Recommendations for Application of Genetic Stock Identification (GSI) Methods to Management of Ocean Salmon Fisheries.

Special Report of the GSI Steering Committee and the Pacific Salmon Commission's Committee on Scientific Cooperation.

January 2008

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The Pacific Salmon Commission is charged with the implementation of the Pacific Salmon Treaty, which was signed by Canada and the United States in 1985. The focus of the agreement are salmon stocks that originate in one country and are subject to interception by the other country. The objectives of the Treaty are to 1) conserve the five species of Pacific salmon in order to achieve optimum production, and 2) to divide the harvests so each country reaps the benefits of its investment in salmon management.

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Recommendations for Application of Genetic Stock Identification (GSI) Methods to Management of Ocean Salmon Fisheries

Report of the GSI Steering Committee and the Pacific Salmon Commission's Committee on Scientific Cooperation (CSC)

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PREFACE

Over the past twenty years, new genetic technologies and analysis methods have generated increasingly valuable applications in fisheries management. For Pacific salmon species, there have been numerous successful applications of these new genetic approaches in terminal or near-terminal areas (e.g., identification of origins of stocks in mixed stock marine or freshwater fisheries once fish have neared or entered their natal river system, including in-season management of Fraser River sockeye; evaluation of reproductive performance of hatchery and wild fish on natural spawning grounds). There is also considerable emerging interest in application of genetic stock identification methods (GSI) to estimate stock proportions in mixed stock ocean fisheries (e.g., project CROOS, http://projectcroos.com/; application of GSI to protect WCVI Chinook in the northern BC troll fishery). Applications of GSI methods to broader management issues in ocean salmon fisheries have thus far been limited.

The rapid development and application of modern genetic methods in fisheries contexts has given rise to widespread interest regarding the potential use of GSI methods in ocean salmon management. Indeed, a recent Pacific Salmon Commission (PSC) Expert Panel on the future of the coast-wide coded wire tag recovery (CWT) program was established in part due to the belief that modern genetics methods could augment or possibly completely supplant the coast-wide CWT system (see Report of the Expert Panel, 2005). Among other things, the CWT Expert Panel concluded that existing GSI methods could not produce data that could directly substitute for the kind of data produced from the CWT system, but they also identified some promising possibilities for practical use of a combination of GSI and CWT data and they encouraged further exploration of the use of GSI in ocean salmon management.

In December of 2006, members of the PSC's Committee for Scientific Cooperation (CSC) submitted a two page concept proposal to the Northern and Southern Restoration and Enhancement Funds for a set of workshops devoted to assessing the potential for application of emerging GSI methods to management of ocean salmon fisheries. For a variety of reasons, greatest focus was to be placed on management of Chinook salmon stocks due to its coast-wide distribution across management jurisdictions and substantial existing genetic database, with less focus placed on sockeye salmon (less extensive distribution across management jurisdictions) and coho salmon (less developed genetic database and less extensive distribution across management jurisdictions). After the CSC received approval for submission of a full proposal, it established a Steering Committee to assist the CSC in further proposal development. A subsequent full proposal, reflecting Steering Committee input, was submitted by the CSC and received joint funding support from the Northern and Southern Funds. The approved proposal called for two workshops. The first workshop was held in Portland on 15-17 May 2007, and the second workshop was held in

Vancouver, B.C., on 11-13 September 2007. The workshops consisted of discussions and presentations made by a large number of invited participants including fishery biologists, managers, geneticists and biometricians who were separated into four thematic workgroups: (a) Logistics, (b) Management, (c) Genetics, and (d) Modeling/Sampling. For each workgroup, funding was provided for a workgroup coordinator to direct the activities of that workgroup and to prepare a workgroup report. Prior to the first workshop, the Steering Committee provided each workgroup with a series of questions or issues that were intended to provide focus for the workshops. The overall "charge" to participants at the first workshop was ambitious and was phrased in the following manner:

> "*To develop recommendations for integration of GSI information into a coordinated coast-wide management system to improve the ability of ocean fisheries to access abundant stocks within impact constraints established for other specific stocks and, to the extent possible, to identify and quantify the costs, implementation steps and timeframes to incorporate these recommendations."*

Prior to the second workshop, the Steering Committee provided workshop participants and coordinators with a list of key issues to focus the discussions. Presentations were made on most of these issues at the second workshop, and workgroup members provided workgroup coordinators with written materials for inclusion in the final workgroup reports. (Appendixes provide a summary of basic terms and acronyms; the full CSC proposal as submitted, including the list of questions identified for the first workshop; a complete list of Steering Committee members, workgroup participants and coordinators; workshop agendas; and the list of key issues used to focus the second workshop.)

Following the second workshop, workgroup coordinators worked with workgroup participants to prepare reports on important issues that had been previously identified. These reports consisted of informal but substantial and often thought-provoking contributions submitted by workgroup participants, along with a series of recommendations developed by workgroup coordinators in consultation with workgroup members. Coordinators submitted their workgroup reports to the Steering Committee in October 2007. These workgroup reports are available online at the Pacific Salmon Commission's website.

After receipt of the workgroup reports, most members of the Steering Committee and one member of the CSC met in Seattle on 08 November 2007 to develop a set of consensus recommendations and findings that could be presented to the PSC. Following this meeting, a draft report was circulated among members of the Steering Committee and CSC for review. The final report, developed jointly by members of the Steering Committee and the CSC, constitutes the deliverable product from the two Fund-sponsored GSI workshops and is intended to provide guidance to the PSC. The broad geographic scope of the management jurisdiction of the Pacific Salmon Commission makes the PSC well positioned to inform fishery managers coast-wide of the capabilities, limitations and potential promise of GSI methods in management of ocean salmon fisheries.

We acknowledge the Southern and Northern Funds for supporting the two workshops, and we extend thanks to all workshop coordinators and participants who together devoted extensive time and energy to the workshop process, most without any compensation. We believe that it would be wise to convene future meetings like those that were sponsored via these workshops, to ensure that there is continuing constructive dialog between those who are at the cutting edge of application and development of new genetic technologies, those who are responsible for developing fishery management models, those who are responsible for maintaining fishery databases, and those who are responsible for fishery management decisions. Only through such continuing dialog can the full potential of these new technologies be realized in management of ocean salmon fisheries.

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INTRODUCTION

For the past 30 years, achieving the broad management objectives of the Pacific Salmon Commission (stock sustainability and harvest) for Chinook and coho salmon has been based substantially on data generated from the coast-wide coded wire tag recovery (CWT) system. Estimated age- and fishery-specific recoveries from individual CWT release groups in ocean and freshwater fisheries and in freshwater escapements (including at hatcheries) have allowed estimation of stock-age-fishery-specific exploitation rates based on application of cohort analysis methods. These estimated exploitation rates have been incorporated in quantitative management models used in the preseason processes to plan fisheries to achieve the management objectives of the PSC and other fisheries agencies, and to assess the performance of these management regimes after the fisheries have occurred.

Over the past 20 years or so, genetic methods have found increasing applications in management of Pacific salmon. Technologies for application of these methods have improved rapidly, and it has become increasingly feasible to collect large quantities of genetic data at reasonable cost. It has therefore been reasonable to expect that these new technologies may have substantial value for management of ocean salmon fisheries. Indeed, there has been a developing view that modern genetic methods (loosely identified as *GSI* throughout this report) could, in the near future, completely supplant the existing coast-wide CWT system.

Partly in response to this emerging belief, in some quarters, that GSI could supplant the CWT system, and responding also to recent deterioration in the CWT system that has resulted from reduced ocean recoveries and complications introduced by mass marking and mark-selective fisheries, the PSC established an Expert Panel on the future of the CWT system. Among other things, the CWT Expert Panel found that existing GSI methods could not produce data that could directly substitute for the kind of data produced from the CWT system (i.e., that GSI could not directly supplant the CWT system), but the Panel also identified some practical uses of a combination of GSI and CWT data and encouraged additional exploration of the potential use of GSI in management of ocean salmon fisheries.

Based in part on the findings from the CWT Expert Panel, the PSC's Committee for Scientific Cooperation proposed and received funding for a series of two workshops designed to explore the potential for use of GSI in management of ocean salmon fisheries (see Preface for details). A GSI Steering Committee, chaired by a member of the CSC, developed a detailed structure for these two workshops and identified a set of key issues to serve as a focus for the workshops. Based on oral presentations made at these two workshops, and on final reports submitted by Coordinators for each of four workgroups (genetics, logistics, management, modeling/sampling) established as part of the workshop process, the GSI Steering Committee, along with members of the CSC, developed a consensus set of recommendations that are presented in this brief summary report.

The main body of this report consists of a list of these high level, but actionable, consensus recommendations. Following each recommendation, we provide a brief sketch, in bullet form, of major findings or conclusions that support the recommendation. In addition to specific recommendations for actions, we also attempt to identify pressing needs for research and we propose some high priority tasks that might be carried out by technical committees of the PSC.

RECOMMENDATIONS FOR IMPROVING THE SCIENTIFIC BASIS FOR OCEAN SALMON MANAGEMENT THROUGH THE USE OF GENETICS AND CODED-WIRE TAGS

Recommendation 1:

The PSC should recommend that agencies undertake measures to restore the structural integrity of the CWT system and improve its performance. Additionally, the Northern and Southern Fund Committees should consider how their respective Funds can contribute to this improved performance.

- Management of Chinook and coho fisheries are becoming increasingly focused on conducting fisheries within allowable impacts on stocks of conservation concern which often comprise a very small proportion of the catch. Managers are seeking to manage fisheries at increasingly finer levels of resolution for populations, fisheries, time periods, and areas. Demand for more information at finer scales of resolution will prove challenging to both CWT and GSI technologies. Unless large sample sizes are taken and issues relating to stock and age assignment error are resolved, GSI is generally not well suited for such fine-scale management. For mixed-stock ocean fisheries, relatively small GSI samples can be expected to produce useful estimates of contributions of aggregates of stocks with similar GSI characteristics and which comprise a relatively large proportion of the sampled population. It is, however, unrealistic to expect GSI to provide reliable estimates for stocks that contribute only minor proportions to a fishery (say, less than 3% of total catch), regardless of sample sizes.

- The current management system for Chinook and coho salmon depends critically upon the ability to reconstruct cohorts and estimate stock-age-fishery- specific exploitation rates for specific populations of interest. The CWT system is the only system which can presently provide the coast-wide data required for cohort reconstruction. At this point in its development, GSI is not capable of providing these data for coho or Chinook salmon stocks.

- The quantity and quality of data generated by the CWT system has substantially deteriorated in recent years due to harvest restrictions, marked selective fisheries, mass marking, and other factors examined by the CWT Expert Panel established by the PSC. The PSC formed a CWT Workgroup to address the most serious concerns identified in the Panel's Report, and a report from this Workgroup will be delivered to the PSC in January 2008.

- Although maintenance of the structural integrity and performance of the CWT system is fundamentally a programmatic responsibility of the management agencies, PSC Endowment Funds may contribute to the CWT system by supporting research that tests basic assumptions or hypotheses associated with analysis and interpretation of CWT recovery data or that propose innovative methods for collection or analysis of CWT recovery data.

Recommendation 2:

Genetic and CWT technologies can and should be integrated to improve the scientific basis for management of Pacific salmon. These technologies can be applied separately, or in combination, as appropriate, where potential benefits of derived information are sufficient to justify costs.

- Unless the management of coho and Chinook salmon fisheries changes from its current dependence on stock-age-fishery exploitation rates, genetics at the present time can best be applied in a supportive or supplemental role, providing information that the CWT system is poorly suited to provide.

- Generally, CWT recovery data and genetic data provide quite different information. For example, assuming adequate sampling programs in ocean and freshwater areas, coast-wide collection of CWT recovery data can allow run reconstruction and post-season estimation of stock-age-fishery specific exploitation rates. However, the CWT system is not well-suited for estimation of stock compositions in fisheries because the system relies on a selected sub-set of tagged indicator stocks. Genetic methods allow direct estimation of the stock compositions of fisheries, both for landed catch or for fish that are caught and released, either in-season or post-season. However, genetic methods are not presently capable of providing data required for coast-wide cohort reconstruction and, therefore, stock-age-specific exploitation rates, especially for species like Chinook salmon that have multiple ages at maturity. Nearly all ocean fisheries for Chinook salmon currently are managed based on stock-age-specific exploitation rate constraints.

- Genetic information has already demonstrated considerable value for fishery management in terminal and near-terminal areas; practical applications in ocean salmon fishery management have been limited to-date, but will no doubt emerge in the future. Research into further integration of genetic methods into fishery analysis should be encouraged.

- GSI could provide stock composition information for evaluation of the performance of fishery planning models used by the PSC (see Modeling and Sampling workgroup report).

- GSI can be employed in-season to inform local (regional) management decisions concerning fishery impacts on particular stocks of concern, but such use should also consider the implications of such decisions on other stocks of concern and/or downstream fisheries.

- Genetic technology has the potential to provide information that may help decision-makers cope with issues of critical importance to future salmon management (e.g., parentage, hatchery/wild interactions, habitat utilization, and adaptation to climate change).

- A combination of CWT recovery data and GSI estimates of stock-specific catches may allow estimation of spawning escapement for natural stocks for which there are poor or no existing escapement estimates. For many Chinook and coho stocks, programs to estimate spawning escapements are costly and produce highly uncertain results. For such stocks, a combination of CWT recovery data and GSI may enable managers to generate better estimates of spawning escapements at lower cost.

- Application of genetic methods to complement the current CWT system will require additional and perhaps substantial investment beyond the costs of maintaining and improving the existing CWT system.

- A novel genetic concept, termed *Parentage-Based Tagging,* may someday be capable of providing group-specific release and recovery data for individual hatchery release groups (sets of parents). If implemented on a coast-wide basis, this concept might provide the same kinds of data that can today only be provided through release and recovery of marked CWT groups. The practical feasibility and cost-effectiveness of applying this theoretical concept on a coast-wide basis, including collection and analysis of required GSI data in ocean and freshwater fisheries and in spawning escapements, have yet to be demonstrated, however. Implementation on a coast-wise basis would likely require significant reductions in costs of genetic analyses (on a per fish basis) as well as development of a coordinated coast-wide SNPs-based data base.

- The CWT Expert Panel identified many technical issues relating to challenges of estimating stock-age-fishery exploitation rates under mass marking and mark-selective fishing. GSI alone will not resolve those issues. Under mark-selective fishing, marked and unmarked fish experience different patterns of exploitation. Although GSI could potentially provide estimates of the composition of major stock groups released in mark-selective fisheries, GSI would not provide the data needed to reconstruct cohorts so that mortalities could be accurately quantified and properly allocated coastwide to specific groups as required to estimate stock-age-fishery exploitation rates for unmarked components of interest. Also, GSI (with the exception of Parental-Based Tagging) could not distinguish between yearling and fingerling marked or unmarked releases from the same genetic hatchery Chinook stock; these release types typically have markedly different patterns of exploitation..

Recommendation 3:

The PSC should initiate a two-stage response process to integrate and prioritize recommendations from the CWT Workgroup, the GSI Workshop report, and the Expert Panel report. These prioritized needs may differ by species and should be communicated to fishery management agencies and administrators of the Southern and Northern Endowment Funds.

- Implementation of the recommendations of the reports produced by this GSI Steering Committee, by the CWT Expert Panel, and by the PSC's CWT Workgroup, may significantly affect future PSC programs. Implementation of several of the recommendations contained in these reports would require commitments of large sums of money. These recommendations need to be summarized and prioritized for use by policy/decision makers.

- Recognizing that resources are limited and that recommendations flowing from both the CWT Workgroup and GSI Steering Group reports need to be considered in the broader context of management needs and fiscal constraints, it is recommended that the PSC undertake a two-stage response to this report. The first step should be to task a small workgroup comprised of individuals who participated in the CWT Workgroup or the GSI Workshop process (or, better yet, both) to synthesize recommendations from the two (three) processes and, where possible, provide an initial prioritization to the PSC for consideration and action at its February 2008 Annual Meeting. This report could also provide the basis for the second step, which would involve a more considered review and prioritization of management needs versus resource constraints undertaken at the level of the PSC's participating management agencies. The PSC should consider how it could provide oversight to the agencies' review to ensure completion in a timely manner and coordination of results among agencies.

- Prioritized lists should first be developed by lead management agencies within the Parties to the Pacific Salmon Treaty and between them where collaboration is essential. Lead agencies are recommended since the PSC technical committees are designated by species and/or regions and individually may not represent full consideration of all priorities and issues. A specific time for a response within 2008 (we suggest September) should be established by the PSC.

Recommendation 4:

The PSC should task the Data Standards Workgroup of the Data Sharing Committee (or create a new workgroup with subject matter expertise and suitable agency representation) with determining whether sufficient consistency can be achieved coast-wide to support multi-jurisdictional analysis for species and stocks that are exploited by fisheries over extensive geographic ranges based on GSI information. The task assignment should include projections of costs for providing GSI-based information coast-wide and an assessment of the processing capacity (throughput) needed to support management needs for timely analysis of large-scale, coast-wide GSI sampling programs.

- Collaborative development of methods, standards, and protocols for collection, reporting, and data sharing are essential for effective use of GSI methods to provide data required for stock-specific analyses of fishery impacts on Chinook and coho salmon (see Logistics Workgroup Report at PSC website).

- Application of GSI methods on a coast-wide basis would require considerable investment to (1) develop standardized genetic baselines, including consistent sampling at spatial and temporal scales to insure that important spawning populations are represented, with sufficient coverage and power to identify fish from populations of interest to managers; (2) establish protocols for representative (statistically unbiased) collection, handling, and analysis of genetic tissue samples; (3) achieve consistency in inter-laboratory genotyping (allele calling); (4) determine agreed upon methods for estimation of stock contributions from fishery samples; and (5) establish a standardized coast-wide GSI database, including protocols for coding, reporting, and archiving data, and for timely and comprehensive analysis.

- We concur with the logistics workgroup recommendation (see Logistics workgroup report) that a standardized coast-wide GSI database should be maintained by the Pacific States Marine Fisheries Commission (PSMFC), currently responsible for maintenance of the CWT release/recovery database. It is our understanding that the PSMFC is willing to undertake this task, subject to a reliable source of new funding for this purpose.

- The capacity of existing agency genetics laboratories to contribute to the development of fisheries genetic science could be compromised should they be required to process large quantities of genetic tissue in the time frames desired by managers seeking in-season information. Full scale implementation of GSI to support fishery management may require contracting with commercial laboratories to complete the annual sample process load.

Recommendation 5:

The PSC should support research into the development of protocols for GSI fishery analysis, including sample size criteria, statistical methods, guidelines for the interpretation of results, and characterization of uncertainty of results.

- Decision tools are needed to facilitate GSI experimental design, including templates for explicit specification of statistics of interest, risk tolerance for uncertainty, and level of resolution required to meet management/information requirements.

- There are several sources of imprecision and bias in GSI analyses which need to be better understood before GSI can be fully accepted and utilized in fishery management.

- Presentations made at the second GSI workshop and related sections in the report of the Modeling and Sampling Workgroup describe methods for determining GSI sample size requirements in the *absence* of stock-age assignment errors. Further statistical research is needed to address the implication of assignment errors on sample size requirements, particularly for estimation of stock proportions for small populations.

- In some cases, a mismatch exists between the capacity to distinguish between stocks based on genetic characteristics and the level of stock resolution desired by managers. Genetic differences between some stocks may not be sufficient to support desired levels of resolution for management.

<u>Recommendation 6:</u>

The PSC should adopt a strategy to keep its technical committees and panels abreast of developments and opportunities for GSI to improve fishery management. For example, the PSC could establish an annual science forum where new scientific approaches or methods, such as developments and applications of GSI technologies, could be communicated and discussed. Such a science forum could be appropriately supported by the Northern and Southern Endowment Funds.

- Genetic technologies are undergoing rapid and significant change.

- The PSC is well positioned to facilitate coordination and advancement of coast-wide applications of GSI methods.

- Communication among fish geneticists, fishery managers, and fishery modelers has historically been limited. Thus, geneticists have a limited understanding of how fisheries are managed and how genetic information could be incorporated, and managers have a limited understanding of the kinds of information that GSI can provide. The GSI workshops provided an important forum for researchers to learn of management needs and for managers to learn of the capabilities and limitations of GSI. This kind of communication between scientists and managers should advance mutual understanding and seems critical for the effective and efficient application of GSI to improve management of salmon stocks and fisheries.

- An annual science forum could be used as a vehicle to inform the PSC of new emerging methods, information or concepts as well as opportunities for collaborations between scientists and managers.

MOST PRESSING AREAS FOR RESEARCH

STATISTICAL METHODS

Recommendation 7:

Methods should be developed to better address stock and age assignment errors for GSI methods, including development of algorithms for bias-correction and for determination of effects of sample size on these errors.

- With CWTs, individual fish can be assigned to specific release groups with little chance of error, on a coast-wide basis. The development of effective methods to minimize or adjust for stock assignment errors is a prerequisite for the capacity of GSI to provide the data required for cohort reconstruction (with the possible exception of Parentage Based Tagging).

- Even given error-free assignments to stock, age assignment errors may be considerable, particularly for mixed stock fisheries, if based on analysis of scales.

- Previous findings concerning reliability of scale aging in mixed stock ocean fisheries may, however, not be pertinent to future scale aging errors associated with GSI estimates of stock composition. With GSI, it would be possible to first assign a scale to stock or stock grouping and then age the scale given that stock assignment information. Such *conditional* aging of scales is likely to have reduced errors when compared to traditional *blind* aging where readers are provided with no information concerning stock origin.

Recommendation 8:

The potential for application of *small area estimation* in analysis of ocean salmon fishery data should be explored. This method may be used to characterize the consistency of stock distribution patterns and has potential to reduce sample size requirements for stocks which comprise small proportions of the total exploited population.

- Collection of the large sample sizes that would be required to detect and accurately quantify the contributions of stocks which comprise a small proportion of the landings will in most cases be cost-prohibitive. Using small area estimation, inferences for small stocks might be based on performance of nearby, but larger, populations that share similar fishery vulnerabilities and life histories.

GENETICS

Recommendation 9:

The adequacy of genetic baselines should be evaluated in the context of the stock mixtures likely to be encountered in ocean fisheries and the stocks for which managers or researchers have greatest need to identify at the level of individual populations.

- In some circumstances, a substantial portion of the uncertainty surrounding GSI estimates (and capacity to support the level of desired resolution) can be traced to the adequacy of the genetic baselines employed for analysis. The discriminatory power of GSI methods to provide the information desired by managers depends on the genetic differences between populations included in the baseline and the relative contributions of those populations in the sample of interest.

Recommendation 10:

The PSC should continue to support microsatellites as a demonstrated coast-wide tool for GSI for Chinook salmon and continue to support development of SNPs. Both micro-satellites and SNPs have demonstrated capabilities in estimation of stock composition. The value of SNPs has been clearly demonstrated at a regional level, but the effectiveness of coast-wide application of SNPs remains to be explored.

- Both microsatellite and SNP technologies are capable of providing estimates of stock composition.

- It is clear that SNPs can be used to separate stocks at a regional level, but the effectiveness of coast-wide application of SNPs has not been evaluated because so far only regional baselines have been developed. Substantial additional investment would be required to establish coast-wide SNP baselines, but some potential benefits are apparent (reduced complexity of standardization of laboratory methods and reporting protocols, reduced speed/costs for processing tissue sampling).

- Several research studies are now underway to compare the capacities and requirements of microsatellite and SNP based methods of stock identification. For example, ongoing work in the Alaska-Canadian boundary area on sockeye salmon contributions to fisheries includes use of a developing SNP baseline by Alaska and use of a microsatellite baseline by Canada.

- Additional comparisons of current and future costs and performance of microsatellites and SNPs will be required before an objective selection of a single approach might be justified.

Recommendation 11:

Two or more independent assessments of the (large scale) application of Parentage-Based Tagging (PBT) should be undertaken, including an evaluation of logistic considerations and the probable costs of implementing sampling regimes that would be necessary to provide data necessary to support cohort-analysis-like calculations based on this approach.

- PBT appears to have considerable theoretical promise, but has not yet been validated at a salmon production hatchery. An initial test of this approach at a Washington Department of Fish and Wildlife hatchery has been proposed to the Southern Fund for 2008.

- Generation of data suitable for cohort analysis would require collection of GSI data in all ocean and freshwater fisheries, in freshwater spawning escapement and at hatcheries, essentially duplicating the scope of the existing CWT system.

- Ancillary information from PBT could prove to be capable of providing important information for salmon management. Such ancillary information might include direct estimate of effective population size, monitoring of genetic changes under climate change, and assessment of inheritance of traits such as age at maturity, run timing, and many others.

FISHERY MANAGEMENT

Recommendation 12:

Uncertainty needs to be better characterized in PSC salmon management models and its implications need to be better conveyed to managers. Managers should be explicitly advised of the uncertainty associated with estimates used for management and of how that information might be applied in accordance with precautionary management principles.

- Statistics derived from CWT or GSI data are often presented without information as to sources, magnitude, or consequences of uncertainty, even though such information could be produced.

- Quantified estimates of uncertainty are rarely presented to decision makers and are rarely taken explicitly into account..

- Uncertainty is incorporated into current management models for salmon fisheries in inconsistent and often *ad hoc* ways (e.g., through use of conservative estimates of ocean abundance and spawning escapement, or conservative model parameter values, such as release mortality rates). These ad hoc and inconsistent ways for addressing uncertainty are not easily defended at a time when many are arguing for more effective and transparent precautionary fishery management policies.

- More rigorous and more effective methods and models are needed to capture the implications of uncertainty in parameter estimates on formation of management policies. Although rigorous and effective methods have been developed for single stock management of groundfish species (e.g., the Methot Stock Synthesis model), development of such methods and models for salmon is greatly complicated by the large number of multiple stocks constituting the mixed stock ocean salmon fisheries.

Recommendation 13:

GSI should be employed to selectively validate stock composition assumptions that are incorporated in existing PSC Chinook and Coho FRAM models, to produce estimates of stock compositions of landed and non-landed (sublegal) ocean catches, and to identify stocks that are currently not represented in models.

- GSI methods and microsatellite standardization for Chinook salmon have been sufficiently developed to generate estimates of contributions of major stock groups in ocean catches for comparison with model-generated values.

- Current model-derived calculations of stock composition are based upon assumptions imbedded in planning models, including the assumption that CWT recovery patterns for hatchery indicator stocks are representative of those for wild stocks associated with the indicator stocks.

- The results of this validation effort can identify needs for model improvement and opportunities for future model development that might incorporate GSI information.

Recommendation 14:

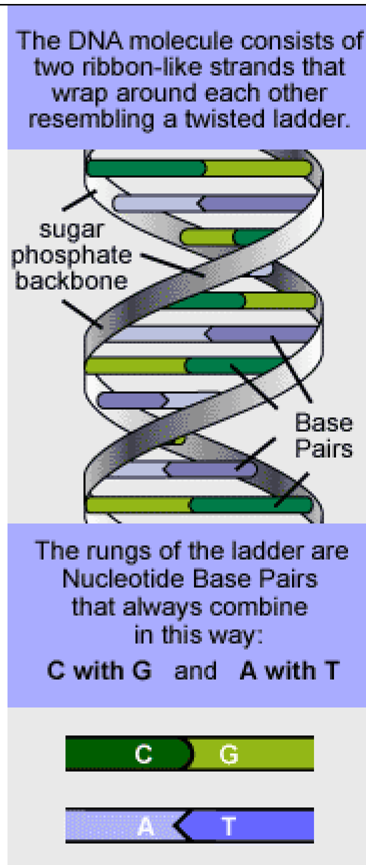
The accuracy and precision of estimating spawning escapement using a combination of CWT recovery data and GSI methods should be explored.

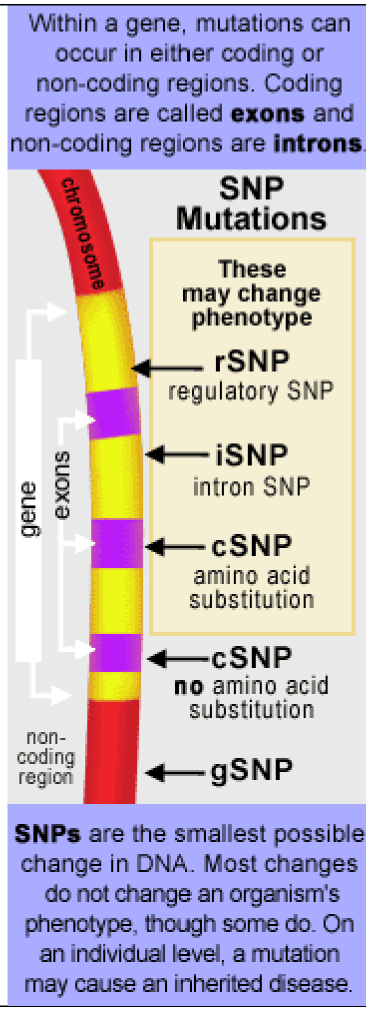
- The potential for using this approach was first noted in the CWT Expert Panel Report. More extensive analysis and development of this approach is presented in the Modeling and Statistics Workgroup Report.

- Data for a selected set of CWT indicator stocks with escapement estimates generated by traditional survey methods or dam/weir counts are available to evaluate the potential quality of escapement estimates generated through this approach.

- Proof of concept of this approach could improve the ability to obtain escapement estimates for both Chinook and coho stocks coast-wide, probably at lower cost than for conventional survey methods. Due to the multiple marine age classes in Chinook salmon, the technical challenge of accurately assigning age needs to be simultaneously addressed.

Appendix A. List of Acronyms and Terms.

CWT	Coded Wire Tag
CSC	Committee on Scientific Cooperation established by the Pacific Salmon Commission
DNA	 Deoxyribonucleic acid. DNA is the chemical responsible for preserving, copying and transmitting information within cells and from generation to generation. It is a molecule in the memorable shape of a double helix, a spiral ladder. DNA is contained in tightly coiled packets called chromosomes, found in the nucleus of every cell. Chromosomes consist of the double helix of DNA wrapped around proteins. The twisted ladder is made up of repeating units called nucleotides, each of which is a single building block of DNA. Nucleotides are composed of one sugar-phosphate molecule (the linear strands or outer rails of the ladder) and one base. DNA consists of two nucleotide strands joined by weak chemical bonds between the two bases, forming base pairs. A base pair is a rung or step on the ladder of the DNA which consists of two paired chemicals called bases. There are four types of bases, termed nucleotides: adenine (A), thymine (T), cytosine (C), and guanine (G). Certain bases always pair together (AT and GC). Illustration and much of the description from GlaxoSmithKline. http://www.genetics.gsk.com/overview.htm#chromosomes These bases *always* pair up in the following way: (A+T) (C+G) A single strand of DNA is made of letters: ATGCTCGAATAAATGTGAATTTGA The letters make words: ATG CTC GAA TAA ATG TGA ATT TGA The words make sentences: <ATG CTC GAA TAA> <ATG TGA ATT TGA> These "sentences" are called genes. Genes tell the cell to make other

	molecules called proteins. [Proteins]() are required for the structure, function, and regulation of the body's cells, tissues, and organs.
GSI	Genetic Stock Identification
MM	Mass Marking
MSF	Mark Selective Fishing
PBT	Parentage-Based Tagging
PSC	Pacific Salmon Commission
PSMFC	Pacific States Marine Fisheries Commission
SNP	 Single Nucleotide Polymorphism. A genetic (usually biallelic, two possible variations of a given DNA sequence that are detectable) marker at a particular position within a DNA sequence, consisting of a single nucleotide variation in DNA code. It is the most common type of stable genetic variation. SNPs can result from a base transition (A for G, T for C), transversion (G or A for T or C) or single-base deletion. Illustration from GlaxoSmithKline. http://www.genetics.gsk.com/overview.htm#chromosomes

Allele	One of two or more alternative forms of a gene at a given position (locus) on a chromosome, caused by a difference in the sequence of DNA. Usually alleles are sequences that code for a gene, but sometimes the term is used to refer to a non-gene sequence. An individual's genotype for that gene is the set of alleles it happens to possess.
chromosome	A single long molecule of DNA which contains many genes.
Gene	A basic biological unit of heredity, comprised of a sequence (string) of combinations of the four types of bases (see DNA) and located at a specific site on a chromosome.
genetic marker	A segment of DNA with an identifiable physical location on a chromosome and whose inheritance can be followed. A marker can be a gene, or it can be some section of DNA with no known function
genetics	The branch of biology that deals with heredity, especially the mechanisms of hereditary transmission and the variation of inherited characteristics among similar or related organisms.
locus	A fixed position on a chromosome, such as the position of a gene or a biomarker (genetic marker). A variant of the DNA sequence at a given locus is called an allele.
microsatellite	A short sequence of DNA that is used as a marker to track the inheritance of genes, which can be consistently identified, using a laboratory procedure, across all individuals. Microsatellites are sequences (usually) comprised of 1 to 4 basepairs of DNA which are repeated together in a row along the DNA molecule
phylogenetic	Pertaining to the evolutionary history of a particular group of organisms
polymorphism	The existence of two or more alternative forms (alleles) of a gene, or other DNA segment, that differ in base sequence, or that have variable numbers of repeated sequences.

Appendix B. CSC GSI Workshops Proposal.

Pacific Salmon Commission Invited Workshops:

Current and Future Applications of Genetic Stock Identification (GSI) to Ocean Salmon Management

Focus and Content:

Workshops will be tightly focused on the current and future capabilities, limitations, and uses of GSI methods in ocean salmon management. Alternative technologies will be considered to the extent that they may be used as a direct complement to GSI data collections or analyses.

Overall Objective:

To develop recommendations for integration of GSI information into a coordinated coast-wide management system to improve the ability of ocean fisheries to access abundant stocks within impact constraints established for other specific stocks and, to the extent possible, to identify and quantify the costs, implementation steps and timeframes to incorporate these recommendations.

Workshop Structure and Format:

We propose a two workshop format, with each workshop lasting three days. A notice announcing the proposed workshops would be posted on the PSC website. Formal invitations would be sent to management agencies, proposed members of workgroups, and workgroup coordinators. The first day of workshop 1 would be open to individuals from management agencies and the general public, but attendance would be limited (150-200) and a modest pre-registration fee ($25) would be charged (no fee would be charged to presenters, or members of workgroups, the Steering Committee or the CSC). Attendance on days 2 and 3 of workshop 1 and on all days of workshop 2 would be limited to workgroup members, Steering Committee members, and members of the CSC. A detailed outline of the proposed schedule for Workshop 1 is included as Attachment A.

At the first workshop, a first day's session would consist of essential background presentations on "What manager's want" (AM) and "GSI: State of the Science" (PM). Several case studies will illustrate use of GSI in ocean salmon management. Although the primary audience is intended to be the members of invited workgroups, a limited opportunity will be available for the public to listen to the presentations by pre-registering and paying a nominal fee to defray costs. On the second and third days of the first workshop, invited participants would break into four pre-assigned workgroups (Genetics, Logistics, Management, and Modeling/Sampling), each charged with addressing a set of issues and questions and, working with a coordinator, begin to develop a set of proposed actions or recommendations designed to contribute to achievement of the overall objective specified above. Members of all four workgroups would reconvene at the end of the second day to exchange preliminary findings and recommended products. Workgroup deliberations would continue on the third day. Workgroup *Coordinators* (see below) would meet with members of the *Steering Committee* (see below) at the end of the third day to agree upon direction for preparation of workgroup reports.

Following Workshop 1, Workgroup *Coordinators* (compensated) would be responsible for interacting with workgroup members to develop written reports/proposals which would be formally presented at a second workshop. Participants from all workgroups would be expected to participate at the second workshop. Deliberations would be focused on the contributions of workgroup recommendations to the overall objective, identification and resolution of incompatibilities, and development of specific implementation plans. Workgroup Coordinators would meet with workgroup members on days 2 and 3 of the second workshop, revising the draft report and addressing newly identified issues, and would thereafter be responsible for delivering a final revised workgroup report to the GSI Workshop Steering Committee. The Steering Committee would discuss the merits of the four final reports, resolve, if possible, any incompatibilities across reports, compile them, submit the reports to a group of three peer reviewers, and subsequently provide the reports to the PSC

Compensated ($1,000 per review) peer reviews would be solicited from each of three fishery scientists, selected by the CSC, who are qualified to assess the merits of the combined reports but did not participate in the GSI Workshops. Peer reviews would be provided to members of the Steering Committee who would then attach the peer reviews, along with Steering Committee response, to the PSC.

We anticipate that the product delivered through this process would consist of (a) explicit recommendations for field protocols and sample sizes regarding collection of GSI data, (b) explicit recommendations for how GSI data might best be incorporated into ocean salmon management models and regimes, and (c) explicit proposals for further research that is needed to ensure effective incorporation of GSI data in management of ocean salmon fisheries.

Steering Committee:

Although the original idea for the workshops originated as a proposal from the bilateral Committee for Scientific Cooperation (CSC) to the Northern and Southern Restoration and Enhancement Funds, detailed development of workshop format and objectives has been tasked to a Steering Committee. Steering Committee members are as follows:

Craig Busack, WDFW
Al Cass, DFO
John Clark, ADFG
David Hankin, CSC (Chair)
Robert Kope, NMFS
Paul MacGillivray, PSC Commissioner, Canada
Gary Morishima, MORI-ko LLC
Dave Peacock, DFO
Larry Rutter, PSC Commissioner, US

Workshop Dates and Schedule for Deliverables:

Workshop #1: Portland, OR 15-17 May 2007
Workshop #2: Vancouver, BC 11-13 September 2007
Final Workgroup Reports to Steering Committee: 15 October 2007
Reports sent out for Peer Review: 15 November 2007
Workshop Reports & Peer Reviews Submitted to PSC: 15 January 2008

Workgroups:

The Steering Committee has recommended the formation of four workgroups: Genetics, Logistics, Management, and Modeling/Sampling. Although these workgroups are structured around traditional disciplinary areas in Fisheries, proposed workgroup membership is designed to ensure cross-fertilization so that managers, geneticists and modelers communicate with one another. Each workgroup will be expected to contribute to the overall objective: to develop recommendations for integration of GSI information into a coordinated coast-wide management system. Steering Committee members would be assigned to specific workgroups to provide clarification, guidance and direction during deliberations.

The Steering Committee has developed a list of recommended participants for each of the four proposed workgroups and has identified candidate individuals who might serve as coordinators of the workgroups. Workgroup members would be expected to be present and working at both workshops (3 days duration each) and would be expected to make themselves available on a limited basis between workshops, as requested by workgroup coordinators. Workgroup coordinators, serving as compensated consultants, would be expected to prepare written workgroup products and to orally present the draft workgroup product on the first day of the second workshop. Initial lists of workgroup participants range in size from 11-14 per group plus 2 or 3 additional members from the Steering Committee. We anticipate that final workgroup sizes will be approximately 10 individuals, including Steering Committee members and workgroup Coordinators. A list of proposed workgroup participants is included as Appendix B.

For the Genetics, Management, and Modeling/Sampling workgroups, the expected content of the final deliverable product to be produced by individual workgroups is not explicitly stated. Instead, workgroup products are intended to be guided by their response to a series of sample questions that have been posed by the Steering Committee to each workgroup. If workgroups address these questions, we expect that their reports will contribute to the overall thematic objective of the workshops. Note that some workgroups may wish to address questions that have been posed for other workgroups and that workgroups are expected to pose additional questions of their own construction.

For the Logistics work group, however, members of the Steering Committee have crafted a very explicit deliverable product:

> To develop a proposal for development and implementation of a GSI infrastructure for coast-wide application of GSI for Chinook (and coho?) salmon for management of ocean fisheries which operates within a multi-jurisdictional environment and is capable of supporting (a) the level of resolution of stock identification required by harvest managers, and (b) an adequate turnaround time for sample analysis. (Included in this proposal would be a recommended GSI baseline, standardized protocols for data collection, analysis and reporting, database design and access, including costs and timelines for implementation).

Sample Questions to Focus and Guide Workgroup Discussions and Analyses

Genetics:

- What level of stock resolution can be reasonably expected from genetic methods? What are the *intrinsic* possibilities and how do these possibilities depend on the number of loci examined. For example, without full parental genotyping (FPG) it appears impossible to use GSI to identify hatchery release groups and the "standard" microsatellite loci may not allow separation of closely related wild and hatchery stocks, closely related races, or fish that have the same genetic heritage but different rearing strategies (e.g., yearling vs fingerling releases). What is the level of classification (e.g., population?, “reporting groups”?) that can be expected from the current GAPS baseline. Will this level be sufficient for harvest management needs? If not, could level of classification be improved by modest augmentation of the GAPS baseline?

- What types of genetic markers are best suited to advance the overall workshop objective, and what are the states of development of techniques used for each marker type?

- What are the species-specific states of GSI baseline development and how standardized are collection and analysis protocols? What are the collection dates for data used for the baselines? What further effort is required to develop baselines that can be expected to support coastwide ocean salmon management at the level of resolution desired by managers? Do protocols provide for assessment of temporal stability of population markers, particularly for small populations?

- What are the significant differences between the use of mixture and individual fish assignment models to assign fish to their correct parent populations? How are assignment errors influenced by sample sizes, true stock proportions, # of loci examined? What are the magnitudes of errors assignment using the current 13 microsatellite standardized baseline for Chinook salmon? What methods can be employed to correct for assignment error?

- How might the potential performance, management value, and cost of the FPG concept best be explored?

- What are the advantages and disadvantages of SNPs versus microsatellites? Is it true that SNP analysis may reveal genes important for traits subject to natural selection? Do those have any value for management of ocean fisheries?

Logistics

- What standardized protocols should be developed for collection of field samples? What are the logistics and costs of making field GSI collections?

- What are the sample processing issues that would be raised by widespread application of GSI methods to ocean salmon management? What turnaround times would be feasible (collection to reporting of GSI results)? What lab facilities are available or would be needed? What kind of throughput is feasible now and what are current lab costs? How might throughput and lab costs change over the next ten years? Should agencies plan on expanding the sizes of their own labs, or would it be more cost-effective to send samples to commercial labs for processing?

- What kind of data management system would be needed to maintain a coast wide GSI database of fishery management? What procedures would need to be established for data reporting, for access to archived samples, "voucher" samples, and setting up a standardized database system (as has been developed for the CWT system)?

Management

- What are the basic management data that must be collected/estimated to support current management regimes? What more do we need than estimates of age- and fishery-specific impacts on specific stocks ?

- What are acceptable levels of error for management? What would be needed to develop standards for bilateral acceptance of GSI data?

- What additional information could be collected by GSI methods that is not currently available but could improve fishery management? For example, how could GSI-based information on sublegal stock composition in size-selective fisheries and stock composition in non-retention fisheries (e.g., Chinook retention only with coho release) be incorporated into management planning processes?

- What other potential uses might GSI-based information have? For example, parentage analysis could be used to assess reproductive performance of wild as compared to hatchery fish spawning in natural spawning streams; hatchery breeding programs might benefit from an ability to separate hatchery from wild fish, or spring from fall races; estimates of stock composition might be combined with estimates of exploitation rates derived from CWT experiments to estimate spawning escapements.

- What are the specific stocks that constrain ocean salmon management today, and what specific stocks are likely to do so in the future? What are the perceived sizes of these stocks? Are there closely-related hatchery stocks mixed with wild stocks that are constraints to ocean fisheries? On what basis will the new Canadian Conservation Units be managed?

- Are in-season GSI-based adjustments to fisheries compatible with pre-season agreements and with achieving overall management objectives? How could GSI-based in-season adjustments to fisheries be designed to generate desired fishery impacts under the Pacific Salmon Treaty?

Modeling/Sampling

- How might GSI data best be integrated with CWT data? For example, could the Methot (groundfish) stock synthesis model/mindset/approach somehow be applied to salmon management?

- Is it realistic to expect that GSI methods would be capable of generating the data required for cohort analysis (analogous to data that have been provided by the CWT system)? If so, what would be the required scale and design of a coast-wide sampling program (as for CWTs) that might be needed for implementation of GSI;

- What are the likely sample size requirements to generate estimates of acceptable reliability for populations of interest assuming (a) perfect classification (no classification errors) or (b) imperfect classification (with stock-specific "mis-assignment probabilities" to be provided by genetics workgroup)

- How could GSI data improve our current CWT-based understanding of ocean distribution patterns of individual stocks? Based on CWT data, how much do these distributions change across years? How could new GSI ocean distribution data be easily incorporated into existing management models?

PROJECTED COSTS

The Steering Committee anticipates that the direct cost of the two workshops will range between $87,000 and $102,000. Uncertainty in total cost in large part reflects uncertainty in projecting travel costs which will, in part, depend on the identity of individuals who agree to serve on workgroups. Agency (US, CA, tribal) participants will be expected to cover their travel costs, but travel costs will need to be reimbursed for non-agency (academic, retired) participants and possibly for a few agency participants unable to secure funding for attendance.

Item	Projected Cost
Travel Costs:	
Workshop Travel: Invited workgroup participants unable to cover travel expenses	$10,000-$25,000
Steering Committee Travel	$ 4,000
Coordinator Travel (to visit workgroup members Between workshops)	$ 6,000
Coordinator Contracts:	
4 contracts, fixed cost agreements, at $8,000 each	$32,000
Steering Committee Expenses:	
Chair compensation:	$ 8,000
Logistical Expenses:	

Room rentals, coffee/pastries, lunches for workgroups:	$20,000
Peer Reviews: 3 each @ $,1000 per review	$ 3,000
Final Report Preparation:	
Contracted assistance in report formatting, editing	$ 4,000

Appendix C. Tentative Agenda for Workshop 1: 15-17 May, Portland, OR

Workshop 1:

DAY 1:

Introduction to Two Workshop Structure, Approach (Pennoyer): CSC involvement in GSI workshop proposal. First day overviews of management regimes, genetic methods. Why four workgroups? Tasks on Days 2 and 3; breaks, meals (20)

Charge to Workshop Participants: What managers need to know (TBA). Issues that prompted the workshop and what we hope to achieve from it. Expert Panel Findings and Recommendations wrt GSI and ocean salmon management. Overall objective of workshops: To develop recommendations for integration of GSI information into a coordinated coast-wide management system. Clear and immediate desire for approaches whereby GSI data might be used to complement CWT data, but also expecting/hoping for thinking "outside the box", e.g. hypothetical management systems that might rely almost exclusively on GSI and landings data, without CWT data. End product: a realistic, objective appraisal of how GSI can be used, now, and in the future, to improve ocean salmon management. (30 min)

Overview of Current Fishery Management Regimes and Management Models (Morishima): ABM vs ISBM fisheries; Ocean vs terminal area fisheries management needs; CWT system; existing ocean Chinook salmon management models. Reliance on exploitation rates and connection with CWT program. Questions that cannot be answered with CWTs (e.g., stock composition of sublegal contacts/mortalities), but which might be answered with GSI techniques. Recognized GSI Issues (previously identified by EP report): accuracy of GSI for racial separation (e.g., Klamath fall vs spring); sample sizes required to estimate contributions from small natural stocks; GSI separation of hatchery & wild when derived from same source; (1 hr)

Break – 20 min

Review of ocean Chinook fisheries management. (Riddell) Expectations for potential use of GSI; review of applications thus far. Constraints: ESU/individual populations vs Canadian CUs. "Weak natural stocks". (1 hr)

Use of GSI in Near-Terminal Fisheries: Northern Boundary and Transboundary Mgt under the PS Treaty (Sandy Johnston, Dave Peacock, Scott Kelly) Need for and use of genetic methods and GSI for management of Chinook and sockeye stocks. Importance of stock composition estimates. (30 min)

Lunch – 1 hr

PM session:

Genetics - State of the Science (Moran). Survey of genetic tools and approaches. What genetic markers are available and what are their relative merits? What kinds of information and analyses are managers getting from GSI now and what can they realistically expect in the future? Review of GAPs process, including current projects and baseline development. Discussion of GSI issues identified in Expert Panel report. (1 hr)

Case Studies

WCVI Fisheries: (Beacham/Candy). Lessons Learned. (30 min)

CROOS: (Banks). Study design, estimated costs, concerns, what will be delivered, preliminary results. (30 min)

Break – 15 min

Puget Sound and Columbia River Chinook Stocks: (Warheit) - Desired level of resolution for GSI. What is the power of the GAPS baseline to identify fish from populations of interest? What would be required for adequate discrimination among stocks? (30 min)

SEAK Chinook GSI (Seeb) (30 min)

GSI applications for Fraser Sockeye: (Lapointe) (30 min)
****

Note: All listed durations for talks include 10 minutes for questions.

DAY 2:

8 AM - Noon: Workgroup Breakouts
1 PM – 3 PM: Workgroup Breakouts
3 PM – 5 PM: Joint Workgroup Sessions – Coordinators make Preliminary Presentations & Lead Discussion of Issues

DAY 3:

8 AM – Noon: Workgroup Breakouts
1 PM – 3 PM: Workgroup Breakouts
3 PM – 5 PM: Workgroup Coordinators Meet with Steering Committee Members

Appendix D. Final List of Workgroup Members and Workgroup Coordinators Participating in Workshop 2.

Last Name	First Name	Affiliation	Workgroup	Email
Banks	Michael	OSU	Genetics	michael.banks@oregonstate.edu
Beacham	Terry	DFO	Genetics	beachamt@pac.dfo-mpo.gc.ca
Habicht	Chris	ADFG	Genetics	chris_habicht@fishgame.state.ak.us
Kalinowski	Steve	Montana State	Genetics	skalinowski@montana.edu
Kostow	Kathryn	ODFW	Genetics	kathryn.e.kostow@state.or.us
Latham	Steve	PSC	Genetics	latham@psc.org
Miller	Kristi	DFO	Genetics	millerk@pac.dfo-mpo.gc.ca
Narum	Shawn	CRITFC	Genetics	nars@critfc.org
Smith	Christian	USFWS, Abernathy	Genetics	christian_smith@fws.gov
Thompson	Brad	WDFW	Genetics	thompbet@dfw.wa.gov
Warheit	Ken	WDFW	Genetics	warhekiw@dfw.wa.gov
Grant	Stewart		Genetics-Coordinator	phylogeo@yahoo.com
Busack	Craig	WDFW	Genetics-Steering Committee	busaccsb@dfw.wa.gov
Clark	John	ADFG	Genetics-Steering Committee	john_h_clark@fishgame.state.ak.us
Candy	John	DFO	Logistics	candyj@pac.dfo-mpo.gc.ca
Cox	Brodie	WDFW	Logistics	coxpbc@dfw.wa.gov
DeHart	Douglas	USFWS	Logistics	douglas_dehart@fws.gov
Garza	Carlos	NMFS, Santa Cruz	Logistics	carlosjg@cats.ucsc.edu
Grover	Allen	CDFG	Logistics	agrover@dfg.ca.gov
Hawkins	Denise	WDFW	Logistics	hawkidkh@dfw.wa.gov
Kang	Richard	NMFS/GAPS	Logistics	richard.kang@noaa.gov
Nandor	George	PSMFC	Logistics	george_nandor@psmfc.org
Volk	Eric	ADFG	Logistics	eric_volk@fishgame.state.ak.us
White	Bruce	PSC	Logistics	white@psc.org
Winther	Ivan	DFO	Logistics	winteriv@pac.dfo-mpo.gc.ca
Johnson	Ken		Logistics-Coordinator	jkenjohnson@gmail.com
Rutter	Larry	NMFS	Logistics-Steering Committee	larry.rutter@noaa.gov
Bartlett	Heather	WDFW	Management	bartlhrb@dfw.wa.gov
Clemons	Ethan	ODFW	Management	ethan.r.clemons@state.or.us
Dygert	Peter	NMFS	Management	peter.dygert@noaa.gov
Gray	Andrew	Auke Bay Lab	Management	andrew.gray@noaa.gov
Johnston	Sandy	DFO	Management	johnstons@dfo-mpo.gc.ca
Kelley	Scott	ADFG	Management	scott_kelley@fishgame.state.ak.us
Lapointe	Michael	PSC	Management	lapointe@psc.org
Moran	Paul	NMFS	Management	paul.moran@noaa.gov
Patillo	Pat	WDFW	Management	pattiplp@dfw.wa.gov
Spidle	Adrian	NWIFC	Management	aspidle@nwifc.org

Last Name	First Name	Affiliation	Workgroup	Email
Starr	Paul		Management-Coordinator	paul@starrfish.net
Cass	Al	DFO	Management-Steering Committee	cassa@pac.dfo-mpo.gc.ca
Morishima	Gary	MORI-ko LLC	Management-Steering Committee	morikog@aol.com
Alexandersdottir	Marianna	NWIFC	Modeling/Sampling	malexand@nwifc.org
Bernard	Dave	ADFG	Modeling/Sampling	drbernardconsulting@gci.net
Carlile	John	ADFG	Modeling/Sampling	john_carlile@fishgame.state.ak.us
Lawson	Pete	NMFS	Modeling/Sampling	peter.w.lawson@noaa.gov
Mohr	Michael	NMFS, Santa Cruz	Modeling/Sampling	michael.mohr@noaa.gov
Packer	Jim	WDFW	Modeling/Sampling	packejfp@dfw.wa.gov
Pella	Jerome	NMFS, retired	Modeling/Sampling	jpella@gci.net
Riddell	Brian	DFO	Modeling/Sampling	riddellb@pac.dfo-mpo.gc.ca
Ryding	Kris	WDFW	Modeling/Sampling	rydinker@dfw.wa.gov
Schwarz	Carl	SFU	Modeling/Sampling	cschwarz@stat.sfu.ca
Sharma	Rishi	CRITFC	Modeling/Sampling	shar@critfc.org
Templin	Bill	ADFG, genetics lab	Modeling/Sampling	bill_templin@fishgame.state.ak.us
Korman	Josh		Modeling/Sampling-Coordinator	jkorman@ecometric.com
Hankin	Dave	Humboldt State	Modeling/Sampling-Steering Committee	dgh1@humboldt.edu
Kope	Robert	NMFS	Modeling/Sampling-Steering Committee	robert.kope@noaa.gov

Appendix E. Workshop Agendas.

WORKSHOP 1 AGENDA

Day 1 Presentations: Tuesday 15 May

- Received titles are in quotes and in **bold font.**
- Presentations are intended to allow for 5-10 minutes of questions/discussion.

Speaker	Topic	Time
Steve Pennoyer	**Introduction to Workshop - Proposal History, Workshops Format, Logistics**	8:20 - 8:40
AM: BACKGROUND		
Larry Rutter	**"Charge to the PSC GSI Workshop: Why we are here, and what is expected of us."**	8:40 - 9:10
Gary Morishima	**"Harvest Management of Chinook and Coho Salmon: Current Practices and Opportunities for Improvement"**	9:10 - 10:10
BREAK		10:10 - 10:30
Brian Riddell	**"Ocean Fishery Management processes: Chinook and Coho salmon"**	10:30 - 11:30
Paul Moran	**"Current affairs in DNA typing for fishery management: From GSI to FPG…marker wars to useful augmentation of CWTs"**	11:30 - 12:30
LUNCH BREAK		12:30 - 1:45
PM: CASE STUDIES		
Wilf Luedke	**"A Short History of the WCVI troll fishery and application of GSI"**	1:45 - 2:15
Sandy Johnston Scott Kelly, Chris Habicht	**"[Potential] Applications of Genetic Stock ID in the Transboundary and Yukon Areas: A Canadian fishery manager's perspective."** **"Summary of Transboundary and Northern Boundary Commercial Salmon Fisheries in Southeast Alaska and Potential Management Applications of GSI Technology"**	2:15 - 2:45

Speaker	Topic	Time
Michael Banks	**"Project CROOS: GIS/GSI Prospects for Real-time Fishery Management"**	2:45 – 3:15
BREAK		3:15 – 3:35
Ken Warheit	**"Factors influencing the efficacy of GSI; examples using Washington, Oregon and Idaho stocks in the GAPS 2.1 database."**	3:35 – 4:05
Lisa Seeb	**"Genetic Stock Identification of Chinook Salmon from Southeast Alaska: A review of the past and a look forward"**	4:05 - 4:35
Mike Lapointe	**"GSI applications in Fraser River Sockeye Management: Confessions from a skeptic turned addict"**	4:35 - 5:05

WORKSHOP 2. AGENDA

Date	Time	Topic
11 Sept	8:00-9:00 AM	Plenary Session. "Charge" to group (Larry Rutter), expectations, process, logistics. (Note – Laura Richards to introduce speakers, etc.)
	9:30 - Noon	Workgroup Meetings – brief reports on assignments; clarify presentations, status, positions, potential recommendations
	Noon – 1 PM	**Lunch (Working if needed)**
	1:00 – 5:00 PM	Workgroup Presentations
12 Sept	8:00 AM – Noon	Workgroup Presentations
12 Sept	Noon – 1 PM	**Lunch**

Date	Time	Topic
	1:00 – 5:00 PM	Workgroup Presentations
13 Sept	8:00 – 10:30 AM	Plenary Session. Group Discussion: Proposals for Recommendations
	11:00 – Noon	Workgroup Coordinators meet with workgroup members – Bye, thanks, follow-up assignments?
	Noon – 3 or 4 PM	Working lunch; steering committee meets with coordinators to discuss status, timeline, debrief, next steps, etc.

Detailed Presentation Schedule:

Date	Time	Speaker (Workgroup)	Topic
11 Sept	1:00	Moran (Management)	GAPS Chinook Baseline vs Mgt Model Structure & Needs
	1:30	Morishima (Management)	Alternative Management Strategies
	2:00	Volk (Logistics)	Potential for use of otolith marks in ocean salmon management
	2:30	Starr (Management)	Incorporation of uncertainty in management process
11 Sept	3:00	**Break**	

Date	Time	Speaker (Workgroup)	Topic
	3:20	Packer (Management)	Using GSI to improve escapement estimation for natural stocks
	3:50	Candy (Logistics)	Standardized GSI Reporting Data formats, data access
	4:20	Hawkins (Logistics)	Collection and Curation of GSI samples
12 Sept	8:00	Habicht/Beacham/Moran (Genetics)	Status of Agency GSI Databases and recommendations
	8:40	Nandor (Logistics)	Feasibility of PSMFC serving as coastwide database coordinator, database access

Appendix F. Contrast of data and information generated from GSI and CWTs relative to their suitability for managing ocean fisheries.
(Developed by G. Morishima and B. Riddell, based on their presentation at Workshop 1.)

Topic	CWT	GSI
Accuracy and precision	Formulas for estimating uncertainty surrounding CWT statistics, based on the number of tags recovered and the level of confidence about estimates of total catch (or escapement) by strata have been developed. Depends on number of CWTs recovered and QA/QC for sampling and reporting. Little chance of stock or aging assignment error	Formulas to reflect uncertainty surrounding estimates of GSI statistics, which reflect sampling variability, stock and age assignment error, have not been developed. Depends on adequacy of baseline to represent populations of interest, sample size, and the proportion of the stock of interest in the sampled population. Assignment error can bias estimates, particularly for stocks that comprise a small proportion of the sampled population. Temporal stability of genetic baseline is uncertain, particularly for small populations.
Resolution	Statistics provided for individual release group for stock, race, brood year, release type, size, location, time.	Depending on level of resolution needed, current GAPS baseline may require auxiliary means to separate fish with similar genetic characteristics
Cohort analysis	Required data can be obtained from CWT release and recovery data, collected and reported coastwide.	Coastwide sampling, reporting, or analysis protocols/methods/systems not in place. Standardization of methods required to provide consistent data for use in cohort analysis. Ability to assign individual fish to appropriate age-stock groups is problematic. Auxiliary means required for aging, separation of groups with similar genetic composition (e.g., yearling vs fingerling releases, hatchery stocks originating from common broodstocks, hatchery production utilizing wild fish as broodstocks, natural stocks influenced by straying or hatchery or nearby natural fish, etc.). Difficulty in generating accurate estimates of escapement problematic for some stocks, exacerbating challenges for cohort reconstruction.

Topic	CWT	GSI
Sample size requirements	Coastwide standard guideline of at least 20% of catch. Specific sample size requirements depend on statistic of interest, stock/fishery distribution patterns, tagging levels, stratification, sample rates, and level of uncertainty surrounding estimates of the size of the sampled population (catch or escapement strata). Sample size requirements can be determined using available formulas for estimating uncertainty surrounding CWT statistics, based on the number of tags recovered and the level of confidence about estimates of total catch (or escapement) by strata.	No standard sampling guideline. Specific sample size requirements depend on statistic of interest, *a priori* estimates of the proportion of the sampled population comprised of the stock of interest, the statistic of interest, genetic baseline employed, assignment error, uncertainty surrounding estimates of the size of the sampled population. Formulas for determining sample size requirements, which reflect sampling variability, uncertainty surrounding estimates of catch (or escapement by strata), and stock/age misassignment have not been developed.
Signal amplification	Statistics depend on recoveries of individual CWT experiments. Not dependent on relative proportion of the stock of interest in the sampled population	Each fish carries its own genetic “tag”. Depends on the proportion of the sampled population comprised of the group of interest and the DNA baseline employed
Representation of natural stock impacts	Hatchery stocks commonly employed as indicator stocks for natural populations, based on brood stock, rearing & release strategy. Historically, CWT’s have been intermittently applied to many stocks. Limited indicator stock program. Some hatchery production not associated with CWT releases. Some stocks not routinely CWT’d because of little evidence of substantial impacts by ocean fisheries (e.g., Columbia River upriver spring chinook)	Each fish carries its own genetic “tag”; representativeness depends on DNA baseline employed for analysis.
Data acquisition cost	Depends on the number of CWTs released, and recovered and processed (visual or ETD sampling to minimize cost). Marginal benefit of additional recoveries decreases asymptotically as the recoveries for individual release groups increases.	All fish in sample must be processed; data extraction and analysis cost dependent on level of resolution required. Marginal benefit of additional recoveries decreases asymptotically as the recoveries for individual genetic groups increases.

Summary

Most Suitable	Less suitable
CWT's – Basic source of management data for 30 years	
Cohort analysis for individual release groups Assessing probable fishery impacts on a small natural population, IF a CWT release group is a valid surrogate for the natural population	Estimation of stock composition Estimation of incidental fishing mortalities (e.g., "shaker", drop-off, non-retention) Fine-scale shaping based on in-season data (related to port-based sampling scheme and roll-ups into reporting strata)
GSI – Emerging Technology	
Estimating contributions of major stocks (those comprising relatively large proportions of sample) in/post season Obtaining information through non-lethal sampling Parentage (pedigree) analysis	Estimating contributions of stocks which comprise a small proportion of sampled population, when genetic classification error is large. Cohort analysis (sampling plus, stock/age assignment error, escapement estimation)