Report of the Independent Scientific Advisory Board
Regarding a Research Proposal for Inclusion in the 1998 Smolt Monitoring Program

Proposal Reviewed: Comparative Survival Rate Study of Hatchery PIT Tagged Chinook

Independent Scientific Advisory Board
for the National Marine Fisheries Service
and the Northwest Power Planning Council

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Summary Findings, Concerns and Recommendations, Comparative PIT Tag Study

Findings

- The number of PIT tags to be applied is appropriate to the purposes of the study.
- The utility of PIT tagging now and in the future goes beyond the immediate purposes of this study. Annual PIT tagging of similar numbers of juvenile salmon as a basis for management of the hydroelectric system is advisable.

Points of concern

- Questionable comparability of results on hatchery spring chinook to those that would be obtained from naturally produced spring chinook, other chinook life history types, and other life history types of other species of salmon, increases the uncertainty of advice given to managers.
- The two hatcheries most distant from the hydroelectric system in the 1997 study, Pahsimeroi and McCall, are not proposed for tagging in 1998. Loss of information on geographic variation in survival to Lower Granite Dam that could be important to management should be avoided.
- Comparability of survivals of PIT tagged juvenile salmon relative to survivals of juveniles not PIT tagged is unknown.
- The present suite of survival estimation programs, including this project, does not provide estimates of survival applicable to the entire Snake-Columbia River federal hydroelectric system.
- Coordination and cooperation among agencies applying PIT tags and other marks may not be sufficient to insure the maximum return on the tagging dollar.

Recommendations

1. Fund the proposed study.
2. So long as the present configuration and operation of the federal hydroelectric system exists, extend (or continue) PIT tagging to include naturally reproducing populations of spring chinook whenever population sizes may permit. Continue PIT tagging other chinook life history types, and extend PIT tagging to other life history types of other species of salmon, including steelhead, whenever possible.

3. Apply enough PIT tags to spring chinook production from Kooskia, Pahsimeroi, McCall, Sawtooth, and Clearwater (Powell, Crooked River and Red River Ponds) hatcheries to estimate survival to Lower Granite Dam. Whenever possible apply enough PIT tags to spring chinook at these hatcheries to estimate survivals to McNary Dam.

4. Compare rates of return to each hatchery of PIT tagged and untagged adults to establish degree of comparability of survivals of PIT tagged juvenile salmon to survivals of juveniles not PIT tagged. To investigate rate of shedding of PIT tags through the adult stage, and where straying of adults from another hatchery is possible, investigate thermal mass marking of all hatchery production. Where smolt to adult survival of PIT tagged fish is compared to that of coded wire tagged (CWT) fish, develop a procedure to study tag loss and to compare rate of return of PIT to CWT within the hatchery release.

5. Make estimates of survival applicable to the entire Snake-Columbia River federal hydroelectric system as soon as possible.

6. Use the funding proposal format to promote coordination and cooperation among agencies applying PIT tags and other marks by including a list of other agencies marking salmon and steelhead of the same origin in the proposal, along with comments from those other agencies. Sponsor an interagency workshop on the use of tagging data at five-year intervals. The workshop would produce consensus recommendations and procedures for coordinating tagging activities.

Introduction

To review the chronology of the project from the ISAB perspective, the Council first requested review in December 1996. The first ISAB review, entitled Report of the Independent Scientific Advisory Board Regarding a Research Proposal for Inclusion in the 1997 Smolt Monitoring Program, was provided in January 1997. Subsequently, a subcommittee of the ISAB met with the project scientists in Spokane in April 1997. An oral report of the technical meeting was given to the Council at its Spokane session the day following. In May 1997 two members of the ISAB subcommittee made a site visit to Lower Granite Dam to view sampling procedures and methods during the emigration of tagged fish. The present report is submitted in response to a request from the Council submitted in October 1997.

Specific concerns identified in the first ISAB report to the Council may be summarized as follows:

- An apparent lack of coordination and cooperation among salmon tagging entities working on the resolution of common questions. A coordinating committee of technical experts from the agencies that apply and analyze tagging data was recommended to focus the talents and resources of the region on those problems amenable to solution by tagging experiments.

- Insufficient PIT tag detection capabilities to make estimates of juvenile survivals in the reaches below McNary Dam. The lack of detection capability below Bonneville Dam precludes making estimates for survivals of PIT tagged juvenile salmon for the entire federal hydroelectric system (Lower Granite to Bonneville).

- A high likelihood of a low degree of acceptance in the scientific community for the concepts of using long time series of smolt to adult survivals, SAR, to 1) evaluate smolt migration mitigation actions within the hydroelectric system, and 2) use of the SAR of down river stocks to isolate the effect of the hydroelectric system on the stocks from farther up the river.

- The rationale for determining how many fish to tag.

In the report to the Council in April, the ISAB noted ongoing discussions with project scientists (the steering committee) were showing progress in the following areas:

- Coordination and cooperation in project design with the National Marine Fisheries Service.
- Response of the steering committee to the technical concerns of the ISAB, including number of fish to tag, and lower river fish as hydroelectric controls for upriver fish.
- 1997 project implementation.
- The role of the comparative survival study in regional monitoring and evaluation.
- ISAB liaison with the technical group appointed to develop a regional monitoring and evaluation program.

- A process of periodic consultation between the steering committee, the monitoring and evaluation work plan development group, and the ISAB.

A review of the following documents was completed to determine the present status of the project and to formulate our recommendations.

- 1997 Research Proposal for Inclusion in Smolt Monitoring Program. Principal Investigator, Michele DeHart, Manager, Fish Passage Center.
- 1998 Work Plan for the Comparative Survival Rate Study of Hatchery PIT Tagged Chinook. Memorandum dated September 8, 1997. Michele DeHart, FPC Manager.
- 1997 Hatchery PIT Tag Study Survival Estimates for Planning 1998 Releases. Memorandum dated August 28, 1997. Tom Berggern, Fish Passage Center.
- Comparative Survival Rate Study of Hatchery PIT Tagged Chinook – ISAB Concerns from 1/14/1997. E-mail and fax dated 12/9/97. Tom Berggern, Fish Passage Center, for the Hatchery PIT Tag Study Oversight Committee.

At this time the issue of how to compute the number of fish to tag to answer specific research questions has been resolved to the extent possible with current information (see Basic Statistical Issues in the Comparative Survival Rate Study of Hatchery PIT tagged Chinook, below). Further progress may be expected as experience in understanding the variabilities in survival rates and how to apply them.

Outstanding issues not yet resolved either await the results of tag returns over the next several years, or lie beyond the control of the project steering committee. For example, none of the issues surrounding coordination and cooperation has been resolved, although the steering committee did make an effort. To date the project steering committee is staffed by only the agencies directly involved in the tagging (see 1998 Work Plan). An additional agency concerned with Snake River research involving tagging of hatchery and wild chinook is the National Marine Fisheries Service. We understand from the 1998 Work Plan that the steering committee and NMFS have not made any progress on coordination and cooperation since initial contact last spring. Similarly, the technical group to advise regional monitoring and evaluation that was promised in April has yet to take action. Fueling our concern over the present lack of coordination and cooperation is the knowledge that an earlier interagency monitoring and evaluation group (MEG) that advised the Council during the 1980's has been defunct for more than five years.

Progress on lower Columbia River PIT tag detection sites has been made, however the latest final survival estimates for Snake River origin spring chinook available to us (Smith, Muir et al. 1997) contain survival estimates applicable only as far as the tailrace of McNary Dam. Efforts to implement PIT tag detection for juveniles and adults in the lower CR and at hatcheries need to be accelerated.

Discussion of Recommendations

1. Fund the proposed study.

Recently published work (Newman 1997) has suggested methods to compute ratios of survivals to adult of spring chinook tagged as juveniles that were detected or not detected as emigrants. Newman points out that relatively large numbers of fish need to be PIT tagged to achieve low coefficients of variation in estimates of SAR ratios based on PIT tags, however these numbers appear to be attainable, at least for hatchery chinook and steelhead. Note that past estimates of survival for hatchery and wild chinook by geographic origin have had relatively large standard errors due to the small numbers tagged (for example see Smith et al. 1997, Table 22).

The numbers lost between tagging at the hatcheries and arrival at the upriver dam are highly informative. Every effort should be made to locate these tags in the areas between the hatchery and Lower Granite Dam. The ultimate effectiveness of mainstem hydroelectric mitigation tools such as transportation and bypass as management tools is determined by the relative proportion of total mortality that occurs in the hydroelectric system. Losses between release locations and entry into the hydroelectric system are therefore important quantities to understand.

2. So long as the present configuration and operation of the federal hydroelectric system exists, extend (or continue) PIT tagging to include naturally reproducing populations of spring chinook whenever population sizes may permit. Continue PIT tagging other chinook life history types, and extend PIT tagging to other life history types of other species of salmon, including steelhead, whenever possible.

Status quo operation of the hydroelectric system requires accounting for losses of emigrant salmon. Current technology and emerging technologies present unprecedented opportunities to understand the impacts of the hydroelectric system on salmon. Current information on the effects of the hydroelectric system on salmon is heavily weighted toward two species, chinook and steelhead, and one life history type, the yearling emigrant or stream type salmon. Recently published work by Rondorf and Tiffan (1997) on the ocean type, or subyearling chinook demonstrates the differences in behavior among life history types that can influence survival. . Survival to the tailrace of Lower Granite Dam for Clearwater fish was about one-fourth (0.175) that of fish released upstream (0.676) and downstream (0.660) (Rondorf and Tiffan 1997). Some of the difference in survival between Clearwater and Snake river emigrants was caused by differences in fish capture probability, estimated at 0.523 and 0.434 for upstream and downstream Snake respectively, and at 0.377 for Clearwater emigrants. The smaller size of emigrants from the Clearwater relative to that of emigrants from the Snake River and the later timing of emigration could have influenced the fish guidance efficiency FGE, since size and physiological development are known to influence the ability of turbine screens to divert fish into the bypass system where they are counted (Rondorf and Tiffan 1997).

3. **Apply enough PIT tags to spring chinook production from Kooskia, Pahsimeroi, McCall, Sawtooth, and Clearwater (Powell, Crooked River and Red River Ponds) hatcheries to estimate survival to Lower Granite Dam. Whenever possible apply enough PIT tags to spring chinook at these hatcheries to estimate survivals to McNary Dam.**

Programs to PIT tag relatively small lots of hatchery spring chinook salmon and steelhead at Snake river basin hatcheries have been in place in some facilities since 1993 (Iwamoto, Muir et al. 1994; Smith, Muir et al. 1997). Standard errors of survival estimates for some lots have often been greater than 10 percent. Knowing the extent of mortality prior to Lower Granite Dam allows understanding of the relative impacts of the hydroelectric system on total mortality. Understanding the timing and location of total mortality is key to implementing effective mitigation measures for salmon. Understanding mortalities in reaches below Lower Granite Dam is similarly important to designing mitigation measures for salmon.

4. **Compare rates of return to each hatchery of PIT tagged and untagged adults to establish degree of comparability of survivals of PIT tagged juvenile salmon to survivals of juveniles not PIT tagged. To investigate rate of shedding of PIT tags through the adult stage, and where straying of adults from another hatchery is possible, investigate thermal mass marking of all hatchery production. Where smolt to adult survival of PIT tagged fish is compared to that of coded wire tagged (CWT) fish, develop a procedure to study tag loss and to compare rate of return of PIT to CWT within the hatchery release.**

PIT tags are used to measure mortality in salmon. Questions regarding the influence of PIT tags on mortality are therefore important. Near term mortality due to handling and tag application are routinely measured. Longer term effects require parallel tagging to measure. The problem with estimating tag shedding is similar. Multiple tagging using methods that require injury to the fish impose further risk of mortality. Mass marking of otoliths (fish ear bones) by deliberate, controlled changes in the thermal regime during rearing of embryos and alevins is a proven method of marking that does not require bodily injury to the fish. Otoliths receive “bar codes” from the thermal events that can be used to identify hatchery and experimental lot. Such thermally induced bar codes are widely used to identify populations of hatchery and wild salmon, and other species of fishes (Finn, Burger et al. 1997; Fitzhugh, Nixon et al. 1997).

The proposed study also intends to use coded wire tag survivals to compare to PIT tag survivals. The same caution is advised in establishing the relative effects of invasive tagging techniques on long-term survivals.

5. **Make estimates of survival applicable to the entire Snake-Columbia River federal hydroelectric system as soon as possible.**

It is particularly important to establish a station below Bonneville Dam where PIT tags can be detected. All dams with bypass facilities should be so equipped. Fishery sampling programs should include PIT tag detectors for catch (incidental mortalities) and landings.

6. Use the funding proposal format to promote coordination and cooperation among agencies applying PIT tags and other marks by including a list of other agencies marking salmon and steelhead of the same origin in the proposal, along with comments from those other agencies. Sponsor an interagency workshop on the use of tagging data at five-year intervals. The workshop would produce consensus recommendations and procedures for coordinating tagging activities.

As soon as possible a coordinating committee of technical experts from the agencies that apply and analyze tagging data is recommended to focus the talents and resources of the region on those problems amenable to solution by tagging experiments. This should be part of the basin wide monitoring and evaluation group.

Basic Statistical Issues in the Comparative Survival Rate Study of Hatchery PIT tagged Chinook

The following computations are given as an independent evaluation of the number of smolt proposed to be PIT tagged in the "1998 Work Plan for the Comparative Survival Rate Study of Hatchery PIT Tagged Chinook." These calculations are conducted under the assumption that each smolt can be assigned to one of two categories (e.g., does or does not return as an adult) and the number of smolt which belong to one of the two categories follows a binomial distribution. Implicit in this assumption is the independence of the fate of smolt once tagged and released into the river system. If groups of tagged smolt are released under different conditions or times then dependencies may exist in, for example, survival rates or rates of entry into the bypass system at dam sites. If dependencies exist then this assumption may be violated and resampling procedures (e.g., bootstrapping) may be required for planning future studies or for analysis of data arising from the study.

A second issue addressed in the document "Comparative Survival Rate Study of Hatchery PIT Tagged Chinook – ISAB Concerns from 1/14/1997" is the anticipated precision and analysis of results when the sizes of groups of smolt are estimated by the Cormack-Jolly-Seber method. In general, the assumption of independence of fates of smolt released at the bypass system of a dam site with analysis by standard binomial, multinomial, contingency tables, etc. may be appropriate, because the number of smolt released is known (see above paragraph). It is recognized that the numbers of smolt in at least two groups of interest are unknown and are estimated by the Cormack-Jolly-Seber method. These groups include:

1) The In-river Control Group 1 (the fish alive in Lower Granite Dam tailrace that were not detected at Lower Granite Dam, plus the number of fish returned to river at Lower Granite Dam), and
2) The group of fish alive in Lower Granite Dam tailrace that was not detected at Lower Granite Dam.

Estimation of the numbers of smolt in these groups implies that the denominators of the corresponding SARs are random variables with variances estimated by the Cormack-Jolly-Seber method. The PIT Tag Study Oversight Committee recognizes the difficulty in planning for adequate sample sizes given uncertainty in the denominator of these SARs and proposed values judged to be conservative for important contrasts among SARs. The ISAB agrees that exact procedures do not exist to determine adequate sample sizes in this case and that there are a variety of reasons to propose rather conservative values for the numbers of smolt to PIT tag. However, it might be possible to develop a Monte Carlo simulation exercise that would shed further light on the issue.

Modern variations of the Cormack-Jolly-Seber method (e.g., Dauble et al. 1993 and Lebreton et al. 1992) with covariates should be used for current estimation of the numbers of fish alive in

Lower Granite Dam tailrace and in similar groups of smolt. Also, protocols for future analysis of anticipated data should be developed because these data are likely to be made public and may be incorrectly analyzed when the numbers of smolt are estimated with variance. Consideration should be given to use of covariates such as length of smolt, stock, distance to Lower Granite, etc. in modeling the survival rates. Resampling or other appropriate protocols for statistical analyses should be developed to correctly estimate the variance of all SARs, compute confidence intervals, and test hypotheses.

Estimation of sample sizes assuming independence of fates of smolt.

An independent formulation of the sample size problem follows. Suppose we have 10 salmon populations from 10 different watersheds (hatcheries), i = 1, 2, .., 10. Survival of smolt to the entry to the hydroelectric system, sse(i), is different for each watershed; approximately inversely proportional to distance of the watershed from the entry point. Assume values of sse(i, i = 1, 10) are 0.25, 0.35, 0.40, 0.45, 0.5, 0.55, 0.60, 0.6, 0.6, 0.65), or that this range contains the value of interest. Smolt to adult survival rate, SAR(i), as measured at the entry to the hydroelectric system, may be expected to average about, SAR = 0.01, and is evaluated within the range {0.0025 to 0.04}.

Two approaches are reasonable in the evaluation of adequate sample sizes. The PIT Tag Study Oversight Committee required a certain power to reject a null hypothesis of equality of two proportions when the ratio of the proportions is specified to be some value other than 1.0. They then modeled the range of numbers of PIT tagged smolt expected to be alive in the tailrace of Lower Granite Dam and took this range into account in proposing conservative values for the sample sizes. In the confidence interval approach, a certain precision is required for the difference of two proportions (with fixed known values in the denominator) and conservative estimates of the variance. Both methods give insight into the art of design of the study.

The confidence interval procedure is illustrated assuming smolt detected in the bypass system are apportioned 60% into treatment group 1 and 40% into treatment group 2 on entry to the hydroelectric system. Sample sizes are large enough that standard normal distribution theory will give good approximations for numbers of smolt to tag. Commercial software products are available which provide improvements in the approximations (e.g., the square root, arc sine transformation for proportions might be used in computations). The method is illustrated by assuming that an 80% confidence interval on the difference of two SARs should not contain 0.0 when there is a 50% reduction in the SAR of one treatment group compared to another. These values of the parameters are often used in planning studies; but, other more (or less) conservative parameters could be used in the computations.

The formula used here is:

$$(SAR_1\text{-}SAR_2) \pm z_\alpha\{((SAR_1)(1- SAR_1)/(0.6)N)+((SAR_2)(1- SAR_2)/(0.4)N)\}^{1/2}$$

where z_α is the upper $(1\text{-}\alpha)100^{th}$ percentile of the normal distribution (z_α = 1.282 for an 80% two-sided confidence interval) and N is the number of smolt to PIT tag in the ratio 6:4 at Lower Granite Dam. The required sample size is obtained by requiring that the half-width of the interval be less than the desired precision. Require that

$$z_\alpha\{((SAR_1)(1- SAR_1)/(0.6)N)+((SAR_2)(1- SAR_2)/(0.4)N)\}^{1/2} \leq \text{(precision), or}$$

$$z_\alpha\{((SAR_1)(1- SAR_1)/(0.6)N)+((SAR_2)(1- SAR_2)/(0.4)N)\}^{1/2} \leq (0.5)SAR_1$$

where we assume SAR_1 is larger than or equal to SAR_2. Solving for N, the formula can be written in the form

$$N \geq (z_\alpha^2)\{((SAR_1)(1- SAR_1)/(0.6))+((SAR_2)(1- SAR_2)/(0.4))\}/((0.5)SAR_1)^2\text{, or}$$

$$N \geq (z_\alpha^2)\{((SAR_1)(1- SAR_1))(1/(0.6)+1/(0.4))\}/((0.5)SAR_1)^2$$

Note that this is conservative, because $(SAR_1)(1- SAR_1)$ is larger than $(SAR_2)(1- SAR_2)$ when SAR_1 is larger than SAR_2. Table 1 contains conservative values of N computed by this formula using 80% confidence (z_α = 1.282). Values of N in the column A (footnoted by "a") might be used for planning studies when the SARs are expected to vary in the high end of the range, say, from 0.02 to 0.04. Values of N in the column D (footnoted by "d") might be used if all SARs are expected to be below 0.01. Values in the last column are the least conservative and should probably not be used for planning purposes.

Tables 2 and 3 illustrate computation of the approximate numbers of smolt which need to be PIT tagged at the watershed (hatchery) in order to provide the appropriate numbers of smolt detected at Lower Granite Dam. Tables 2 and 3 correspond to columns A and D in Table 1, respectively. A further conservative assumption in the illustration is that at least 32% of the smolt will pass Lower Granite Dam through the bypass system. For example, assume the survival rate from the hatchery to Lower Granite Dam is at least 55%, the SAR of transported smolt is about 0.03 = 3% and at least 32% of the smolt are passed through the bypass system. Reference to Table 2 suggests that about 6,600 smolt should be PIT tagged at the hatchery to detect a 50% reduction in SAR of smolt returned to the river (for the indicated hatchery). On the other hand, if SARs are expected to be below 0.01 = 1%, assume the survival rate from the hatchery to Lower Granite Dam is at least 55%, the SAR of transported smolt is about 0.005 = 0.5% and at least 32% of the smolt are passed through the bypass system. Reference to Table 3 suggests that about 61,600 smolt should be PIT tagged at the hatchery to detect a 50% reduction in SAR of smolt returned to the river (for the indicated hatchery). If results of PIT tagged smolt are to be pooled from four hatcheries then the numbers of smolt to be tagged at each hatchery might be reduced by a factor of about 4 to provide the indicated precision on the pooled SARs.

Admittedly, the values computed by this method are conservative when we can assume independence of fates and fixed sample sizes arising from the bypass system at Lower Granite Dam. Comparisons among groups which include the estimated number of smolt alive in the tailrace of Lower Granite Dam should also be conservative, because the numbers of PIT tagged smolt are much larger. However, researchers will undoubtedly be interested in smaller groups of PIT tagged smolt, e.g., smolt that are detected only one time during out migration. Uncertainty in: the size of groups to be compared, assumption of independence, variation in the estimates from capture-recapture statistics, and in river conditions, requires a certain level of conservative logic.

The numbers of smolt to be PIT tagged at Lookingglass, McCall, Rapid River and Dworshak hatcheries (45,000 smolt each) should be sufficient to detect important differences in SARs between transported smolt and smolt returned to the river. Relatively more precision should be available for results pooled across hatcheries when comparing the basic SARs

Conclusion

Consider our limited analysis of precision in 80% confidence intervals under the assumption of independence and known sample sizes. In this case, the number of smolt planned for PIT tagging at each hatchery (i.e., about 45,000) should give good precision for estimation of SARs and for detection of SAR ratios that differ by 50% for each hatchery. Precision and power should be excellent for data pooled across hatcheries in the comparison of SARs for transported smolt and smolt returned to the river at Lower Granite Dam. Precision and power of statistical analyses involving SARs where the numbers of smolt involved are estimated by capture-recapture statistics is unknown and consideration of other uncertainties calls for relative conservative values for the number of smolt to be PIT tagged.

We note that sufficient precision to detect statistically significant differences in SARs does not imply that the differences are of biological importance. A statistically significant increase in SAR for, say, transported smolt relative to the SAR for, say, smolt returned to the river does not necessarily imply that the increase is of sufficient magnitude to contribute in an important way to recovery of T&E stocks.

Recommendations

1. Numbers of smolt to be PIT tagged should not be reduced from the values recommended in the study plan (i.e., about 45,000 from four hatcheries). It can be argued that these numbers are

excessive if results are to be pooled across hatcheries and if sample sizes are known. However, we anticipate that small treatment groups will be of interest (e.g., smolt that are detected in only one bypass at the 8 dams) and/or the numbers of smolt involved must be estimated by capture-recapture statistics. Given the uncertainties in flow, bypass rates, SAR rates, variation in capture-recapture statistics, etc.; the numbers may be reasonable for making inferences to many smaller treatment groups which may be of interest.

2. Modern versions of capture-recapture statistics with covariates (e.g., length of smolt) should be used for estimation of survival rates and numbers of smolt alive in the tailraces of dams during the downstream migration. It is not clear in the plan whether these methods are in use or not.

3. Resampling or other appropriate methods should be further developed for statistical analysis of SARs where the denominator is estimated with a certain variance (i.e., standard deviation). These methods will take into account the variance in estimation of numbers of smolt alive in the tailrace of Lower Granite Dam.

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Table 1. Conservative values of N, number of PIT tagged smolt needed at the bypass system to provide 80% confidence intervals on the difference of two SARs, which do not contain 0.0 when the ratio of SARs is 0.5 (or, 2.0). These values apply to the case where independence of fates of smolt can be assumed and where the denominators of the proportions are known.

SAR	A	B	C	D	E
0.04	657[a]	657[b]	657[c]	657[d]	657[e]
0.0375	748	703	703	703	703
0.035	859	755	755	755	755
0.0325	996	815	815	815	815
0.03	1169	886	886	886	886
0.0275	1391	1054	969	969	969
0.025	1683	1275	1068	1068	1068
0.0225	2078	1575	1190	1190	1190
0.02	2630	1993	1342	1342	1342
0.0175	3435	2603	1753	1538	1538
0.015	4675	3543	2386	1799	1799
0.0125	6732	5101	3436	2164	2164
0.01	10519	7971	5369	2712	2712
0.0075	18700	14171	9545	4821	3625
0.005	42074	31884	21475	10847	5451
0.0025	168297	127537	85902	43389	10929

[a] N computed with (SAR)(1-SAR) replaced by the maximum value (0.04)(0.96)=0.0384 for SAR $\leq$ 0.04.
[b] N computed with (SAR)(1-SAR) replaced by the maximum value (0.03)(0.97)=0.0291 for SAR $\leq$ 0.03.
[c] N computed with (SAR)(1-SAR) replaced by the maximum value (0.02)(0.98)=0.0196 for SAR $\leq$ 0.02.

[d] N computed with (SAR)(1-SAR) replaced by the maximum value (0.01)(0.99)=0.0099 for SAR $\leq$ 0.01.

[e]N computed with (SAR)(1-SAR) = theoretical value.

Table 2. Approximate numbers of smolt to be PIT tagged at each hatchery to provide the target numbers of smolt in the bypass system at Lower Granite Dam indicated in column A of Table 1 (footnoted by the letter a). Further assumptions are that at least 32% of the smolt will pass the dam through the bypass system. Results are conservative for SARs below 0.04 = 4%. These values apply to the case where independence of fates of smolt can be assumed and where the denominators of the proportions are known.

					sse[a]				
SAR	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
0.04	8217[b]	6848	5870	5136	4565	4109	3735	3424	3161
0.0375	9350	7792	6678	5844	5194	4675	4250	3896	3596
0.035	10733	8944	7667	6708	5963	5367	4879	4472	4128
0.0325	12448	10373	8891	7780	6916	6224	5658	5187	4788
0.03	14609	12174	10435	9131	8116	7305	6641	6087	5619
0.0275	17386	14488	12419	10866	9659	8693	7903	7244	6687
0.025	21037	17531	15027	13148	11687	10519	9562	8765	8091
0.0225	25972	21643	18551	16232	14429	12986	11805	10822	9989
0.02	32870	27392	23479	20544	18261	16435	14941	13696	12642
0.0175	42933	35777	30666	26833	23852	21466	19515	17889	16513
0.015	58436	48697	41740	36523	32465	29218	26562	24349	22476
0.0125	84148	70124	60106	52593	46749	42074	38249	35062	32365
0.01	131482	109568	93916	82176	73046	65741	59765	54784	50570
0.0075	233746	194788	166961	146091	129859	116873	106248	97394	89902
0.005	525928	438273	375663	328705	292182	262964	239058	219137	202280
0.0025	2103711	1753092	1502651	1314819	1168728	1051855	956232	876546	809120

[a]sse = survival of smolts to the entry to the hydroelectric sys.

[b]Number of smolts to be marked to achieve target number at Lower Granite Dam if 32% collected in the bypass

Variance is computed at the maximum assuming all SARs are less than or equal to 0.04.

Table 3. Approximate numbers of smolt to be PIT tagged at each hatchery to provide the target numbers of smolt in the bypass system at Lower Granite Dam indicated in column D of Table 1 (footnoted by the letter d). Further assumptions are that at least 32% of the smolt will pass the dam through the bypass system. Results are conservative for SARs below 0.01 = 1%. These values apply to the case where independence of fates of smolt can be assumed and where the denominators of the proportions are known.

	sse[a]								
SAR	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
0.04	8217[b]	6848	5870	5136	4565	4109	3735	3424	3161
0.0375	8788	7324	6277	5493	4882	4394	3995	3662	3380
0.035	9440	7867	6743	5900	5245	4720	4291	3934	3631
0.0325	10193	8494	7281	6371	5663	5097	4633	4247	3920
0.03	11071	9226	7908	6919	6151	5535	5032	4613	4258
0.0275	12109	10090	8649	7568	6727	6054	5504	5045	4657
0.025	13354	11128	9538	8346	7419	6677	6070	5564	5136
0.0225	14875	12396	10625	9297	8264	7438	6762	6198	5721
0.02	16778	13981	11984	10486	9321	8389	7626	6991	6453
0.0175	19223	16019	13731	12015	10680	9612	8738	8010	7394
0.015	22484	18737	16060	14053	12491	11242	10220	9368	8648
0.0125	27050	22541	19321	16906	15028	13525	12295	11271	10404
0.01	33898	28248	24213	21186	18832	16949	15408	14124	13038
0.0075	60263	50219	43045	37664	33479	30131	27392	25109	23178
0.005	135591	112992	96851	84744	75328	67795	61632	56496	52150
0.0025	542363	451969	387402	338977	301313	271181	246529	225985	208601

[a]sse = survival of smolts to the entry to the hydroelectric system.

[b]Number of smolts to be marked to achieve target number at Lower Granite Dam assuming 32% are collected in the

bypass system.
Variance is computed at the maximum assuming all SARs are less than or equal to 0.01.

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