GSI Workshop: May & September 2007

Report from the Management Workgroup

October 2007

Recommendations

The Management WG felt that the following three questions are crucial to the consideration of how to integrate GSI into the management of Pacific salmon stocks:

1. What are the current management objectives?

   A clear and consistent set of management objectives is a crucial requirement for setting the standards by which fisheries data are collected. These will set the level of stratification needed to achieve these objectives, either on a temporal or spatial scale. Stratification will be affected by technical limitations associated with each data system, either in terms of feasibility or excessive cost, but nevertheless the required resolution and technologies employed should be driven by the management requirements.

2. What deficiencies in the current data impede achieving these objectives?

   The current data systems need to be reviewed and analysed in the context of the suite of management objectives to determine whether they can deliver the necessary information to support the achievement of these objectives. This step is necessary in order to place the benefits and costs of applying a new technology such as GSI in its proper context.

3. How can GSI be applied to remedy these deficiencies?

   It should be relatively straightforward to insert GSI into our data collection systems once the first two steps have been carried out. This is because the management requirements will have been clearly laid out and the gaps in the existing methodologies will be exposed. It is also possible that GSI can be used to augment or replace existing technologies, but this has to be done in the context of the suite of management objectives and how information is collected in support of these objectives.

The Management WG felt that GSI has the potential to accomplish several important tasks, including a number of recommendations:

1. Validate and test assumptions in current models.

   Existing models and data collection systems have been based on a range of crucial assumptions. The introduction of a new and somewhat independent source of information provides an opportunity to test a number of these assumptions.

   a. Model predictions of stock composition (derived from CWT) can be matched with equivalent observations based on GSI techniques. This provides an opportunity to test the assumption that unmarked fish behave similarly to marked fish. GSI provides a data set that is independent of, and not limited by the number of external marks, and thus provide a valid potential comparison.

b. Another useful validation would be to compare the stock composition of discarded sub-legal salmon as determined by GSI against current CWT-derived estimates of the same quantities.

2. Improve current models or create new ones by introducing additional information.

GSI has the potential to add information to existing models that presently is not available through other methodologies. The WG identified several tasks which might fall into this category.

a. GSI could be added to existing transboundary models for chinook and sockeye so that the resolution and predictive power of these models can be improved.

b. Existing levels of stratification based on CWT and GSI methodologies could be aligned to explore inserting the latter information into existing models.

3. Assist in the recognition of uncertainty and the inclusion of uncertainty in advice.

a. GSI information provides an opportunity to investigate variation, particularly temporal variation. Salmon models presume a high level of interannual stability, an assumption which can be tested using stock composition information generated by GSI methods. Such variation is amenable to investigation using CWT data, but the existence of additional sources of information will allow a comparative study of this issue.

b. Model-based investigations of sampling precision and potential bias are possible once a models which incorporate realistic levels of uncertainty are developed. Such models could also integrate GSI and CWT data, providing a platform that may be able to test the compatibility and relative utility of these data.

But all this has to be placed in the context of clear and agreed management objectives, including:

1. Conservation
2. Sustainable use
3. Acceptable cost and benefits
4. Operational/in-season objectives
5. Research and data legacy issues

This list is presented to remind us that there are a range of valid and useful management objectives to which GSI and other data-generating methodologies can be applied.

The Management WG discussed a range of recommendations which cover a range of issues:

- Co-ordinate systems across agencies and jurisdictions to achieve consistency in resolution and methodology

  There is an impediment in adopting GSI on a coastwide basis due to inconsistencies in methodology, both at a technical level and at the levels of chosen resolution. For instance, there is the potential that a requirement for high levels of resolution in one jurisdiction can affect the resolution (and cost) requirements in other jurisdictions. For instance, this could occur when an agency requires detailed information for an ESA stock which occurs at such low abundance in some fisheries that there is little hope of obtaining sensible information from sampling. These types of inconsistencies need to be discussed and reconciled in order to facilitate the introduction of coastwide systems and standards.

- Evaluate existing uncertainties to put new information into context

  Although this task has always been possible, a complete and systematic evaluation of the true level of uncertainty in the existing data-gathering and management advice system is not currently available. However, such information is crucial to the understanding of the benefits of the introduction of GSI into the present system. How can we fully understand the effects of adding new information when the existing system is not completely described?

- Genetic information has demonstrated its utility and should be integrated into existing systems

  There is already a large body of information that indicates that there is enormous potential for GSI providing useful information for the management and assessment of salmon. Otherwise there would be little point in discussing the issue. Also, there are clear examples where existing technology (for example, the introduction of mass marking of hatchery fish) has been compromised or is not able to deliver adequate information for management.

- The introduction of new technology should be considered in the context of the added costs and the value of the new information

  There are many examples where it is feasible to collect data at a very fine scale, either temporally or spatially. Many of the in-season data collection programmes which are based on GSI methodology demonstrate this. However, such programmes often come at a high cost, either in terms of high dollar expenditures or overloading limited laboratory capacity. These costs need to be evaluated in the context of the additional information obtained, its utility in responding to the management issues, and possible alternative options, including changing the management imperatives. This does not imply that such programmes are not useful, only that they need to be placed in the context of the overall management of the system.

- Examine and evaluate the potential of applying alternative management strategies to achieve management objectives

  Further to the recommendation that the cost of new technology should be evaluated in the context of the overall management, there is the potential to rethink our management systems so as to maximise the benefits while minimising the costs. Such changes may require radical changes in how salmon are assessed, managed and harvested. It may be that the current system, which has evolved over time, can be modified to improve benefits and reduce uncertainty. Such changes will not happen easily and will likely require a substantial background of supporting analysis. However, alternative management strategies could be proposed and evaluated in the context of these discussions on improving the overall salmon management system.

- Improve the representation of uncertainty in existing assessment models and/or explore new types of models

  Current models which are used to manage salmon do not adequately explore the underlying uncertainty which characterises these systems, nor is the true level of the uncertainty well communicated to managers and other levels of policy makers. There are obstacles to a full representation of the uncertainty because managers are often not accustomed to receiving this information and may require additional training to be able to use this information in management situations. However, it is desirable that uncertainty is adequately represented in the advice that is presented to managers and policy makers and provision should be made to either upgrade existing models or to develop new models which are capable of performing this function. Additionally, such models provide an opportunity to develop harvest control rules and management strategies which have the potential to incorporate uncertainty into management advice.

- The effects of errors in the ageing of chinook should be further investigated in the context of using auxiliary ageing data to augment the information obtained when using GSI to separate stocks

  In particular, the propagation of error in cohort analyses should be investigated through simulation. This is especially true if methodologies to apply cohort analysis based on GSI data are progressed. While there is potential for GSI data to be used for this type of analysis, such use also requires a good understanding of the limitations of the current data and their potential for introducing unquantified error.

Report

The Management workgroup (WG) met twice: once from 16–17 May and 11–13 September. The WG agreed that its primary task was to provide advice on how GSI could be integrated into the management of Pacific salmon stocks that are of concern to the Pacific Salmon Commission. The WG agreed that it would structure its report into three sections:

1. What do managers want in terms of objectives and how they might be achieved?
2. What are the current deficiencies in the data collection programmes that impede these objectives?
3. How can GSI be applied to remedy these deficiencies?

1. Management Objectives: What Do Managers Want?

The WG agreed that there were two primary objectives pursued by Managers: a) those that addressed stock sustainability issues and b) those that addressed harvesting objectives. While the WG agreed that there was overlap between these objectives, the primary difference between these sets of objectives was that the first were stock oriented while the second were directed at fisheries and addressed a number of varying objectives.

The stock sustainability objectives addressed issues such as:

1.a) Putting an adequate escapement on the spawning grounds;

1.b) Keeping the total exploitation rate on a stock to acceptable levels;

1.c) Meeting short- and long-term rebuilding goals, such as stopping the decline in escapement and building the escapement up to a target level.

The harvesting objectives all encompass an overall objective of providing maximum fishing opportunities while meeting sustainability goals. This overall objective implies a number of sub-objectives:

1.d) Meeting various allocation objectives, including allocating catch between Canada and the US, as well as meeting a variety of domestic allocation objectives in each country;

1.e) The objective of maximising fishing opportunities includes meeting a number of social and economic objectives that will be specific to each fishery;

1.f) The allocation and social benefit objectives are tempered by the requirement to minimise the impact of the fishery on stocks and other species which are taken as a bycatch.

The WG also agreed that both stocks and fisheries could be managed to meet an objective of increasing the knowledge associated with the fishery or stock which would in turn improve future management. This objective was not fully elaborated or pursued during the two-day meeting.

2. Management Tactics: What Are The Current Deficiencies In The Data?

Stock sustainability goals are applied in a number of ways. These include:

2.a) Setting and reaching escapement objectives. These are monitored either directly or indirectly by estimating both hatchery and wild escapements, including monitoring the age and sex composition of both components of the population;

The WG noted that, although estimating the total escapement of a salmon population was important, it was even more important to estimate the escapement of the CWT associated with either the hatchery or wild component of the population.

2.b) Estimating stock exploitation rates. The recovery of CWT in the suite of fisheries and on the spawning grounds has historically been the primary tool for performing this task for chinook and coho. Indicator stocks, which are relatively more abundant, are often used as a proxy to monitor depleted and less abundant stocks requiring protection to meet sustainability goals. The stratification needed to achieve the objective of keeping the exploitation rates at an acceptable level often requires in-season intervention and consequently requires information with fine scale temporal and spatial stratification.

2.c) Maintaining biological diversity. Both countries require that managers maintain biological diversity while harvesting salmon populations. This includes tasks such as monitoring the reproductive success of hatchery strays on the spawning grounds, ensuring that a full range of life history components remains in the natural population and maintaining the spatial and temporal structure of the natural population.

The harvest objective of providing maximum fishing opportunities while meeting sustainability goals is implemented through a range of tactics:

2.d) Projection of preseason abundance and fishery impacts. This is an important task for modelling and pre-season planning. Currently, abundance forecasts for both chinook and coho commonly employ sibling relationships to predict abundance at age which are derived from the analysis of CWT recoveries.

2.e) Estimating total salmon catch by species, including non-retained fishing mortalities. The expansion of CWT requires estimating total catches by species in each fishery stratum, including non-retained mortalities. Otherwise the CWT recoveries will not be expanded to the correct level and exploitation rates consequently may be biased. This task may need to be completed on an in-season basis in order to monitor the catch of indicator stocks and to potentially modify the harvest of stocks under sustainability protection.

The WG noted that this was a difficult task that was not always completed satisfactorily.

2.f) Estimating the concentration of stocks within specified temporal and spatial strata. The WG considered this to be one of the key tasks associated with the management of all salmon species, although the WG noted that the exact specifications for the required spatial and temporal stratifications would vary among fisheries, depending on the component stocks that were present and the specific management requirements. These range from large offshore fisheries that tend to be managed on an annual basis (e.g. SE Alaska, northern BC and WCVI troll fisheries) to more terminal fisheries which are managed domestically and which may require weekly estimates of stock composition over relatively small areas. This task often needs to be performed on an in-season basis to ensure that sustainability and harvesting goals are met.

2.g) Estimating age specific exploitation rates for stocks within specified temporal and spatial strata. This task differs from the previous task by being more stock oriented and requiring age specific information. However, it is accomplished by using the same information collected in the two previous tasks. As noted in the previous task description, in-season estimates of these quantities are often required to meet specific sustainability and harvesting objectives.

2.h) Observing the patterns of migrating salmon. This task is accomplished almost entirely through inference from the recovery of CWT for both chinook and coho populations. Sockeye, pink and chum make use of scale pattern analysis (SPA) and GSI sampling to monitor the passage of migrating stocks.

2.i) Monitoring effort and CPUE by fishery. The WG identified that obtaining effort and CPUE data by time and area stratum within important fisheries may help interpret stock distributions and timing by allowing using abundance-based calculations rather than simple proportional distribution. This would be particularly important for fisheries which are managed in-season to meet sustainability and harvesting objectives. The WG noted that adequate effort data are not being collected in many fisheries and that there existed no consensus on how to measure or report effort or best to perform CPUE analyses.

The WG noted that many of the above tasks are made more difficult due to the implementation of Mass Marking (MM) of hatchery fish and subsequent Mark Selective Fishing (MSF). The source of these problems and general issues associated with MM and MSF are discussed in the following paragraphs:

2.j) The WG discussed the implications of MM and MSF on harvest management. The current management of chinook and coho salmon is focused principally on the conservation of naturally-spawning stocks and uses hatchery indicator stocks marked with CWT to monitor fishery impacts on associated natural stocks. In recent years, MM and MSF have received increasing attention as a means to improve economic and social performance of mixed-stock fisheries by increasing the harvest of hatchery fish within constraints established to protect natural stocks. Since the purpose of MSF is to impart differential exploitation rates on MM and unmarked fish, the recovery of CWTs can no longer be relied upon to provide data to obtain fishery-specific estimates of mortalities of unmarked stocks. The PSC Selective Fishery Evaluation Committee devised a Double Index Tagging (DIT) method that would provide information on the differential exploitation rates experienced by MM hatchery and unmarked fish from a given stock. DIT involves the release of paired CWT groups, one of which is mass marked with the other unmarked; otherwise the groups are identical. The method relies on estimating the underlying differences in recovery rates between the paired mark groups to estimate the cumulative effect of MSF. However, this method is unable to estimate fishery specific effects, particularly for chinook, because of confounding between natural and fishing mortality rates. As well, all the CWT recoveries will contain observation and process error, which increase the interpretation difficulty of the recovery results.

DIT is not capable of providing stock-age-fishery specific estimates of mortality experienced by unmarked fish for either chinook or coho when multiple MSFs or sub-stocks exist . Under MSF, impacts on unmarked fish require the use of additional assumptions regarding encounter rates and non-catch mortalities, increasing the uncertainty in the estimates of fishery impacts. The impact of MSF on the recovery of CWT is stock and fishery-specific, depending on the proportion of MM fish that is removed.

2.k) MM of hatchery stocks has made the identification of mass-marked hatchery fish relatively easy and can facilitate the estimation of the extent hatchery fish stray to spawning grounds.

2.l) Significant portions of MM hatchery releases do not have representative CWT tagging. This consequently increases the difficulty of allocating harvests of some MM fish.

2.m) Under the DIT methodology, both MM and unmarked fish must be sampled in non-mark-selective fisheries and escapements. The cost and complexity of sampling programs increases under MSF and electronic tag detection may be required to reduce costs of tag recovery. These costs may affect the availability of funding to support harvest management, stock assessment, research, information management, and other programs.

2.n) The WG noted that, in the absence of DIT and given that significant portions of MM hatchery releases do not have representative CWT tagging, the existence of MSF meant that differences in return rates between marked and unmarked fish could not be estimated.

3. Available tools: how can GSI be applied to address these deficiencies?

The Management WG discussed how GSI could be applied to each of the above management tasks and can be used to address or ameliorate some of the identified deficiencies. Notes from these discussions follow:

3.a) Setting and reaching escapement objectives. The WG noted that GSI methods can be applied in terminal areas to estimate the stock distribution of the run passing through that fishery. These terminal run distribution estimates can be converted to escapement estimates if escapement estimates are available for one or two indicator stocks. This methodology can be applied to coho or sockeye where age composition information is either less important or can be estimated reliably through alternative methods. However, this application may be less suitable for chinook salmon because of the difficulty of accurately ageing chinook using either scales or otoliths. GSI may also fail in this application if the stocks which require separation presently do not have sufficient genetic resolution in the baseline database (e.g., as presently exists for Puget Sound chinook salmon, distinguishing hatchery from natural progeny produced by local broodstock).

3.b) Estimating stock-age-fishery exploitation rates. Current management of chinook and coho is based principally on stock-age-fishery exploitation rates estimated from cohort analysis from CWT experiments. GSI [other than perhaps FPG: see Paragraph 3.g) below] is incapable of providing the data required to estimate stock-age-fishery exploitation rates, unless combined with other data that can provide: (a) sufficient separation of fish into discrete groups for cohort analysis; and (b) the total age of individual fish. These data can be difficult to obtain due to a variety of limitations, including, but not limited to, stock and age assignment error, the lack of sufficient genetic resolution in some stock groupings, the inability to separate genetically similar hatchery and wild stocks, the difficulty of generating accurate escapement estimates, and the large sample size required to obtain sufficient recoveries of stock-age groups that comprise a small proportion of the exploited population in order to meet stratification and desired levels of error tolerance. These issues will be discussed more fully in Paragraphs 3.f) and 3.g) (below).

3.c) Maintaining biological diversity. GSI might be applied to evaluate habitat use by different life-history. This could be particularly useful in freshwater and estuarine/near shore environments. Parentage analysis based on GSI has been used to provide information on reproductive success of potential spawners, including interactions between hatchery and naturally produced fish.

The harvest objective of providing maximum fishing opportunities while meeting sustainability goals is implemented through a range of tactics:

3.d) Projection of preseason abundance and fishery impacts. This task requires models which use the available distributional and age information, regardless of how they are obtained. Therefore, the addition of GSI information to improve the data sources used for management as described in other Paragraphs in this section will improve the capacity to carry out this task.

3.e) Estimating total salmon catch by species, including non-retained fishing mortalities. Although this is a difficult task that is not always completed satisfactorily, it is not likely that GSI can be used to address this problem.

3.f) Estimating the distribution of stocks within specified temporal and spatial strata. This is a task where GSI could prove useful for large stocks if coastwide sampling is performed to gather concentration data and standardised reporting protocols are implemented for multi-agency sharing of GSI results. GSI is capable of differentiating stock structure within a fishery, depending on the level of required resolution and the proportion of the total catch which is comprised of the stock(s) of interest. For chinook and sockeye, supplemental age information is generally required which in turn limits the usefulness of this methodology. GSI has an advantage over CWT because it is a non-lethal methodology which can be applied to released fish to determine their stock composition. CWTs alone can rarely be used to determine stock composition directly, given that many hatchery stocks are not consistently tagged and additional information is often required to quantify contributions from wild stocks.

GSI methodologies are currently implemented to estimate the stock composition of sockeye in Bristol Bay and the Fraser River, as well as for chinook in the large outside troll fisheries in SE Alaska, northern BC and the WCVI (by way of example as this list is not exhaustive). However, the capacity to use this methodology is limited by the level of resolution which is required, which in turn will be fishery and task specific. Chinook salmon are further limited because the technology cannot presently deliver reliable estimates of the age distribution in a fishery. However, there remains one major potential use of GSI information, even for chinook: the observed stock concentrations obtained by GSI methods can be compared to model predictions of stock compositions for particular fisheries.

3.g) Estimating age specific exploitation rates for stocks within specified temporal and spatial strata. GSI methods are likely to be less suitable for this task, particularly for chinook because of the inability to age fishery samples reliably. However, the GSI method may fail even for coho and sockeye because the stock resolution available through genetic methods may not match the stock resolution required for management. For instance, GSI methods cannot separate the chinook populations which spawn in the Puget Sound area or distinguish between spring and fall chinook in the Klamath River.

A developing methodology, based on the tracing of parental genotypes into the child generation (Full Parental Genotyping: FPG), has the potential to provide accurate determination of siblings throughout the fishery and in the escapement, thus improving the estimates of total exploitation rate for hatchery indicator stocks. This methodology also has the potential of overcoming the ageing problem because the specific parents are known. However, the details of this methodology have yet to be worked out, including some unresolved technical and sampling issues. While this technique may hold considerable potential, its cost and logistic feasibility would need to be demonstrated before it can be used in management applications.

3.h) Observing the patterns of migrating salmon. As noted above, GSI can be used to monitor the migration of salmon stocks through important gauntlet and terminal fisheries, providing estimates of stock concentration. There is the potential of combining this type of information with acoustic monitoring of escapement to provide some measure of the total migration. There is also the potential to use archival tags, but this method would be limited by sample size and total cost.

3.i) Monitoring effort and CPUE by fishery. Some members of the WG suggested that trip-based sampling using GSI methods could be used to track schooling behaviour in salmon species. This could be used to test the validity of sample independence that is commonly used in the evaluation of CWT recoveries (and which would be also applicable to the sampling done for GSI determination).

4. Issues and Research

The following is a list of research topics to address issues that arose during the WG discussions.

4.a) Establish a formal process by which GSI technical experts can interact with fishery managers and stock assessment experts.

This task was discussed at the WS Plenary session on 13 September and there was no consensus on the preferred approach. Some favoured setting up a separate GSI

Technical Committee which could advise the PSC while others preferred to incorporate GSI expertise into the existing Technical Committees which advise the PSC. Finally, there was some support for the view that there existed sufficient expertise in the current advisory groups which could provide adequate advice in the short term.

This issue was not resolved and needs to be addressed by the GSI WS Steering Committee in its final recommendations.

4.b) Compare level of aggregation required for GSI compared to currently accepted indicators used for CWT.

- the match will be affected by underlying genetic diversity
- how does the level of aggregation that is specified by the current GSI databases compare to the level of aggregation required for management?

Paul Moran, in collaboration with Gary Morishima, presented a report which summarised an EXCEL worksheet which matches, for chinook, the PSC Chinook Technical Committee (CTC) stock groupings based on CWT with the available GAPs baseline groupings. As well, this spreadsheet compares the GAPs groupings with the chinook FRAM model. Finally, the spreadsheet compares the alignment of GSI groupings of southern coho (VanDoornik 2007) with the coho FRAM model. This spreadsheet forms part of the report from the Management WG.

The matchings show promise, with reasonable levels of resolution in most areas. In many cases, the available level of resolution from GSI methodology exceeds the existing resolution based on CWT. However, there are areas of exception to this generalisation, notably Puget Sound where there has been considerable mixing of genetic material across watersheds.

This issue will remain as an on-going requirement that will need to be addressed by each PSC technical working group to specify functional stock groupings that make the best use of the available technologies and which address the management issues specific to the species and areas of concern to the PSC.

4.c) Representative sampling: how can this be achieved for GSI?

- how to select a representative GSI sample from a time/area stratum

This issue was addressed by papers from Dave Bernard and Michael Mohr of the Modelling and Sampling WG.

4.d) Are we fooling ourselves on the level of stratification that we are requiring of the data?

- can the level of fine scale management currently demanded from the data be supported scientifically?
- how can uncertainty surrounding harvest rate estimates and the projections of fishery impacts be effectively conveyed to managers and the public?
- this problem affects both CWT and GSI estimation methodologies.

This issue was also addressed by the papers from Dave Bernard and Michael Mohr of the Modelling and Sampling WG.

4.e) Risk tolerance: what is the relationship between the level of risk tolerance acceptable to managers and other agency personnel and the management precision required from sampling for CWT and GSI? How can GSI-derived information be best incorporated into the current management tools and models?

This issue was addressed in part by a presentation by Paul Starr on incorporating uncertainty in management decision making, with specific examples of how this issue is approached in groundfish and shellfish management regimes in New Zealand and western Canada. The primary recommendation by Starr was to move to a system of "operational management procedures" (OMP), where a feedback control system of management decisions is simulation tested against an operating model which represents the fishery system being managed, including a realistic level of uncertainty. Appropriate management strategies and tactics can then be evaluated and compared on the basis of their outcomes, either in terms of sustainability or other desired outcomes.

Starr noted that this approach is based on stock assessments which incorporate uncertainty in the stock reconstructions. Currently, this is best done in the context of statistical catch-at-age or catch-at-length models, which are presently in the early stages of development for salmon species . Rishi Sharma described such a model which he is developing for chinook salmon. However, he acknowledged that the complexity of this species and its management system meant that a realistic model may exceed the capacity of the current data to support realistic model parameterisation (implying that assumed values for some model parameters would continue to be required) and would also require considerable computer and software development.

A statistical catch-at-age model such as the one described by Rishi Sharma of the Modelling/Sampling WG is a promising methodology to use for linking GSI and CWT data in a sensible manner. Such models are designed to incorporate data from various sources and are capable of interpreting these data as long as the relative weighting of the data can be resolved. It is likely that there exist other methodologies for achieving this task, including modifying existing PSC assessment models.

The WG notes that OMPs have the potential to address risk quantitatively. However, the development of OMPs for salmon species will require investment in model development and testing and are likely to take several years to reach a level where they can be used operationally.

Statistical catch-at-age models represent a methodology which can incorporate uncertainty into salmon assessments and which can be used to provide the basis for developing operating models for use in OMPs. Therefore, there are considerable potential benefits from moving to this type of modelling over the longer term.

4.f) How can the estimation methods of spawning escapements be improved using CWT and GSI methodologies?

Jim Packer and Brad Thompson from the Modelling/Sampling WG presented a paper on this issue.

4.g) Evaluate the sensitivity of cohort analysis to ageing and assignment error.

Marianne McClure presented a paper on scale ageing errors in chinook on behalf of the Management WG. She concluded that scale ageing for chinook was greatest for age 5 fish and became less acute as fish age dropped. This error was largely associated with errors in understanding the scale growth patterns associated with the wide range of life history types associated with this species. She particularly noted how a period of estuarine rearing could form checks which are incorrectly interpreted as an annual ring. Resorption of scale material during the spawning period also was a large contributor to ageing error in this species. She recommended that ageing error be explicitly evaluated and reported when providing age composition information for chinook. She also suggested that there could be more co-operation being ageing laboratories using digitising and other methodologies in an attempt to standardise chinook ageing across agencies and other entities.

The WG noted that simulation testing of realistic levels of ageing error in the context of currently used chinook assessment methodologies should be performed to provide advice on acceptable levels of ageing error.

4.h) Can other methods be used to identify hatchery fish (e.g. thermal mark to age mass marked hatchery fish)?

Eric Volk from the Logistics WG presented a paper describing otolith thermal marking and its potential application to ocean management.

4.i) Evaluate the relative capacity of CWT and GSI to estimate a fishery specific harvest rate using equivalent data sets based on each method for <u>coho</u>.

- this task requires specifying the GSI sample size that is required to achieve a level of precision equivalent to that achieved by CWT in two instances: (a) assuming no stock assignment error; and (b) with stock assignment error.
- this exercise should be based on the FRAM coho model base period stock mixtures.

This task was not addressed by this Workshop.

4.j) Repeat the 4.i) task for chinook, assuming that age can be obtained from thermal mass-marked [no CWT] hatchery fish.

- this task requires specifying the GSI sample size that is required to achieve a level of precision equivalent to that achieved by CWT in two instances: (a) assuming no stock assignment error; and (b) with stock assignment error.
- this exercise will be based on the FRAM chinook model base period stock mixtures.

This task was not specifically addressed by this Workshop.

4.k) Evaluate the costs and benefits of replacing the current CWT-based system with an entirely GSI-based sampling programme.

Christian Smith from the Genetics WG began to address this issue in his talk which compared the relative costs and merits of different marker types. However, this is a complex topic which requires considerable detailed work and which may not be productive, given that it is not likely that a GSI-based programme is presently capable of replacing the current CWT programme.

4.l) Evaluate the incremental costs and benefits which would be obtained from augmenting the current CWT-based system with GSI-based sampling.

The response to this task is similar to that for Paragraph 4.k). This is a complex topic which will require detailed work, commissioned as a formal research project.

4.m) Make recommendations on the most appropriate measures of effort in salmon fisheries.

- identify and quantify measures of effort;
- associate appropriate catch with effort.

This task was not further considered during the GSI WS.

4.n) Estimate appropriate levels of uncertainty to go with the estimates of total catch by time and spatial stratum.

This task was not further considered during the GSI WS.

4.o) Evaluate the performance of planning models in projecting (pre-season) and estimating (post-season) stock compositions.

The use of GSI in pre-season planning models was not addressed at the GSI WS. Brian Riddell from the Modelling/Sampling WG presented a paper on the use of GSI for in-season management, an application which is used to a considerable extent in several locations in the regions of interest to the PSC. Riddell pointed out that this methodology has many limitations, including being unable to provide information on abundance or harvest rates without collecting additional information. As well, the methodology was highly sensitive to sampling issues and the interpretation of the results was dependent on how representative is the sampling.

Riddell suggested that such programmes are expensive and that mounting in-season programmes based on GSI should be closely tied to clear, achievable and reasonable management objectives. He also suggested that alternative approaches should be considered before embarking on such projects.

4.p) For some stocks, GSI may be able to provide information that could help identify changes in marked:unmarked ratios if mark-selective fishery impacts become significant.

This task was not further considered during the GSI WS.

4.q) There is a need to develop alternative management strategies for chinook and coho. Current management of chinook and coho is based primarily on stock-age-specific exploitation rates. However, it may be possible to devise alternative approaches to constrain impacts on stocks of concern based on combining CWT and GSI data.

Gary Morishima presented a paper on applying an alternative approach to managing chinook and coho stocks, particularly weak stocks which are not well represented by CWT in the large ocean mixed-stock fisheries. This approach would involve aggregating stocks in these fisheries and placing numerical limits on the catch of the stocks of concern which could be used to constrain the overall effort in the fishery of concern. Catches of the aggregated stocks of concern could probably be most easily obtained using GSI methodology.

The WG recognised that this type of approach represents a departure from the current management of these fisheries, but also provides potential to resolve problems that are not well addressed by the present system. This (and other) approaches should be quantitatively evaluated in comparison with the current management system with the intent of making recommendations on the feasibility of these approaches to the PSC. There is also a good possibility that such an approach could be combined with the OMP methodology described in Paragraph 4.e) to develop appropriate responses to this type of information.