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DEPARTMENT OF FISH AND WILDLIFE

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December 16, 2005

Mr. Don Kowal
Executive Secretary
Pacific Salmon Commission
600-1155 Robson Street
Vancouver, B.C., V6E 1B5

Dear Mr. Kowal:

Re: Pacific Salmon Commission Final Report of the Expert Panel regarding the Coded-Wire Tagging Program

The Washington Department of Fish and Wildlife (WDFW) has reviewed the Report of the Expert Panel on the Future of the Coded Wire Tag Recovery Program for Pacific Salmon, prepared for the Pacific Salmon Commission (November, 2005). We appreciate the opportunity to provide this agency's comments on the Expert Panel's findings and recommendations, but would first like to make a few general remarks about the importance of this investigation and my expectations for the review process and potential action steps taken by the Commission and salmon managers coastwide.

This agency supported the Pacific Salmon Commission's undertaking with an expectation that the Expert Panel would address the real world salmon management challenge of how to maintain and improve the technical basis for managing our salmon resources. The data collection and management systems employed by chinook and coho salmon managers are complex, so we are not surprised that the Expert Panel required considerably more time than originally envisioned to complete its review. Although only a few weeks were provided to the agencies for review and comment on the Expert Panel's report that took more than a year to complete, we hope that our comments contribute constructively to the purpose of this project.

You will see by our comments that WDFW supports the majority of the Expert Panel recommendations. We have provided additional information where the Panel's findings appear to be based on an incomplete understanding of an issue, and we believe that some of the recommendations are not sufficiently developed to provide a basis for critique at this time (e.g., Recommendation 8 - the Grand Experiment). WDFW does not support Panel recommendations that, in our view, do not address the Panel's charge to provide practical and effective solutions to identified real world management problems.

WDFW has been a lead agency on the Pacific Coast supporting implementation of effective stock assessment programs including the coast-wide system of coded wire tagging and recovery. This agency pioneered development and applications of new stock identification technologies to address evolving management issues and associated data needs, including technologies related to mass marking and the appropriate use of selective fishing techniques. By our experience, we have demonstrated our commitment to finding practical solutions to real world challenges.

The Expert Panel's investigation was instigated at least in part by ongoing concern for the effects on the CWT system related to the introduction of mass marking and selective fisheries. As part of Finding 6, the Panel has concluded that mass marking and selective fisheries pose a serious threat to the integrity of the CWT system, underscoring that finding by including a 1991 letter to the PSC from the Chinook Technical Committee that had reached a similar conclusion. We strongly disagree with the Panel's finding and hope the Commission is able to see how far we have traveled since the CTC claim that "*removal of the adipose fin from untagged fish would destroy a long-standing program of international cooperation in the use of the CWT as an important management tool*". This finding is inconsistent with the fact that mass marking and selective fisheries have been implemented in a responsible manner for more than 10 years. It is also inconsistent with the Panel's recommendation (7) for a conceptual approach linking CWT analytical methods with the intensity of mark-selective fisheries. WDFW will continue to invest in the CWT system and explore creative alternative methods for providing the information necessary to effectively manage our salmon resources.

We concur with Commissioner Larry Rutter's charge to the Expert Panel that the practical impact of the Expert Panel's report ultimately depends on the degree that findings and recommendations are accepted and implemented by the various U.S. and Canadian management agencies. The process for actual implementation is uncertain except that it will definitely take more time. Action on many of the recommendations will require new funding, coast-wide coordination and, by the very nature of those requirements, additional time for the management community to consider the costs and benefits of investments. WDFW is committed to work with the PSC to define a process for detailed review of the recommendations for the purpose of achieving consensus or acceptance by the agencies and potential implementation of recommendations having merit. I expect the process for finding acceptance and implementing the recommendations will extend well beyond the initial deliberations on these issues during the Commission's January PSC Post Season meeting.

Sincerely,

Jeff Koenings, Ph.D.
Director

Enclosures

Washington Department of Fish & Wildlife
Review of Recommendations:
Report of the Expert Panel on the Future of the Coded Wire Tag Recovery Program for Pacific Salmon

RECOMMENDATION 1. *Substantial improvements must be made in the CWT system to insure that the quality and reliability of collected data are consistent with the increasing demands being placed on these data by fishery managers. Areas requiring attention include quality control/quality assurance, and various sampling design issues including expansion of catch and escapement sampling in areas where little or no sampling currently takes place.*

WDFW acknowledges the increasing demands being placed on the CWT system in response to increasingly complex management issues confronting fishery managers. We agree with the Panel's findings that significant shortcomings exist with the CWT system with respect to the historic and future capacity to provide reliable data. In spite of these shortcomings, WDFW believes the CWT system remains a viable program and we will continue to invest in the CWT system with the intention of improving the quality of information obtained from our investments in the CWT system, at least in the short-term (at least 5+ years).

WDFW does not agree with the Panel's finding related to this recommendation (Finding 6) that mass marking and selective fisheries pose a serious threat to the integrity of the CWT system. This finding is inconsistent with the fact that mass marking and selective fisheries have been in implemented in a responsible manner, consistent with recommendations of PSC ASFEC and other technical recommendations, for more than ten years. It is also inconsistent with the Panel's Recommendation 7 for a conceptual approach linking CWT analytical methods with the intensity of mark-selective fisheries. We can only conclude that the Panel believes that mass marking and selective fishing can exist without serious threat to the integrity of the CWT system, depending on the intensity of the MM and MSF and if reasonable actions are taken to insure that basic data are collected.

As one of the agencies responsible for tagging, marking, and recovery programs, WDFW has made substantial investments to the CWT system and has acted to insure the quality and reliability of collected data by:

- Conducting new research on escapement estimation methods leading to more accurate expansion factors for escapement recoveries;
- Expanding sampling programs for CWT recovery (e.g., CWT sampling rates in Puget Sound marine sport fisheries have increased from approximately 5% prior to the advent of electronic detection sampling to 20% in recent years);
- Improving catch estimation methodologies leading to more accurate sampling expansion factors;
- Participating in coordinated technical activities on committees utilizing CWT information (SFEC, CTC and CoTC);

- Conducting biometric reviews of tagging and sampling programs at hatcheries and in fisheries (e.g., DIT program review);
- Reforming hatchery practices to improve representation of CWT release groups as natural stock indicators.

The degree to which this or any other agency is willing to make substantial new investments in the CWT system in the future depends on the availability of alternative data systems that either augment the CWT system or replace it altogether.

RECOMMENDATION 2. *Explicit criteria should be developed for the precision of statistics to be estimated from CWT recovery data. New guidelines for CWT release group sizes and fishery and escapement sampling rates should be based on these explicit criteria.*

WDFW strongly supports this recommendation but recommends that desired levels of precision and accuracy of estimates in the future need to be defined considering the full array of stock assessment technologies, not limited to the CWT system. We caution that the prospect of reaching agreement on management criteria for estimates of interest to all coast-wide managers is daunting, especially given the fact that such criteria have not been established with more than twenty five years of CWT applications. Nevertheless, we agree that clear and explicit performance criteria are essential for evaluation of the benefits of investments in our technologies. Especially now, with alternative technologies under consideration, explicit criteria are needed to help evaluate different implementation options.

> ***RECOMMENDATION 3***. *We recommend that the utility of a decision-theoretic approach, integrating costs, benefits, and risk into a formal evaluation structure be investigated as a means of prioritizing potential improvements (e.g., measures to improve CWT data – reporting, sample design, and protocol) to the CWT system. The approach should identify the release group sizes and recovery programs required to meet the statistical criteria for CWT recovery data. Sampling programs should include all fisheries, hatcheries, and spawning ground areas where CWT exploitation rate indicator stocks are present.*

WDFW may be supportive of investigations into structured approaches to prioritization of actions taken to improve our stock assessment capabilities, but specific action described by the Panel is vague.

> ***RECOMMENDATION 4.*** *We recommend completion of a comprehensive survey and statistical analysis of all relevant published and unpublished CWT studies that concerns the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts. This review should also include new analysis of relevant agency-collected data that have not yet been previously subject to analysis. Recommendations for additional studies should be made if they are judged necessary.*

WDFW supports this recommendation and concludes that studies to address this Panel finding would be undertaken consistent with Recommendation 9 and Recommendation 10.

> ***RECOMMENDATION 5.*** *Evaluate the utility of band-recovery or state space modeling approaches to estimate exploitation rates and maturation probabilities from cohort reconstructions based on CTW recovery data. These alternative modeling schemes may allow information from multiple cohorts to be combined to improve estimators compared to current single-cohort methods for which each cohort is treated indepenently.*

WDFW recommends that evaluation of alternate methods for CWT analysis, such as those suggested by the Panel, would be an appropriate task for the PSC's Chinook and Coho Technical Committees with input from the SFEC-AWG, *if* the PSC considers this activity has a reasonable prospect of solving problems identified by the Panel related to the CWT system. It is unclear from the Panel's report how such alternative methods will provide improvement to current methods used to estimate exploitation rates that are straightforward, understandable, and only rely on assumptions necessary to make estimation problems tractable.

Limited and preliminary comments specific to the two alternative model approaches presented by the Panel include:
Band-recovery models- The Brownie model described is under-parameterized. Current management needs would dictate that the harvest rate parameters (f's) should vary within a year from age to age. However, by increasing the number of parameters to the appropriate amount, the model will be over-parameterized and not tractable.
State-space models- Application of this modeling approach seemed to be unfinished or lacked sufficient description for managers or scientists to appreciate the potential utility.

> ***RECOMMENDATION 6.*** *To provide greater assurance that stock conservation objectives will be achieved, future fishery management regimes should compensate for increased uncertainty of fishery impacts on unmarked natural stocks due to degradation of the CWT system and non-landed mortality impacts related to MM and MSFs.*

WDFW agrees with the concept that uncertainty and risk should be considered in the design and specification of management objectives, including limits on the rates of total fishery related exploitation. As an example of this concept in application, WDFW and the Northwest Tribes incorporated risks associated with management and estimation error in the development of ceiling exploitation rates for our Puget Sound Chinook harvest management plan. We are concerned that the Panel's recommendation addresses only the relative increase in uncertainty associated with mass marking and selective fisheries, particularly given the Panel's findings related to substantial problems with CWT estimation unrelated to mass marking or mark-selective fishing (e.g., Finding 2: inaccurate or non-existent estimates of freshwater escapement, and inadequate sampling of some fisheries).

> ***RECOMMENDATION 7.*** *The Panel has conducted a preliminary evaluation of a number of potential enhancements to the basic CWT system and analytical methods that address the complexities introduced by MM and MSFs. This evaluation indicates that no single solution will provide precise and accurate estimates of the stock-specific mortality of unmarked fish over all types of MSFs. Instead, we recommend an approach in which marking, tagging, and analytical methods are linked to the anticipated intensity of mark-selective fisheries.*

WDFW agrees with this recommendation and considers the concept of a categorical or threshold level approach to be a practical means of addressing problems associated with estimation of fishery impacts using CWT or other systems. We support the development of a framework for addressing the effects of bias in exploitation rate estimates on unmarked fish based on the intensity of the fishery.

Substantial staff time has been expended investigating the possibility that "*intensive MSF could have devastating impact on the long-term viability of CWT tag recovery programs*". Our analyses indicate that mark-selective fisheries actually implemented for chinook and coho salmon represent only a small total exploitation rate, and we have concluded that the impacts to the CWT system are negligible. For example, all mark-selective fisheries implemented in 2005-06 combined are projected to have a total exploitation rate of less than 5% on any individual Puget Sound natural chinook stock. Although this agency continues to advocate for expanded use of selective fisheries as a means of increasing access to hatchery produced fish, given constraints on total exploitation rates for Puget Sound chinook and Columbia River chinook stocks listed under the Endangered Species Act, WDFW does not envision a significant increase in the total exploitation rate on these stocks in mark-selective fisheries in the foreseeable future (e.g., total exploitation rates < 10% over next 5+ years). We believe the intensity level of selective fisheries on unmarked coho stocks is unlikely to increase in future years and all analyses to date have indicated undetectable or nearly undetectable impacts. Therefore, we support the imputation of non-landed mortality impacts using assumed values for non-landed mortality rates and estimating exploitation rates for marked fish based on cohort reconstruction methods applied to a single CWT release group.

> ***RECOMMENDATION 8.*** *The PSC should explore the interest of fishery agencies in participating in a Grand Experiment to improve the basis for harvest management decisions coast-wide through an intensive program conducted over a short period of time. If interest is sufficient, the PSC should: (a) charge its Technical Committees (Chinook, Coho, and Selective Fishery Evaluation) with the task of preparing draft specifications for the Grand Experiment; (b) solicit proposals to assess the feasibility of conducting the experiment and develop a detailed experimental design, including cost estimates; (c) seek funding for implementation; and (d) coordinate conduct of the experiment.*

WDFW finds this recommendation lacks practical details and, especially given the likely large investment costs of the "Grand Experiment", has little interest in exploring the concept at this time.

> ***RECOMMENDATION 9.*** *The PSC and management agencies should initiate a coordinated research and implementation plan to assure application of improved technology in the management of salmon fisheries.*

WDFW supports this recommendation (see comments on Recommendation 1).

> ***RECOMMENDATION 10.*** *Additional experiments should be conducted to evaluate the use of alternative marks (e.g., a ventral fin clip or some alternative fin clip) for identification of fish bearing CWTs. Existing published information suggests that application of other external marks (e.g., a ventral fin clip) will reduce the survival of hatchery fish from release to age 2, but there is little evidence of differences in survival or behavior of externally marked versus unmarked fish past age 2. We propose some experiments that would allow, among other things, testing of a null hypothesis that survival rates for (a) AD+CWT+alternative external mark and (b) AD+CWT fish are the same from age 2 on, i.e., that there is not lingering differential mortality due to, for example, ventral fin marking.*

WDFW will support the most effective implementation strategies possible for mass marking of hatchery production, conducting selective fisheries and collecting the data necessary for stock assessment. The Panel revisited an issue that was thoroughly reviewed by the ASFEC for coho salmon in 1995 and numerous problems were identified with alternative fin marking proposals such as the ventral fin for use as the CWT identifier. WDFW has conducted comparative fin mark survival experiments in the past and would support conducting further experiments, in coordination with other agencies, if the study was carefully designed and if managers agree that the results would have a practical application. It should be clear that moving back to visible detection of CWT tagged fish does not alleviate concerns raised by the Panel related to estimation with mark-selective fisheries. Given that alternative fin marks are known to have high and variable mortality, moving away from ETD may actually add new problems in estimation. WDFW encourages further discussion on this issue.

> ***RECOMMENDATION 11.*** *We recommend that programs be developed and implemented to enhance the capacity to apply genetic methods to stock identification problems of concern to the Pacific Salmon Commission.*

WDFW has been a lead agency in the development of genetic methods applied to stock identification problems and will continue to play a lead role. We strongly support the panel's recommendation to enhance stock identification procedures and to expand baseline datasets, however, we would like to address certain shortcomings in the Panel's report on these subjects.

Coordination and Standardization of GSI Procedures

The authors of this recommendation appear to be unaware of existing programs now in effect to coordinate and standardize many of these GSI procedures. The Genetic Analysis of Pacific Salmon (GAPS) group has been tasked by the PSC to develop a standardized microsatellite baseline and scoring criteria for a range-wide Chinook database. At least nine genetic laboratories have met these scoring criteria and Version 1 of the baseline database now includes 111 Chinook populations from Asia to the Central Valley of California. More populations will be added in the first revision in early 2006.

Experience with allozymes and microsatellites has shown that standardization of genetic assays among laboratories takes work, but it is not the major obstacle to implementation of GSI methods depicted in the Expert Panel's report. The GAPS microsatellite effort has been a huge success and has shown that coordination and cooperation are possible even when labs in fierce competition are involved. It has also shown that microsatellites can be successfully standardized and are of great use in GSI.

This successful standardization of microsatellites, a highly polymorphic marker class, was achieved with targeted exchange of standards (samples), and massive sample exchanges were *not* required. For this reason, we do not support "a functional, reciprocal system for accession of tissue samples used for database construction and in fishery samples (for a reasonable, but short, period of time)." This proposed system is unnecessary (data collected in all standardized laboratories are interchangeable), unduly expensive, and impractical due to the finite and limiting amounts of material held by most laboratories. Instead, we recommend periodic and targeted exchange of standards to maintain uniformity among laboratory scoring regimes.

We believe that a management model that requires information that genetics cannot provide presents a bigger impediment to applying GSI to PSC management than does the status of standardization efforts. We agree, however that building genetic datasets capable of providing the stock resolution that managers desire will require continuing coordinated efforts involving multiple agencies and laboratories. The Pacific Salmon Commission has played a leading role in providing the focus and funding for standardized allozyme and microsatellite baselines. Additional funding will be important to expand existing baseline databases and to build new baselines using potentially more powerful genetic markers such as SNPs.

Thermal Marking

The Expert Panel provided a thorough review of thermal marking in Finding 11, including a discussion of its strengths and weaknesses as a tool for harvest management. We feel, that this marking method when combined with extant Genetic Stock Identification techniques and strontium marking by immersion can be used for coast-wide management of pacific salmon. The positive aspects associated with thermal marking include the capacity to mark 100% of the fish produced by a hatchery without individually handling them. The ability to mark every individual greatly reduces the sample sizes needed to estimate the proportions of hatchery-origin fish caught in specific fisheries. For example, estimates that are ± 5% of a true proportion can be obtained with 400 fish and often less depending upon the proportion of hatchery fish present. Moreover,

as the Expert Panel related, this method is currently used to mass mark slightly more than 20% (over 1 billion) of the hatchery salmon released into the north Pacific every year. Consequently the technique is widely known and used by countries surrounding the Pacific Rim.

Identified shortcomings included lack of infrastructure in many hatcheries to induce thermal codes, international coordination and documentation of thermal codes, potential errors in decoding thermal patterns, and the small number of potential codes that may be available. We feel that the Panel did not fully address possible solutions for the shortcomings that they identified.

First, existing water heating and chilling technology has made it possible for a hatchery to have the capacity to produce over 100 gallons per minute of 3 to 4^{o}C chilled water for an initial investment of $45,000 U.S. This capital investment would allow a facility to mark millions of fish per year for a decade or more. Consequently, annual costs for power or fuel, and routine maintenance would represent the total marking cost for each hatchery once a water temperature system had been installed.

Second, the North Pacific Anadromous Fish Commission is currently leading an effort to document and coordinate the thermal codes placed on hatchery salmon produced from facilities located in South Korea, Japan, Russia, Canada, and the U.S. As a result, an existing database for recording the thermal codes used each year is available and could be expanded to cover future marking endeavors.

Third, errors in decoding thermal marks may occur if codes have similarities to natural patterns or if the signal to noise ratio is not adequate when marks are applied. As will be shown below, however, the incorporation of a band or bands of strontium into a code matrix would eliminate the possibility that natural–origin recruits (NORs) are misidentified as thermally marked fish. Moreover, it is has been our experience that most decoding errors occur when information is inserted into a database. When two people independently read each otolith and merge their databases the occurrence of keyboarding mistakes is greatly reduced.

The Expert Panel felt that the most significant shortcoming of thermal marking was an apparent lack of potential codes that could be applied. Systematic approaches have been developed to produce thermal codes and a brief description of these approaches is presented as an attachment (Attachment I) to this document.

Using thermal and strontium marking procedures would also allow managers to validate the age assignments made on hatchery-origin fish by scales, external otolith patterns, spines, centra, and other structures. By inference, the accuracy of age assignments given to NORs could also be estimated. This would be accomplished by producing codes that provide readers with the broodyear the fish were produced from—a standard feature in the thermal marks produced by WDFW.

Finally, it seems to us that current GSI methods could be linked to the marking methods described above to create an accurate way to estimate the contribution of NORs and hatchery fish to fisheries. Current GSI methods are very capable of identifying the stock origin of sampled fish. A combined thermal/strontium mark would identify the origin of any sampled hatchery fish. The technology to carry out such a program currently exists. In conclusion, we recommend that ideas expressed here be explored in greater detail to assess the practicality of using a hierarchy of identification methods to resolve on-going harvest management issues that currently exist in Pacific Rim salmon stocks.

Reliability of Scale Aging

As a final comment related to Recommendation 11, WDFW has a very different view of the capability to provide information on age or brood year contributions from data sources other than CWT. Many of our stock specific, cohort reconstruction data bases rely on age assignments based on scale reading so we were concerned with the Panel's conclusion regarding reliability of scale reading to age chinook and coho (Finding 14). Our interpretation of published and unpublished studies conducted to evaluate reliability of these methods appears to be just the opposite of the Expert Panel. Results of blind testing with trained scale analysts shows accuracy rates over 90%, and even freshwater fishery samples were aged with a high degree of success. The Expert Panel's conclusion that aging errors can be substantial in "*mixed stock ocean fisheries"* is confusing given the comment that "*these errors are largely attributable to scale resorption*" that occurs in freshwater. We request the Panel provide a more substantial and logical basis for their finding.

> ***RECOMMENDATION 12***. *We recommend that the Pacific Salmon Commission support an immediate evaluation of a coordinated transition for all salmon species from genetic stock identification (GSI) based on the use of microsatellite markers to GSI based on single nucleotide polymorphism (SNPs) markers. It is important to develop standard sets of species-specific SNPs and related protocols now, so that coast-wide implementation of SNP-based GSI will be cost-effective and efficient. The best approach to such a transition is for a multi-jurisdictional agency, such as the PSC, to coordinate broad, multi-agency collaborations such as those adopted during the development of the coast-wide allozyme data bases during the last decade or during the development of the CTC standardized Chinook microsatellite data base developed over the last two years. Such collaborative efforts should include provisions for future tissue sample availability from all stocks included, so as to provide for periodic improvement and expansion of the databases.*

WDFW supports the development and inclusion of SNP markers in coast-wide and pan-Pacific genetic datasets. Nevertheless, the recommendation to transition away from (and to eliminate) microsatellites as a PSC-supported GSI tool is pre-mature, especially before we have had an opportunity to evaluate the power of a functional, range-wide SNP dataset for any salmonid species. We disagree with the Expert Panel that the human genetics community has moved away from microsatellites and into SNPs. SNPs have indeed gained prominence in some applications like human linkage mapping, but of

particular relevance here, the human forensic community has *not* switched from microsatellites to SNPs. In fact, the human forensic applications are much more similar to the stock identification and mixture analysis methods that are important to salmon management than are the linkage mapping applications, and microsatellites continue to serve well the human forensic community.

As we have discussed above, microsatellite standardization among genetic laboratories is not intractable, as implied in Recommendation 12. Again, we point to the success of the GAPS standardization effort for Chinook as an example that the scoring of microsatellites can be replicated among laboratories. The GAPS group has identified a much more practical approach to implement SNPs than what was outlined in Recommendation 12: to expand the current microsatellite dataset to include SNP loci. Most of the collaborating labs in GAPS are enthusiastic about the potential utility of SNPs for Pacific salmon GSI, but many of us believe that the microsatellite baseline that is in place should not be discarded simply because SNPs are attractive markers. As we add SNP loci to the baseline, power analyses, analyses of error rates, and relative cost efficiencies will determine the winners and losers among the loci.

> ***RECOMMENDATION 13.*** *We recommend support of a "proof-of-concept" empirical validation of the Full Parental Genotyping (FPG) method for use in management of Pacific salmon fisheries. This validation should occur in Chinook salmon and should include support for further SNP development, a series of paired CWT and FPG tag recovery experiments, as well as thorough evaluation of relative costs of implementing these methods and the sampling necessary to provide equivalent tag recovery data.*

WDFW does not support investment in a "proof-of-concept" empirical validation of the FPG method at this time. The Panel's report does not provide nearly enough information to evaluate the practicality of replacing CWT with FPG. No simulation results are presented to support the claim that 100 SNPs would be sufficient to actually accomplish the goals of FPG. We, along with many prominent Pacific salmon population geneticists, are skeptical that 100 SNPs would be sufficient. The proponents of FPG need to present their work so that we can examine their model and its underlying assumptions, paramount of which are assumptions about the geographic distribution of polymorphism among the SNP loci and independence of the loci. It might be the case that 100 SNP loci with ideal properties would be sufficient for FPG, but what proportion of SNP loci have these qualities? How do deviations from idealness affect the power for this application? These are two of the many questions that need to be addressed before we would support a commitment to FPG. We urge the proponents of this alternative to present the supporting theory, assumptions, simulations, and analyses so that the population genetics community can evaluate them.

Parentage analyses are more-or-less routine applications of microsatellite markers so the conceptual basis to FPG is well accepted. The big question about FPG centers on the scale of the application. A "proof of concept" empirical evaluation of FPG would need to test the practicality of parentage analyses when tens or hundreds of thousands of potential parents are involved. Such an evaluation would initially require at least a doubling of the number of

SNP loci that currently are available and likely would divert an enormous amount of funding away from initiatives with immediate application and benefit to PSC.

> ***RECOMMENDATION 14.*** *We recommend that a feasibility study be conducted to determine how PIT, RFID or other electronic tags might be applied to generate data suitable for full cohort reconstruction.*

WDFW supports employment of electronic tag methods but considers this alternative technology to have a lower priority than other approaches, particularly given limited funding for studies.

> ***RECOMMENDATION 15.*** *PSC technical committees should explore potential fishery management regimes that would rely less on estimates of age-fishery-specific exploitation (or non-landed mortality) rates, but that would still ensure adequate protection for unmarked natural stocks of concern.*

WDFW strongly supports a coordinated, coast-wide effort to explore future fishery management regimes that are more realistic with respect to capabilities of data collection, while providing necessary protection for natural stocks. We understand the challenge presented to the coast-wide management community by the call for significant change to existing regimes, but the Panel's findings identifying significant shortcomings to stock assessment capabilities underlying the current PSC regimes for chinook and coho, coupled with reduced funding to agencies responsible for implementing these programs, present a compelling set of circumstances to consider modification of our current management structures.

Attachment I
Systematic Approaches to Produce Thermal Otolith Codes

One of the first and most versatile is the interleaved 2 or 5 rule developed by Volk et al (1994). In this code, six thermal events are used to create five spaces, two of which are twice as wide as the remaining three (Fig 1). Ten possible bar codes can be produced by this method. Although this code has been prominently used by WDFW to produce thermal marks, nothing prevents us from using 1, 3, 4, 5 or no wide spaces in a six thermal event pattern. When this is done, 32 possible codes can be produced. Immersing alevins or fry into baths containing stable strontium can create additional codes. For example, Schroder et al. (1995) and Schroder et al. (1996) reported that highly visible bands of strontium are incorporated into the otoliths of alevins, fry, fingerlings and smolts after they had been immersed in a strontium chloride solution for several hours. Fig 2 shows BEI images (backscattered electron

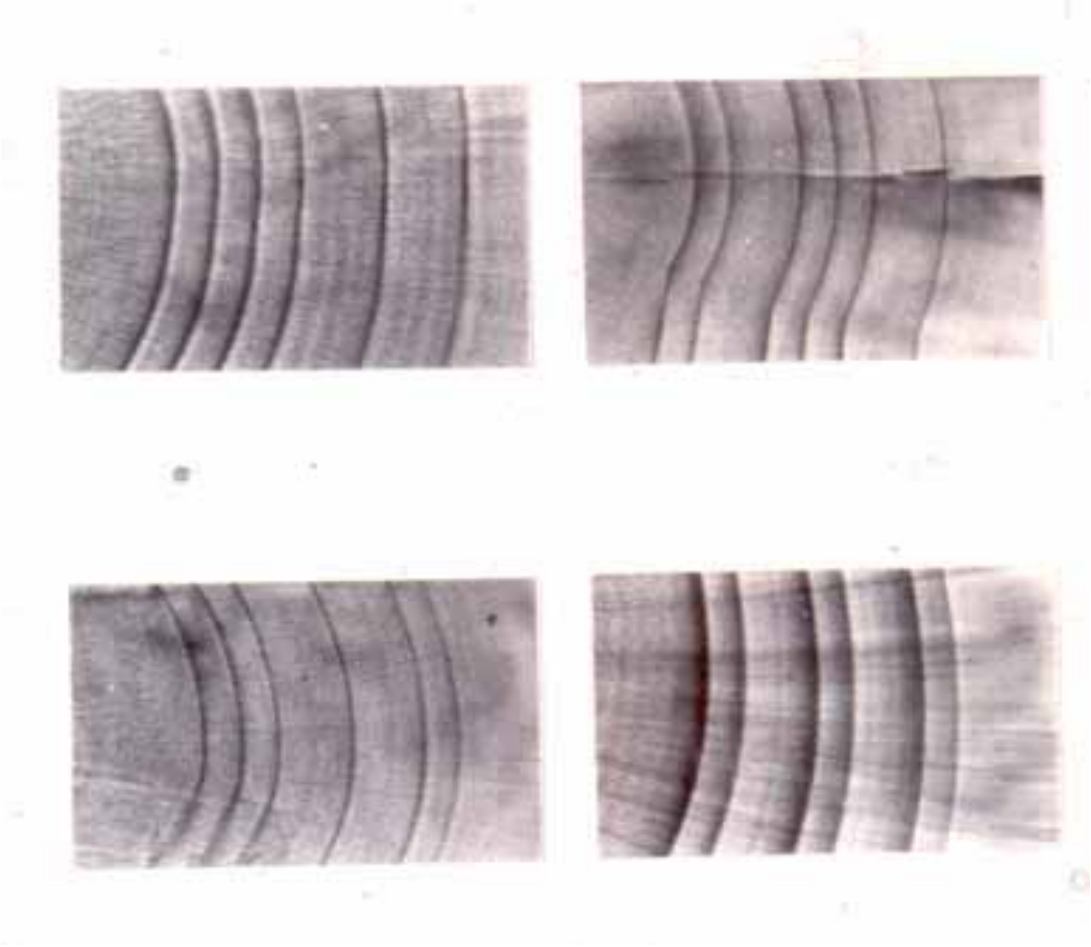

Fig 1. Examples of the “bar code” patterns that can be produced by using the interleaved 2 of 5 rule. The upper left-most image represents the Narrow Narrow Narrow Wide Wide option for this code. There is enough space on a typical salmonid otolith to induce three sets of these patterns providing 1000 potential codes.

images) of otoliths that were collected from salmonid alevins exposed to strontium marking waters. Each intense white band illustrates deposited strontium. The incorporation of a strontium band into a thermal code matrix greatly expands the number of codes that can be applied to hatchery salmon (Table 1). For example if we incorporated two strontium marks, one in the second and one in the third set of 5 bands over 800,000 potential marks are possible. A BEI image of an otolith with a thermal mark and strontium mark is shown in Fig 3.

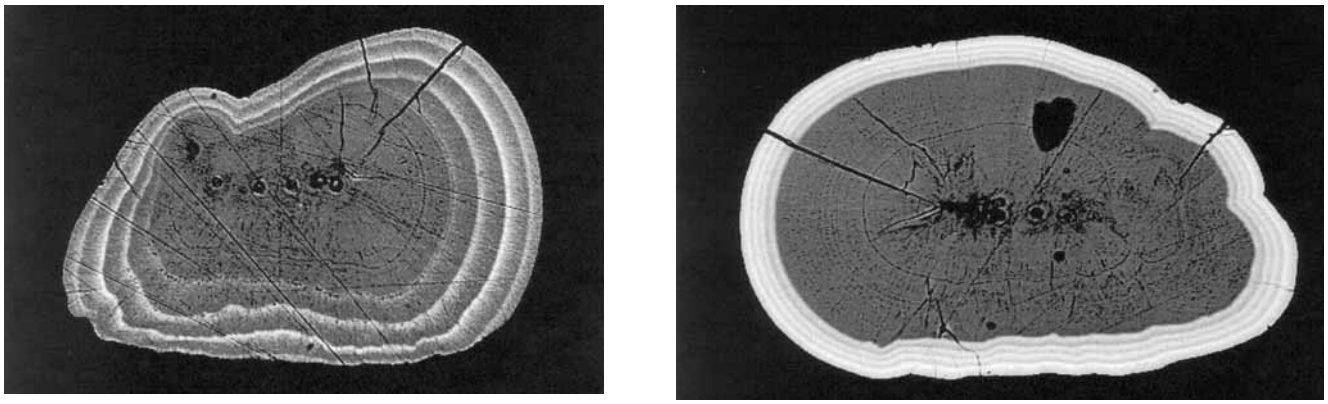

Fig 2. Backscattered Electron Images of otoliths removed from salmon alevins exposed to 1000 ppm strontium chloride hexahydrate solutions. The left-hand otolith was exposed to the solution for 4 hrs with a five-day interval between marking events while the fish producing the right-hand specimen was held for 24 hrs with two-day intervals between marking events.

Table 1. The potential marks that can be produced by combining thermal marking with strontium immersion marking. Strontium bands would be induced within a space defined by two thermal events to produce each pattern. If a single strontium immersion event occurred in post-hatch zones 1 and 2 then there would be 32x160x160 or 819,200 possible codes.

Mark Pattern		Pre-Hatch	Post-Hatch Zone 1		Post Hatch Zone 2	
# Of Wide Spaces	# Of Narrow Spaces	No Of Possible Patterns	No Of Possible Patterns		No Of Possible Patterns	
			No Sr Mark	With Sr Mark	No Sr Mark	With Sr Mark
0	5	1	1	5	1	5
1	4	5	5	25	5	25
2	3	10	10	50	10	50
3	2	10	10	50	10	50
4	1	5	5	25	5	25
5	0	1	1	5	1	5
TOTALS		32	32	160	32	160

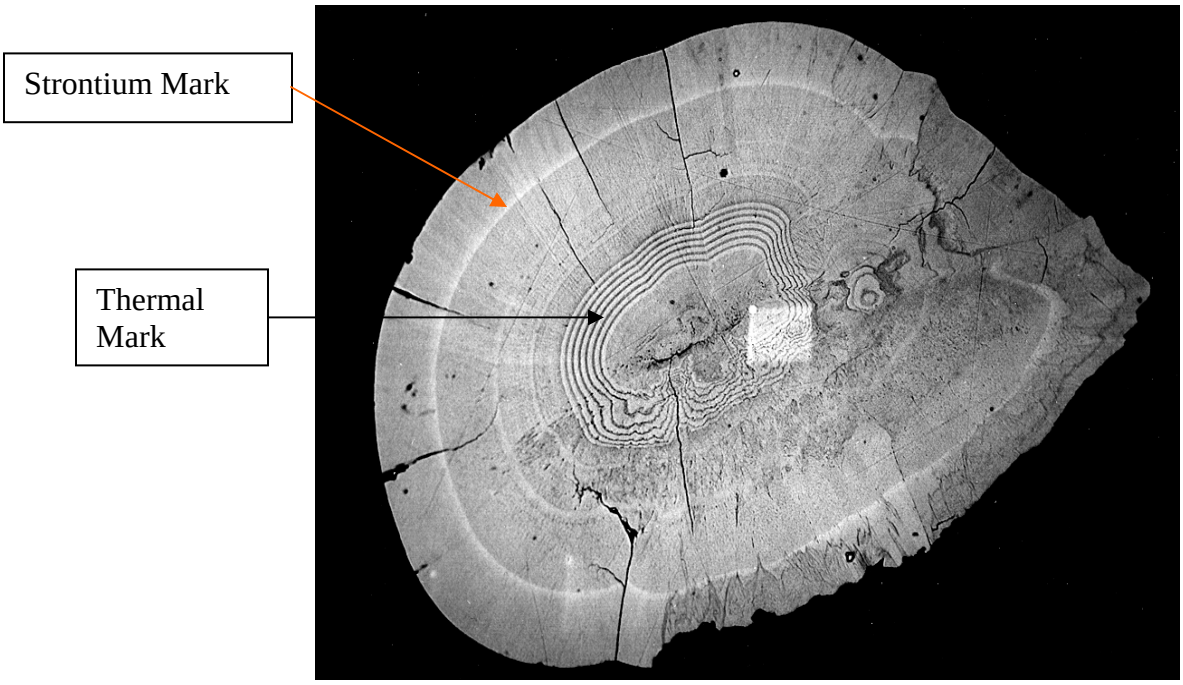

Fig. 3. A BEI image of a thermally marked otolith that also possessed a strontium mark.

Strontium marking would be accomplished by re-circulating marking waters through the incubation devices used to house alevins. Systems that re-circulate strontium marking waters are currently in use in Washington State where they are being employed to mark newly emerged salmon that are leaving natural spawning areas. This approach allows the same marking waters to be repeatedly used to mass mark thousands of juveniles over several months. Marking waters can be safely disposed of by transporting them to local sewage treatment plants. The cost of such a mark is quite reasonable, for example, $50 of strontium chloride hexahydrate crystals can be used to produce about 400 gallons of marking solution, enough to mark millions of fry in a hatchery setting.

A variety of techniques can be used to detect strontium marks. Using a Scanning Electron Microscope for example creates BEI images like those displayed in Figures 2 and 3 and allows their placement within a thermal code to be discerned. Wave Dispersive Spectrometry (WDS), Laser-Ablation Inductively Coupled Mass Spectrometry (LA-ICPMS) and other microprobe methods can also detect strontium marks. A laser track across an otolith section is depicted in Fig. 4. In this type of analysis, strontium marks would show up as peaks of anomalously high concentrations of strontium, anywhere

from 5 to 10 times greater than background levels. Thermal marks are detected by creating polished hemi-sections and then examining them under a dissecting scope. A similar approach is used for strontium marks except in this instance the specimens are coated with thin layer of carbon before being analyzed. Cost per adult otolith would range between 12 to $20 depending on machine (e.g. LA ICPMS) costs.

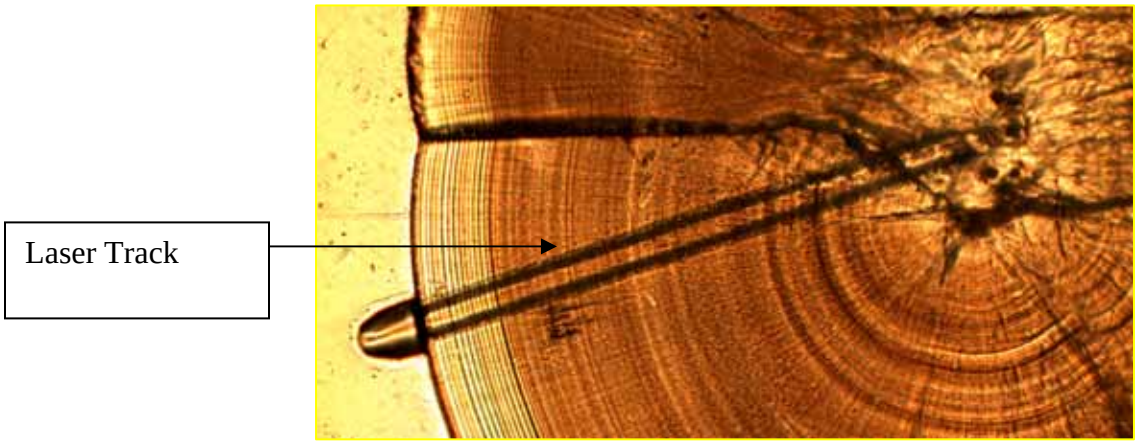

Fig 4. A photomicrograph showing a laser track across one half of an otolith hemi-section.

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