# REPORT OF THE EXPERT PANEL ON THE FUTURE OF THE CODED WIRE TAG RECOVERY PROGRAM FOR PACIFIC SALMON

**Prepared for the Pacific Salmon Commission**

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# PART II. EXECUTIVE SUMMARY

Our major findings and recommendations are grouped thematically and accompanied by brief background information that provides context.

# MAJOR FINDINGS

## The Coded Wire Tag Recovery System

The coded-wire-tag (CWT) system has provided a practical and efficient means for stock and fishery specific assessment for Pacific salmon because it: (a) includes fully integrated tagging, sampling, and recovery operations along the entire west coast of North America; (b) has sufficient resolution for specific assessments of uniquely identifiable experiments; (c) provides data conducive to standardized methods of analysis of stock and fishery assessments; and (d) facilitates multi-decade evaluation of trends in stock and fishery statistics such as survival indices and brood exploitation rates.

As an integral part of the 1985 Pacific Salmon Treaty (PST), the United States and Canada entered into an August 13, 1985 Memorandum of Understanding in which "the Parties agree to maintain a coded-wire tagging and recapture program designed to provide statistically reliable data for stock assessments and fishery evaluations." (Paragraph B). The Parties recognized the central importance of the CWT program to provide the data required to evaluate the effectiveness of bilateral conservation and fishing agreements.

The chinook and coho annexes of the PST are directed at constraining exploitation rates on naturally-spawning stocks in order to provide a means for sharing harvest and conservation responsibilities. The Chinook Technical Committee (CTC) and Coho Technical Committee (CoTC) are charged with assessing the implementation of these annexes and rely on CWT recoveries to complete the required analyses. These analyses: (a) require the capacity to estimate age- and fishery-specific exploitation rates for individual stocks; (b) depend upon the coast-wide CWT system to provide the data required to estimate exploitation rates; and (c) rely on the premise that exploitation rates and patterns on naturally spawning stocks can be accurately estimated from data collected from CWT experiments on hatchery fish surrogates.

## Importance of the CWT Tag Recovery System

***Finding 1.*** *The CWT system is the only technology that is currently capable of providing the data required by the PSC's Chinook and Coho Technical committees. There is no obvious viable short-term alternative to the CWT system that could provide the data required for cohort analysis and implementation of PST management regimes for chinook and coho salmon. Therefore, agencies must continue to rely upon CWTs for several years (at least 5+ years), even if agencies make decisions for development and future implementation of alternative technologies.*

## Problems with the Existing CWT Tag Recovery System

***Finding 2.*** *Historic shortcomings of the CWT recovery data system remain problems today. These problems include inaccurate or non-existent estimates of freshwater escapement, especially of stray (non-hatchery) escapement, and inadequate sampling of some fisheries (e.g., inadequate sampling of freshwater sport fisheries and direct sales).*

***Finding 3.*** *Since the inception of the PST, the quality and quantity of CWT recovery data have deteriorated while increased demands have been placed on these data to provide guidance for protection of natural stocks at risk. Deterioration is due to a number of interrelated factors:*

a. *reduced fishery exploitation rates, sometimes coincident with periods of poor marine survival, have resulted in fewer fishery recoveries of CWTs;*
b. *fishing regulations such as minimum size limits and non-retention fisheries have resulted in significant non-landed (catch-and-release) mortality that is infrequently, or cannot be, directly sampled;*
c. *changes in the economics of commercial fisheries in at least Washington have resulted in an increased percentage of the catch sold in dispersed locations that are difficult to sample;*
d. *increased escapement rates, a reflection of reduced ocean fishery exploitation rates, have increased the proportions of total adult cohorts that return to poorly sampled or unsampled natural spawning areas;*
e. *an increased proportion of the total catch is occurring in sport fisheries which are more difficult to sample than commercial fisheries;*
f. *competing demands for agency budgets have reduced support for CWT tagging efforts and CWT recovery programs in some jurisdictions.*

***Finding 4.*** *Fishery managers are becoming more concerned with obtaining information that cannot be readily obtained through direct observation or data provided by the CWT system. CWTs are not likely to be an effective tool to answer management questions that require identification of the origin of all fish encountered (e.g., stock-age composition of encounters of sub-legal sized fish) or the survival and migration routes of individual fish (e.g., migration patterns of released fish, catch-and-release mortality rates)*

***Finding 5.*** *Although there appears to be substantial empirical support for the critical assumption that exploitation rates and patterns of hatchery indicator stocks are the same as those of associated natural stocks, there are few peer-reviewed, published studies on this topic, especially for chinook salmon. Much pertinent agency-collected data remains unanalyzed.*

## Issues Raised by Mass Marking & Mark-Selective Fisheries

Prior to the initiation of extensive mass marking (MM) and marine mark-selective fisheries (MSFs) in 1993, the PSC established an ad-hoc Selective Fishery Evaluation Committee (ASFEC) to complete an assessment of the implications of MM and MSFs on the CWT system. ASFEC concluded that selective fisheries would disrupt CTC and CoTC analyses in two ways (ASFEC, 1995):

- MSFs "violate the fundamental assumption that the tagged to untagged ratio remains constant through the entire migration of a stock containing both marked and unmarked components. Estimates of fishery exploitation rates from samples of tagged and marked fish will still be unbiased estimates of untagged and marked fish, but *not* of fishery exploitation rates of unmarked fish." As MSFs increase in number and intensity, the discrepancy between the fates of adipose-clipped fish and unmarked fish will increase.

- MSFs result in non-landed mortalities to unmarked fish and "there will no longer be landed catch of unmarked fish to sample as a basis for estimating fishery impacts."

If MSFs were implemented for coho salmon, the ASFEC (1995) recommended: a) an adipose clip as the mass mark; b) ETD for CWTs; and c) double-index tagging of marked (Ad+CWT) and unmarked (CWT only) hatchery groups. The ASFEC (1995) noted that "even with these efforts, however, some information and aspects of the present CWT program will be compromised or lost. The degree to which information is lost is directly related to the size of the selective fishery program'' and "we will not be able to estimate fishery-specific mortalities on unmarked stocks when multiple selective fisheries occur."

The ASFEC recommended that MM and MSFs for chinook not be pursued when it issued its 1995 report because: (a) the technology to MM large numbers of small fish was not available and there were concerns of excessive mortality associated with the necessity to handle the fish

shortly before release; (b) the complex life history of chinook increased the difficulty of assessing impacts of mark-selective fisheries for this species; and (c) impacts would likely extend coast-wide, increasing the cost and difficulty of coordinating implementation.

***Finding 6.*** *The Panel concurs with previous ASFEC findings that MM and MSFs together pose serious threats to the integrity of the CWT recovery data system. In particular, under MSF, recovery patterns for adipose-clipped fish are no longer suitable indicators of recovery patterns for unmarked natural stocks, and under MM there are significant practical and statistical issues raised by the need to find adipose-clipped and coded wire tagged fish (Ad+CWT) from among the much larger number of fish released with adipose clips only. As MSF increase in number and intensity, the discrepancy between the fates of adipose-clipped fish and untagged fish will increase. The seriousness of these threats was previously pointed out to the PSC in the 1991 memorandum reproduced as a frontispiece for this report and in the 1995 report of the ASFEC.*

***Finding 7.*** *For both coho and chinook salmon, it appears possible to generate approximately unbiased estimates of* total *non-landed mortalities at age in all MSFs from a full age-structured cohort analysis of paired DIT releases of CWT groups. The accuracy of these estimated total non-landed mortalities may be poor unless very large numbers of fish are released in DIT groups. Estimates of total non-landed mortalities in all MSFs combined would not, however, meet requirements of current PSC regimes to estimate age- and fishery- specific exploitation rates.*

a. *There does not appear to be any unbiased method to allocate estimated total non-landed mortalities over a set of individual mark-selective fisheries. That is, overall non-landed mortality impacts may be unbiasedly estimated, but impacts in individual MSFs may not be.*

***Finding 8.*** *We have serious methodological and sampling concerns regarding application of the DIT concept:*

a. *We have been unable to find convincing theoretical or empirical evidence that DIT approaches can generate precise, unbiased estimates of age-fishery-specific exploitation rates for natural stocks of chinook or coho salmon (represented by unmarked DIT release groups) in the presence of sub-stocks and multiple mark-selective ocean fisheries. Methods for analysis of DIT recovery data remain incompletely developed for: (a) complex mixtures of non-selective and mark-selective fisheries with varying exploitation rates and different catch-and-release mortality rates, and (b) the full age-structured setting required for chinook salmon.*
b. *The potential utility of DIT is undermined by the reluctance of some agencies to recover CWTs for both marked and unmarked DIT groups. This reluctance can be attributed in part to the additional sampling burdens and costs associated with the use of the adipose fin clip both as a mass mark and as a visual indicator for the presence of a CWT.*

***Finding 9.*** *Concerns have been raised regarding "reliability in practice" of electronic wanding of salmon (especially large chinook) for presence of CWTs, but empirical evidence brought to our attention has consistently suggested that electronic wanding detection of CWTs is very reliable. Problems reported with electronic wanding appear to be operational in nature, centering on purchase and maintenance costs of equipment, availability of back-up detection equipment, training and supervision, increased sampling costs, etc.*

***Finding 10.*** *Based on recent proposals, many chinook and coho salmon stocks affected by PST regimes may be impacted by increasingly complex mixtures of non-selective and MSFs. The overall impact of MSFs will be stock-specific, depending on migration and exploitation patterns. The potential complexity of these fisheries and the limitations of existing assessment tools have significant ramifications for fishery management:*

*a. Management agencies have not yet developed a framework to address the increased uncertainty that would result from the initiation of significant MSFs.*

*b. Improved coordination of sampling and analysis will be required to maintain stock assessment capabilities.*

## Existing and Future Technologies that Might Complement or Replace the CWT System

Expert Panel members were provided with published reports, oral presentations, and email correspondence concerning currently available technologies and proposed future technologies that might somehow complement or replace the existing CWT system. Below we present our findings concerning two existing technologies and two emerging technologies that may have promise. The two existing technologies are otolith thermal marking and microsatellite-based genetic stock identification (GSI) methods. The emerging technologies are genetic - use of SNPs (single nucleotide polymorphisms) for stock or release group identification - and electronic - use of radio frequency identification (RFID) tags (electronic technology). We emphasize that even if these new technologies were introduced and supplemented or replaced the CWT system**, the serious problems that we have identified for estimation of non-landed fishing mortalities, made more serious by mark-selective fisheries, would not be eliminated. These problems would remain.**

***Finding 11.*** *Some existing technologies can complement the existing CWT system. These technologies include at least otolith thermal marking and Genetic Stock Identification (GSI) methods.*

***Finding 12.*** *These alternative existing technologies cannot, by themselves, replace the CWT system, but they might be used jointly to achieve a similar purpose (e.g., GSI + otolith thermal marking). Although such combination of technologies may be theoretically possible, their combined use could have substantial increased costs and would require a degree of interagency coordination and collaboration that exceeds that which was necessary to develop the CWT system.*

***Finding 13.*** *Modern GSI methods can be used to estimate the stock composition of the landed catch in a particular time/area fishery. However, the accuracy and precision of data required to estimate stock-age-fishery specific exploitation rates using GSI methods is dependent upon a variety of factors. For example, microsatellite DNA-based GSI technology is not yet capable of generating consistent, replicable estimates due to the lack of a coast-wide genetic baseline, the history of stock transfers within and among watersheds, and differences in methodologies and mixture separation algorithms.*

***Finding 14.*** *Although GSI methods can provide estimates of stock composition in catches or spawning escapements, they cannot provide (with the exception of full parental genotyping, FPG, see Finding 18) information on age or brood year contribution from a particular stock. This information is, of course, required for estimation of age-fishery-specific exploitation rates. Theoretically, GSI data could be augmented by aging data, e.g. scale ages, to rectify this difficulty. Unfortunately, we do not believe that reliable ages of chinook salmon or coho salmon captured in mixed stock ocean fisheries can be obtained consistently by reading of scales. Based on a review of published and unpublished studies, it seems clear that aging errors can be substantial and that these errors are largely attributable to ambiguities in identification of freshwater annuli (juvenile life history).*

***Finding 15.*** *Large sample sizes will be necessary to use GSI methods to generate reliable estimates of fishery contributions for small (often natural) stocks, and results will be sensitive to small assignment errors for large stocks and ages.*

***Finding 16.*** *If sampling programs were sufficiently well designed, GSI methods could be employed to gather information on the incidence of particular stocks and identify opportunities for time-area management measures to reduce fishery mortalities of natural stocks of concern. However, stock-specific management approaches in the aggregate abundance based management fisheries (AABM) would need to be carefully evaluated and agreed upon by the PSC to ensure that the harvest rates on other stocks do not exceed the target levels appropriate for the AABM abundance index as established under the 1999 PST agreement.*

***Finding 17.*** *Over the past 20 years, first allozymes and more recently microsatellite markers have become the dominant tool for use in GSI. However, we believe that microsatellites will be replaced in the next several years by SNPs as the tool of choice for population genetic applications, as has already occurred in human genetics. The first step in the transition in marker type is the identification of appropriate SNP markers, a process that is already underway for chinook salmon through a multi-agency effort. SNP marker development and databases are also well underway for sockeye and chum salmon. Factors driving the replacement currently include the ease of data standardization, cost, and high throughput. Cost-effectiveness should rapidly improve as more SNPs are developed and multiplex processes drive the cost of analysis down.*

***Finding 18.*** *A novel genetic method, termed full parental genotyping (FPG), has been presented as an alternative to coded wire tagging. The method uses genetic typing of hatchery brood stock to "tag" all hatchery production. The tags are recovered through parentage analysis of samples collected in fisheries and in escapement. Because of the need for a low laboratory error rate, FPG would rely on SNP markers. FPG would provide the equivalent of CWT recovery data, and could be easily integrated with a GSI system to provide stock of origin for all fish and stock + cohort for fish from FPG hatcheries. However, further evaluation of the relative costs of FPG, GSI and CWT systems is needed. Moreover, an empirical demonstration is needed to validate theoretical results that suggest broad feasibility*

***Finding 19.*** *A number of existing or emerging electronic technologies could theoretically replace the CWT and may have substantial advantages over the CWT (e.g., tags can be read without killing the fish, unique tags for individual fish allow migration rates and patterns to be directly observed). Examples include at least Passive Induced Transponder (PIT) tags and Radio Frequency Identification (RFID) tags. PIT tags are currently too large to mark all sizes of juvenile chinook salmon released from hatcheries and are expensive relative to CWTs, but future technological improvements may reduce tag size and tag cost for these technologies.*

# MAJOR RECOMMENDATIONS

## Correct Current Deficiencies in CWT System:

***Remedial measures should be undertaken immediately to correct deficiencies in data collection and reporting throughout the basic CWT system and to improve analysis of CWT recovery data.***

Our findings indicate that the CWT system should remain the primary stock assessment tool for the CTC and CoTC in the short-term (5-10 years). Substantial staff and funding investments will be required to improve the reliability of this system, especially if MSFs are increased in number and intensity. Even if decisions are made now to develop and implement alternative technologies for future PST fishery management, it will be important to maintain a reliable CWT system during the transition period to ensure data continuity and to allow evaluation of the relative performance of some new technology or approach as compared to the CWT system.

***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 samples in areas where little or no sampling currently takes place.*

***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 for fishery and escapement sampling rates should be based on these explicit criteria.*

***Recommendation 3.*** *The utility of a decision-theoretic approach, integrating costs, benefits, and risk into a formal evaluation structure should be investigated as a means of prioritizing potential improvements (e.g., measures to improve CWT data reporting, sampling designs, and protocols) 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.*

***Improving tagging and sampling programs is important, but completion of the following recommendations will strengthen the analysis and interpretation of CWT data:***

***Recommendation 4.*** *We recommend completion of a comprehensive survey and statistical analysis of all relevant published and unpublished CWT studies that concern 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 subjected to analysis. Recommendations for additional studies should be made if they are judged necessary.*

***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 CWT 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 independently.*

## Respond to Mass Marking and Mark-Selective Fisheries

***Implement enhancements to the basic CWT system and introduce new analytical methods that are consistent with the anticipated scope of MSFs.***

Implementation of MSFs will ultimately depend on value judgments that must somehow balance many competing factors: a) the benefits of wild stock conservation as compared to enhanced fishing opportunities; b) the financial costs of selective fishery implementation as compared to the fishery benefits; c) the degree of uncertainty in natural stock assessments that proves politically acceptable for fishery management; and d) the theoretical viability and costs of alternative management strategies that might meet policy objectives. If MSFs are extensively implemented, our Panel has identified analytical methods and short-term enhancements to the current CWT system that could provide improved stock assessment capabilities for the CTC and CoTC. The enhancements considered should depend on the scope of MSF, including the species targeted, the geographic location of the fisheries, and the intensity of fishery exploitation.

***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.*

***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.*

We suggest that the SFEC, or other group appointed by the PSC, develop recommendations for both threshold levels and specific methodologies to refine this concept (Table 4).

**Table 4. Estimation methods for unmarked mortalities in MSFs at varying MSF magnitudes.**

| Selective Fishery Magnitude | Tagging and Marking | Estimation Method for Unmarked Mortalities in Selective Fishery |
|---|---|---|
| Low | CWT-based indicator stock program with single tag code per indicator stock. | Method 1. Multiply CWT recoveries of adipose-clipped fish by selective fishery release mortality rate. |
| Moderate | Option A. CWT-based indicator stock program with double-index tagging (DIT). | Method 2. Multiply recoveries of marked fish by mark-selective fishery release mortality rate and the ratio of the unmarked to marked component of the DIT at release. |
| | Option B. CWT-based indicator stock program with double-index tagging (DIT). | Method 3. Total MSF mortality derived from differences in age-specific escapement rates (or terminal run) of marked and unmarked fish. Mortality allocated to individual fisheries based on distribution of recoveries of marked fish. |
| High | Option A. CWT-based indicator stock program with double-index tagging (DIT) and otolith marking. | Method 3. Total MSF mortality derived from differences in age-specific escapement rates (or terminal run) of marked and unmarked fish. Mortality allocated to individual fisheries based on sampling of otolith marked fish in paired fishery. |
| | Option B. CWT-based indicator stock program with double-index tagging (DIT) and otolith marking. | Method 4. Multiply encounters of marked fish in mark-selective fishery by ratio of adipose clipped and unclipped fish with otolith marks in a paired non-selective fishery. |

***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.*

## Develop a Coordinated Research & Implementation Plan

***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.*

***Recommendation 10.*** *Additional experiments should be conducted to evaluate the use of alternative external 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 fish and (B) Ad+CWT fish are the same from age 2 on, i.e., that there is no lingering differential mortality due to, for example, ventral fin marking.*

***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.*

***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.*

***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.*

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

## Consider New Management Paradigms

***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.*

Alternative types of fishing regimes might provide similar or improved conservation and economic benefits at lower cost to the management agencies. It is likely that technology that could substantially improve salmon management will become financially and operationally available within a 5-15 year horizon.

# IMPLEMENTATION STEPS

The 15 recommendations presented in this report follow a natural sequence for implementation:

1. Correct current deficiencies in CWT system (recommendations 1-5);
2. Respond to Mass-marking and Mark-selective fisheries (recommendations 6-8);
3. Develop a coordinated research and implementation plan (recommendations 9-14);
4. Consider new management paradigms (recommendation 15).

The coded wire tag (CWT) program has been a uniquely successful long-term example of cooperation in resource management, and the data derived have proved to be indispensable in the development of management and assessment methods for chinook, coho, and steelhead. While numerous problems with the current coast-wide CWT program were identified during the review, the majority of concerns can be addressed by a renewed commitment to the marking and sampling programs designed to achieve an agreed set of objectives. However, new demands (e.g., need for age-fishery-specific exploitation rates in an increasing number of fishery recovery strata) placed on the CWT program will increase uncertainty in CWT-based estimates. It will be impossible to respond to these new demands unless marking and sampling programs are redesigned. Even with redesign of marking and sampling programs, there are serious questions regarding whether stock-age-fishery-specific exploitation rates for unmarked fish can be accurately estimated when multiple mark-selective fisheries impact a given release.

For at least the next 5 years, the Panel has concluded that CWTs are likely to remain the only agreed upon coast-wide tool capable of providing the data required to perform cohort analyses for individual release groups of chinook and coho salmon. Consequently, our first several recommendations address restoring the CWT program coast-wide to meet an agreed minimum set of objectives established by the PSC (and consistent with the Memorandum of Understanding within the PST).

The Panel recognizes the current legal requirement in the United States to mass-mark all chinook and coho salmon, and steelhead reared in federal hatcheries. Therefore, we have presented recommendations to respond to estimation problems that are raised by the development of mark-selective fisheries that are intended to take greater advantage of mass-marked hatchery salmon.

Although the Panel is in full agreement that all parties must make a renewed commitment to the CWT program, the Panel also acknowledges the capacity of alternative marking and/or identification systems to augment information from the CWT system and, in the future, to possibly replace the coded-wire tag. While the potential for these new technologies seems substantial, there is currently no agreed upon coast-wide system that could replace the CWT system and there is not agreement on which technology may offer the greatest opportunity for development. It seems clear that certain DNA-based stock identification methods could augment the CWT system and should be seriously considered when considering how to “restore” the CWT system.

Finally, the Panel recommends that management strategies should be adjusted to compensate for increased uncertainty in the capacity to accurately estimate stock-age-fishery specific exploitation rates. This recommendation is intended to ensure that management systems are consistent with the quality and quantity of data available and to ensure adequate protection of the unmarked natural stocks. We are unanimous in our concern that the proposed future versions of PSC management models, which may incorporate as many as 75 fisheries with 4 time steps each, would place unrealistic and impossible demands on data, whether from CWT recoveries or from some future technology.

These conclusions lead to a series of next steps, many of which should be acted on soon since progressive changes to the CWT program require information to be derived from these steps. However, the Panel recognizes that the priority of specific steps will depend on future decisions and may differ from the sequence presented below:

1) The PSC should request that the domestic agencies of both Parties implement corrective measures to assure that standards for sampling and estimation of catch and escapement are met, that CWT release and recovery data are accurately and timely reported to regional exchange points, that proposals for MM and MSF are presented to the PSC early in the annual fishery planning process, and that coordination and cooperation between coast-wide agencies be restored. Restoration of cooperation and coordination is imperative to fully utilize the CWT program (under any scenario for future change) and was a strength of the past program. Two previous reports of the PSC's SFEC have emphasized the necessity for coast-wide cooperation and this Panel strongly supports their conclusion. Data standards for these programs must be integrated with data requirements developed during Step 2.

2) In 2006, the PSC should establish a joint Canada-US technical committee to determine an agreed statistical basis for a restored coast-wide CWT program, including means to estimate uncertainty about age-specific exploitation rates for chinook and coho salmon, objectives for the program design (specifically for the PSC indicator stocks), and the decision-theoretic methods to optimize the information return given limited financial resources. To facilitate immediate implementation of this step, the Panel suggests the use of internal agency experts plus a contract for external experts in statistical design and modeling to implement the necessary analytical framework. The PSC should seek joint funding for this initiative.

3) The PSC should revisit the "desequestering" of the adipose fin and its current frequent use as both a mass mark and a visual indicator of fish containing a CWT. This confounding of indicators greatly increases the costs of recovering CWTs, and the unwillingness of some agencies to use ETD equipment has already lead to incomplete recoveries of unmarked fish which contain CWTs in non-selective fisheries. It is highly desirable to have different visual cues to identify mass marked and CWT fish. If fin marks are to be employed for these purposes, then a decision on which fin to use in MM is essential to financial planning and logistics of a revised CWT program, but a fully informed basis for this decision requires more information on the relative survival of salmonids marked with different fin-clips. The PSC should request agencies in Canada

and the United States to immediately design and conduct (commencing with the 2006 brood year) a coordinated study of the relative survival of fish marked with adipose fin clips as compared to other fin clips, e.g., pelvic fin clip. If fish in such studies were also mass marked using otolith thermal marking techniques, these studies might also allow assessment of the survival impacts of adipose fin clips. These studies should probably be focused on chinook salmon due to the likely greater impacts of marking on this species due to its smaller average size at release.

4) The quality of the CWT program has broad effects on the assessment and management of salmonid resources coast-wide. The data gained is critical to the development of management planning models and agreements developed within the PSC. Therefore, before any sweeping changes to the CWT program are implemented, the Panel recommends a "Grand experiment" (*Recommendation 8*) to provide current and high quality information (at a level of resolution to be decided in (1) above) for the continued evolution of management models and assessments. Such an experiment will require a number of years of data and will require a staged implementation of changes to the CWT program so the goals of this experiment are not compromised in mid-stream. The PSC is the local focus for designing this experiment and should seek to implement this study through the appropriate agencies within one year (fall, 2006).[8]

5) The Panel acknowledges that MM and MSFs are likely to continue to develop in the near-term and that some loss of information from the CWT program will occur. The significance of the bias and uncertainty resulting from MSFs will vary depending on their complexity and intensity. Consequently, the PSC's SFEC should be charged with a detailed evaluation of the merits of the proposed tiered assessment framework modeled on the conceptual framework presented in the discussion of Recommendation 7. In addition, the PSC should undertake efforts to investigate methods to compensate for increased uncertainty in management capabilities without increasing the risk to spawning objectives (mature returns) for the naturally produced populations. PSC working groups for chinook and coho salmon should establish agreements on: methods to quantify the increased uncertainty relative to a base-year; the risk tolerance to be applied; and who (i.e., what fisheries) should accept the cost of increased uncertainty due to executing a mark-selective fishery. This step should be completed and incorporated into the next negotiations of the chinook and coho annexes of the PST. This task will involve technical experts and policy makers and is best addressed within the PSC.

6) The PSC should immediately develop a coordinated research and implementation plan for the application of new technologies for use in salmon assessment and management. The Panel's recommendations identify three research issues that need to be addressed before any broader application of these tools is likely to be agreed upon coast-wide (see *Recommendations 12, 13 and 14*). Suggestions for proceeding with *Recommendations 12 and 13* are included in this Panel report, and merit support through the PSC Endowment funds. Further, *Recommendation 14* addresses the development and application of electronic tags (PIT, RFID or others developed). These tags are not currently applied for

[8] Steps 2 and 3 are of sufficient importance that funding should be considered through the PSC Endowment process for a fixed number of brood years.

management within the PSC but may have significant future value. To examine this potential, the PSC should solicit research proposals through a public request for proposals and fund research in the innovative application of such technologies.

7) In spring 2006, or at the earliest possible time, the PSC should host a workshop concerning 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. The Panel believes that estimating age- and fishery-specific exploitation rates will become increasingly difficult in the future if the number and intensity of MSFs increase and if management models demand increased time/area resolution. The impact of these problems for estimation of stock-age-fishery-specific exploitation rates would depend on the total exploitation rates being imposed on a stock of interest and whether the CWT indicator stock continues to be representative of the naturally-produced salmon for which it is an indicator. Given the current and future difficulties in estimation of age- and fishery-specific exploitation rates on individual natural stocks, the Panel feels it is very important to explore alternative management regimes that would rely less on these estimated quantities. Since the chinook annex must be renegotiated in 2008, dialogue on alternative regimes should be initiated soon.