% for fish 5 g or larger. Juvenile Chinook weighing 2 to 4 g expressed low mortality (usually less than 5%), and mortality appeared to depend on tagging skill. They found that PIT-tagged fish had slightly depressed growth rates at some measurement periods. Field studies showed that PIT-tagged spring Chinook, fall Chinook and steelhead generally had similar or higher recovery rates at Lower Granite and McNary Dams than freeze branded fish. They suggested that the lower recovery rates for the branded fish may have been due to unreadable brands, human error in brand identification, and errors in data recording. The juvenile spring Chinook and steelhead migration times to Lower Granite Dam and McNary Dam were similar between PIT-tagged and freeze branded fish.

Prentice et al. (1993) reported on laboratory studies on sockeye and Chinook salmon. Over a 6 to 8 month period, PIT-tagged and untagged juvenile sockeye had similar growth and survival rates, and survival at 12-14 months post-tagging was greater than 95%. None of the mature male sockeye lost their PIT-tags, while 21% of the mature females lost or rejected their

tags. In a laboratory study on juvenile Chinook, PIT-tagged fish were slightly smaller at the end of the study than untagged control fish, but their survival rates were similar.

Prentice et al. (1994) reported on several evaluations of the effects of PIT-tags on post-release survival. In a predation experiment, they found that internally-tagged (either a PIT-tag or a CWT) and externally-tagged (either a freeze brand or a fingerling tag) steelhead were preyed upon more frequently than untagged controls. In a field study examining overwinter survival and growth of juvenile coho salmon, they compared untagged fish with PIT-tagged, CWT, PIT+CWT, and CWT+VIF (visual-implant-fluorescent) fish. After overwintering, migration rates were not significantly different among the five treatment groups. The untagged group had the highest recovery rate, but this rate was not significantly different than the tagged groups. There were no significant differences in growth among the five treatment groups. They concluded that “PIT tag affects in situ survival no more than the CW tag and that any tagging will generally decrease post-release survival of juvenile salmon.” They also conducted a field study on coho salmon tagged with PIT-tags, CWTs or both on the Skagit River. Tag retention prior to release was 99-100% for all groups. Among the PIT+CWT adults, CWT retention was 98.5% while PIT-tag retention was 68%. PIT-tag loss primarily occurred during late maturation after entering the hatchery, with 11.3% of the males and 47.9% of the females losing their PIT-tags. Based on data uncorrected for tag loss, the hatchery return rates were significantly lower for PIT-tagged fish (1.07%) than for CWT fish (1.45%). The hatchery return rates for the CWT and PIT-tagged groups were not significantly different after adjustment for tag loss. PIT-tagged fish were significantly shorter (2 cm) than CWT fish. Across the studies in Prentice et al. (1993) and Prentice et al. (1994), they concluded that “these data indicate only that PIT tagging does not affect post-release survival more than CW tagging.” Based on other studies and the results of their own studies, they anticipated that “the survival of ocean-ranched PIT-tagged fish would also be lower than that of their untagged counterparts.”

In summation, the Prentice et al. studies raised concerns about tag retention in adult female salmon that were mature and near spawning. Those studies also showed some effects on growth related to the presence of PIT-tags, although not consistently. They concluded that any type of tagging is likely to reduce survival compared to untagged fish, and speculated that PIT-tagging would probably reduce survival to adulthood by 5-10%. The Prentice studies recommended that fish be held a month or more after marking to reduce effects on post-tagging survival to adult return. This recommendation has been implemented within the CSS since its inception.

Double tagging decreases survival

Prentice et al. (1989) found that the effects of PIT-tag on length cannot be separated from the effects of snout CWT tags. They also found an effect of double tagging fish held in seawater net pens. Their analysis determined that double-tagged fish exhibited significantly ($P = 0.001$) lower survival (46%) than the PIT-tagged (66%) or CW-tagged (71%) coho salmon. The survival of PIT-tagged only and CW-tagged only fish did not significantly ($P = 0.622$) differ from each other. Prentice cited Bergman (1968) studies in which survival decreased in juvenile

coho salmon by 4% after eight months of rearing when CWT fish were compared with non-CWT fish, and survival decreased by 8.5% for fish which were CWT with an adipose clip and a pectoral fin clip.

Acoustic tags have been shown to affect survival and behavior

Research has shown that acoustic tags affect juvenile fish survival and behavior. This includes the acoustic tags utilized on juvenile salmonids in the POST array studies, (Welch et al) and the smaller JSAT acoustic tags used in Corps of Engineers studies at dams. Typically the effect of a tag is assumed to be relative to the ratio of the tag weight to overall weight of the organism (tag burden). There is some variability in the accepted range of tag burden used in different studies (Winter (1983, 1996 and 2000; Zale et al. 2005; Adams et al, 1998). Several studies were reviewed by a group of Columbia Basin experts and a series of guidelines were established for study protocols. An intermediate tag ratio 5 to 6.5% was recommended by Peven et al. 2005, in the “Guidelines and recommended protocols for conducting, analyzing and reporting juvenile salmonid survival in the Columbia River Basin. However, acoustic tag studies have used acoustic tags with a tag burden averaging 9.3% (+/- 0.14%), with range of 2.6% to 11.5% (Welch et al., 2008). A joint study, presently being implemented by NOAA Fisheries, Batelle Northwest and the US Army Corps of Engineers (AFEP Research Review December 2007), using yearling Chinook with surgically implanted acoustic tags with an average body burden of 3% by weight showed a significantly lower relative survival for study fish migrating from Lower Granite to McNary Dam, which was consistent with laboratory studies they conducted at the same time. Other studies conducted by this same group of researchers using subyearling Chinook found that tag burdens approaching 5% showed negative effects on the performance and behavior of the subyearling salmon after two weeks. These studies clearly demonstrate the potential for tag effects on study results.

Fishery managers are aware of potential PIT- tagging affects and have undertaken multiple studies to address tag effects.

The fishery management agencies have undertaken several studies to further address the potential affects of PIT-tagging. The ISAB/ISRP reviews of the Comparative Survival Study raised the issue of potential impact of PIT tagging on adult return and study results. The CSS Oversight Committee has undertaken analysis to address the ISAB/ISRP comments. The CSS Oversight Committee is comparing causes of variability in SARs estimated from PIT tagged fish and SARs estimated from non-PIT tagged groups. Thus far these analyses are showing that the estimation of juvenile abundance in the non-PIT tagged groups appears to be the source of uncertainty in comparing SARs..

Ongoing efforts to measure PIT-tag effects on SARs

The U.S. Fish and Wildlife Service have recently developed a study design that could be implemented, with Council support, across the basin to assess PIT-tag effects at hatcheries.

Preliminary sample size calculations indicate that approximately 10,000 PIT-tags would be necessary each year, for 4-5 years to detect differences with high power in SARs compared to CWT fish. They are proposing to begin with Carson NFH spring Chinook, and are interested in conducting a basin-wide study at other hatcheries and with other species.

The Idaho Department of Fish and Game in cooperation with the Lower Snake Compensation Plan (LSRCP) and Comparative Survival Study (CSS) is conducting studies at hatchery facilities to address differences in PIT-tagged adult returns and non-PIT-tagged adult returns. One early result of these studies showed that on site detection using a single reader at the South Fork Salmon River trap was only about 90% efficient. Preliminary results also suggest that run reconstruction based on adult dam counts requires careful accounting for factors such as after hour passage, fallback, and reascension rates, and size criteria used for jacks and adults. Notably, accounting for those factors requires the use of PIT tags. Future expanded IDFG comparative studies are planned in cooperation with LSRCP and the COE multiple hatchery facilities and species.

Review of the Knudsen article

Our conclusions regarding the Knudsen article are that the article does not raise any new questions regarding PIT-tag effects that have not been documented in the literature. There are several study design and analytical factors that seriously limit the management applications of these results.

Specific Questions:

Is it reasonable to assume that mortality and tag loss also occurs in different fish in different reaches, even if the magnitude of the impact varies?

Mortality due to tagging and handling, and tag loss occurs with any tagging activity, with all types of tags at all life stages. The best example of this is the acoustic tag POST array studies in which tagging effects were not addressed in the study yet the study results primarily reflected the tag effects. Studies conducted by Battelle Northwest Laboratories have shown that the JSAT acoustic tags being used in Corps of Engineers studies at dams effect survival and behavior of juvenile fall Chinook. It is reasonable to assume that all tagging methods in all areas at all life stages have some potential for tagging and handling effects. The Knudsen study results however can not be applied specifically to other tagging areas in other reaches. We discussed the reasons for caution, in management application of the Knudsen study in previous discussion. Potential for tagging effects, regardless of the tagging method, should be addressed in each specific research study.

Does this research mean that we need to modify our current pit tagging procedures--using double tagging for example--to get reliable and accurate results?

No, this research does not indicate that PIT tagging procedures need to change. Documented and potential tagging and handling effects should be addressed in study design development and development of analytical methods. Double tagging fish will not address the tagging effect for

PIT tags in all studies. In fact research has shown that double tagging with PIT tags and coded wire tags significantly lowered survival when compared to PIT tagged or coded wire tagged fish alone (Prentice et al 1989). Double tagging may introduce additional and different tagging effects. However, further study into the PIT tag effects should be pursued. This is consistent with recommendations of the ISAB in their recent reviews of the CSS study and in their review of tagging.

Does this research mean that some of our results in the past are not accurate and either need to be revised or discounted?

No, the Knudsen study and analysis has serious limitations for management applications. The status and utility of past results of other studies depends upon the specific study and the specific application of results. In studies in which PIT tagged groups are compared to other PIT tagged groups, such as the CSS study, any PIT tag mortality or tag loss would presumably affect both groups so the study results and conclusions would not be affected.

Which results are potentially most susceptible to this tagging loss and mortality bias? Are these results likely to understate the actual level of fish survival?

Any study results in which the researchers have not specifically accounted for or addressed tag effects, or handling effects in their analysis and conclusions. Any study in which the tag group results (any type of tag) are directly applied to the run at large untagged population without addressing tagging affects in results and conclusions.. In the CSS study comparisons are made among PIT-tagged groups. In considering passage conditions and their effect on fish passage success and survival PIT tag groups are compared to PIT tagged groups. By comparing tagged groups to other tagged groups, it is reasonable to assume that tagging effects or tag loss would be similar in both groups.

What management decisions are made based on information from pit tags that could be affected by this work?

We have previously discussed several issues related to the Knudsen article which seriously limit application of results of this work to management decisions. The Knudsen analysis and conclusions only addressed one group of hatchery fish that along with other concerns limit application of results. We are unaware of any management decisions that are based upon PIT tag results alone. Passage management and fishery management decisions are based upon PIT tag results and acoustic tag results as well as Smolt Monitoring Program passage timing and passage duration data as well as historical data analysis and mathematical modeling. Decision frameworks for management decisions have several components and take into account the limitations of each set of data for each component.

What about slower outward migrants, including the most extreme case being the overwintering fish. Are they undercounted even more than just due to the fact that they may outmigrate when the pit tag detectors are off in the winter, due to expulsion of tags?

PIT tag shedding in adult fish and potential mortality due to tagging in juvenile fish are probably not major factors in overwintering juvenile and adult fish. Data indicates that the overwintering phenomenon in juvenile fall Chinook is primarily a function of hatchery practices, size and time of release. Also historical data indicates that overwintering for fall Chinook has always occurred. Estuary sampling through the winter conducted in the 1970's, found juvenile fall Chinook rearing in the estuaries during winter sampling.. Past data indicates that large numbers of overwintering fall Chinook above Lower Granite Dam were the results of the hatchery back fill releases, in which small fish were released late in the year, a practice that was eliminated several years ago. At the present time some facilities such as Lower Granite Dam maintain PIT tag detection facilities through November, as long as possible before the facilities freeze. Research conducted by NOAA showed that tag loss in juveniles occurs within a month of tagging, resulting in the recommendation that PIT-tagging be conducted a month before release. The same research on adults indicated that PIT-tag loss occurred primarily in adult females that were close to spawning. Based upon this research, it is unlikely that tag loss is a primary issue in detecting overwintering fall Chinook juveniles.

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