**Future of the CWT Program: Challenges and Options**
**A Workshop June 7-10, 2004**

# Data Matrix
# Requirements for assessment of fishery impacts on salmon stocks
By

Gary S. Morishima
Marianna Alexandersdottir

# Data Matrix

# Requirements for assessment of fishery impacts on salmon stocks

**Purpose:** This document is intended to identify the data elements that are required to enable the PSC chinook (CTC) and coho (CoTC) technical committees to reconstruct cohorts so as to determine how stocks of interest are impacted under bilateral agreements for fishery regimes. Data elements are presented in the form of a matrix which can be employed to summarize the capacities of various methods and technologies to provide required information. When completed for each alternative, the data matrices will provide a consistent framework for evaluation and comparison.

In short, the approach is intended to:

- identify the data elements required for cohort reconstruction,
- describe the sample design (indicator stocks, fishery and escapement locations and periods sampled, numbers tagged and proportions of harvest and escapement sampled),
- describe the analytical methods used and the factors that affect their accuracy and precision,
- describe the methods, costs, and uncertainty involved in acquiring data elements
- describe protocols for consistency, coordination and reporting

There are two major components to the proposed framework: (1) a data matrix; and (2) a description of processes for analysis and coordination.

The current methods employed by the CTC and CoTC depend largely upon data from the Coded-Wire-Tag (CWT) system. A completed version of the matrix for the CWT program is attached to illustrate how the matrix is intended to be used.

### The CWT program

CWT are pieces of small diameter wire containing codes that are used to identify specific groups of fish. General guidelines have been established for the number of fish to be tagged in a release group for particular purposes. Codes are reported to a central location and assigned so as to avoid duplication and maintain the ability to assign recoveries to specific release groups. CWTs are recovered coastwide with agencies attempting to sample a minimum proportion of the catch (generally 20%). For many years, the adipose fin clip was sequestered to provide a visual cue to identify fish containing CWTs. For fish without adipose fins, catch samplers remove the snouts and send them to processing labs where the CWTs are read. Recovered CWTs are expanded for the portion of the catch sampled and reported to a central location. The CWT program thus consists of a coastwide system of marking, recovery, and reporting which permits a large number of CWT experiments to be conducted simultaneously to meet a wide variety of research and management needs.

Inferences about impacts on naturally spawning populations of interest. For the most part, PSC agreements on fishing regimes for chinook and coho are based on constraining exploitation rates for selected naturally spawning populations. However, data to permit direct estimation of exploitation rates for these naturally spawning populations are sparse. Consequently, inferences are drawn from surrogates, usually specific groups of artificially propagated and CWT'd fish which are selected as indicators, based on brood stock and rearing/release strategies.

These selected CWT release groups are believed to be subject to the same fishing patterns as the naturally spawning populations they represent. Wild smolt tagging experiments in Puget Sound, Southern British Columbia, and the Washington Coast support the belief that hatchery indicator and wild coho stocks are subjected to similar fishing patterns. This relationship is less clear for chinook, but tagging experiments with progeny from wild and hatchery brood stock suggest that the use of indicator stocks is reasonable.

Estimates generated from cohort reconstruction of the selected CWT groups (e.g., maturation rates, fishery-age exploitation rates) are presumed to apply to associated naturally spawning populations. The CWT-based estimates of fishery-age specific exploitation rates are used as surrogate measures of the impacts of fisheries on naturally spawning populations.

Double Index Tagging. The methods summarized above work when it is reasonable to presume that fisheries impact CWT groups and naturally spawning populations in an identical way. In recent years, managers have employed mass marking (MM) and mark-selective fisheries (MSFs) as a means to increase access to hatchery fish while reducing impacts on unmarked fish. The mass mark of choice is the adipose fin clip, previously sequestered as a visual cue to identify fish containing a CWT.

With the advent of MSFs, MM fish are expected to have different patterns of mortality than unmarked fish. Consequently, fishery impacts on unmarked fish can no longer be estimated using a single release of marked CWT fish. In order to try to provide a means to estimate fishery impacts on unmarked fish, the PSC's Ad-Hoc Selective Fishery Evaluation Committee (ASFEC) developed the concept of double index tagging (DIT). Under DIT, paired groups of CWT's fish are released, one group with adipose fins removed and the other with adipose fins left intact (doubling the number of tags to represent a given release). The DIT groups are supposed to be identical, except for fin clipping and different CWT codes. Impacts of MSFs on unmarked populations were to be evaluated from differences in recoveries of the marked and unmarked DIT groups. Because MM greatly increases the number of fish in the catch without CWTs and the need to recover CWTs from unmarked fish, electronic tag detectors must be employed.

Emerging Concerns for the Viability of the CWT System. The PSC established the ASFEC to investigate potential implications of MM and MSFs on the CWT program. CWT data was so central to management of chinook and coho that a special memorandum of understanding was signed committing the United States and Canada to maintain the viability of the CWT program. In its 1995 report to the PSC, the ASFEC identified three major components to viability:

- The ability to use CWT data for assessment and management of wild stocks of coho and chinook salmon;

- Maintaining the program such that the uncertainty in stock and fishery assessments and their applications does not unacceptably increase management risk; and

- The ability to estimate stock-specific exploitation rates by fishery and age.

While the ASFEC focused on issues directly related to the PSC's ability to establish and evaluate harvest management regimes for chinook and coho, the ASFEC also recognized that CWTs were being utilized for a wide variety of research and management purposes, such as:

- Estimation of survival rates and contribution of hatchery production to catch
- Evaluation of hatchery practices and methods, for example, a hatchery manager may wish to evaluate the effect of alternative rearing or release strategies on survival rates and fishery contributions,
- Evaluation of hatchery impacts on wild stocks, for example, straying of hatchery fish to naturally spawning areas.
- Establishment of ESA jeopardy standards (exploitation rate maximums) and monitoring of compliance with those standards

MM and MSFs pose a number of issues for the CWT program. Budgetary implications include: increased marking costs due to DIT; increased sampling costs due to need to employ electronic tag detection technologies to detect CWTs in marked and unmarked fish; loss of information on CWT recoveries of unmarked fish from jurisdictions that do not employ electronic tag detection; and required modifications to data reporting systems. Technical issues center around the consequences of increased uncertainty surrounding estimates of mortalities of naturally spawning fish.

There are, however, other emerging issues that tend to reduce the quality of statistics based on CWT data, such as, the recovery of fewer tags in fisheries due to reductions in fishery exploitation rates and survival rates, the difficulty of sampling fish that are sold directly to consumers rather than being handled by centralized processors; and allocation of a larger portion of the allowable harvest to recreational fisheries which are harder to monitor and sample.

This combination of MM, MSFs and other factors have led the PSC to convene a workshop to evaluate the capacity of the CWT program to provide information required to implement bilateral agreements on fishing regimes and to recommend improvements, which may involve the use of other technologies to supplement or supplant CWT data.

## Cohort Reconstruction

The capability to reconstruct the cohort of tags groups is central to all these uses. The reliability of CWT-based statistics depends on uncertainties relating to the collection of CWT data from marking and sampling programs, and from the quality of information (e.g., spawning escapements for natural populations) to which the CWT data are applied.

Cohort reconstruction is performed on discrete, well-defined groups of fish. Reconstruction requires estimates of mortalities caused by fishing throughout the migratory range over the entire life history of each group, losses due to natural mortalities, losses due to anthropogenic, non-fishing, factors (e.g., dam passage mortalities), and spawning escapements.

Cohort reconstruction permits the estimation of exploitation rates for implementation of the PSC's chinook and coho regimes in accordance with the following. The total recruitment cohort size (prior to any fishing at any age) is:

$$RCohort = \sum_{f}^{F}\sum_{a}^{A}(LC_{f,a} + IM_{f,a}) + \sum_{a}^{A}(NM_{a} + PSM_{a} + Esc_{a}) \qquad \textbf{Eq 1}$$

*where:*

| | |
|---|---|
| *RCohort* | *Recruitment cohort size* |
| $LC_{f,a}$ | *Landed Catch in fishery(f) at age (a)* |
| $IM_{f,a}$ | *Non-Landed, Fishery Induced Mortality in fishery(f) at age (a)* |
| $NM_{a}$ | *Natural Mortality of age (a) fish* |
| $PSM_{a}$ | *Post fishery, pre-spawning Mortality of age (a) fish* |
| $Esc_{a}$ | *Spawning Escapement of age (a) fish* |

All of the required estimates to reconstruct a cohort are identified in Eq 1. Quantification of LC, IM, and Esc values involves the collection of specific data items. For each of these items, the data matrix is to contain information on the method of estimation, principal assumptions, stratification, sample sizes, uncertainties, and costs.

<u>Methods</u>

Cohorts are reconstructed from the oldest to the youngest age.

The escapement past fisheries (*EPF*) is computed by adding post-fishery, pre-spawning mortalities to estimates of escapement:

$$EPF_{a} = \frac{Esc_{a}}{(1 - psm_{y})} = Esc_{a} + PSM_{a} \qquad \textbf{Eq 2}$$

where $psm_y$ is the post-fishery, pre-spawning mortality rate for the appropriate year.

The terminal run (*TR*) size is estimated by adding mortalities by terminal are fisheries to PSM:

$$TR_{a} = \sum_{f=term}(LC_{f,a} + IM_{f,a}) + EPF_{a} \qquad \textbf{Eq 3}$$

The maturation rate (*mr*) is estimated as:

$$mr_{a} = \frac{TR_{a}}{TR_{a} + Cohort_{a+1}} \qquad \textbf{Eq 4}$$

where $Cohort_{a+1}$ is the number of fish of the next age prior to natural mortality (=0 for the oldest age, hence *mr* for the oldest age = 1)

The number of fish available to pre-terminal fisheries (*PFC*) is estimated by adding mortalities from pre-terminal fisheries:

$$PFC_a = \sum_{f=preterm} (LC_{f,a} + IM_{f,a}) + \frac{TR_a}{mr_a} \qquad \textbf{Eq 5}$$

Natural mortalities (*NM*) are assumed to occur prior to fishing:

$$NM_a = \frac{nmr_a * PFC_a}{(1 - nmr_a)} \qquad \textbf{Eq 6}$$

With these data items, several statistics of interest to the CTC and CoTC can be readily generated.

The exploitation rate (*ER*) by age and fishery is:

$$ER_{f,age} = \frac{(LC_{f,age} + IM_{f,age})}{PFC_{age}} \qquad \textbf{Eq 7}$$

The number of fish from given group killed in a specific fishery and age strata (*TM*) can be readily computed by rearranging the terms of Eq 7.

$$TM_{f,age} = LC_{f,age} + IM_{f,age} = ER_{f,age} * PFC_{age} \qquad \textbf{Eq 8}$$

When coupled with estimates of the number of juveniles outmigrating for a population of interest, several additional statistics can also be generated, such as the survival rate:

$$SurvivalRate = \frac{RCohort}{JuvenileOutMigration} \qquad \textbf{Eq 9}$$

For a CWT group, *JuvenileOutMigration* is considered to be the number of CWT'd fish released in the group.

The exploitation rate per fish released (*ERR*) by fishery and age:

$$ERR_{f,age} = \frac{(LC_{f,age} + IM_{f,age})}{JuvenileOutMigration} \qquad \textbf{Eq 10}$$

The number of fish from given group killed in a specific fishery and age strata (*TM*) can be estimated in a manner analogous to Eq 8 or by rearranging the terms of Eq 10.

$$TM_{f,age} = LC_{f,age} + IM_{f,age} = ERR_{f,age} * JuvenileOutMigration \qquad \textbf{Eq 11}$$

Estimates of various types generated from cohort reconstruction are employed by the CTC and CoTC in a variety of ways. For example, fishery-age exploitation rates observed during selected base periods are employed in models to project impacts of prospective fisheries on stocks of interest to the PSC. Estimates of exploitation rates are combined across stocks to monitor changes in fishery harvest rates (the proportion of fish available to a fishery that is killed by the fishery). Estimates of survival, maturation, and exploitation rates for individual stocks are used in abundance forecasting and model calibrations. CWT-based estimates for selected can be combined with age-specific estimates of spawning escapements to reconstruct cohorts of natural populations. This enables the CTC and CoTC to perform various types of analyses such as evaluation of the relationship between spawning escapement and subsequent production or estimation of contributions of stock complexes to fisheries.

| *Data Matrix* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Data Items** | | | **Analysis** | | **Sample Design** | | | | |
| **Estimate needed** | | **Data Collected** | **Estimation Method** | **Assumptions** | **Stratification** | **Sample Size** | **Uncertainties** | **Sample Methods** | |
| **CWT Based Method** | | | | | | | | | |
| ***Landed Mortalities*** | Of tagged fish | Number of observed recoveries by tag code for all fisheries significantly impacting the release group | Observed tags / Sample fraction | Random sample of landed harvest | Fishery, tag group (=stock/age), period | Sample Rate = 20% minimum for commercial and sport fisheries coast wide | The tag code specifies the group of fish and age, so there is no error in assigning recoveries to specific groups of fish or in determining age of fish. Precision is dependent on number of tagged fish recovered, therefore release tag group size, sample rate in fishery. | Visual or electronic sampling in all fisheries | |
| | | | Sample fraction = Number Sampled in fishery /Total Fishery harvest by recovery and expansion strata | | | | | | |
| | | | Fishery Harvest estimated using for instance, Fish Tickets, Sport creel surveys, CRCs (WA, OR), or Statewide Survey(Alaska) | Varies with Estimation Approach (see attachment xxx) | | | Bias and precision depends on method used. | | |
| ***Non-landed Mortalities*** | Of tagged fish | | **Encounters • release mortality rates** | | | | | | |
| | Sublegal mortalities | | Estimate proportion vulnerable under sub legal size for encounters | Size and Fishery specific Release Mortality Rate | Fishery, tag group (=stock/age), period | | Potential bias is dependent on bias in release mortality rate and estimates of encounters | | |
| | Dropoff | | Proportion of landed mortalities or encounters in non-retention fisheries | Proportion by fishery | | | Potential bias is dependent on bias in proportion dropoff. | | |

## *Data Matrix*

| Data Items | | | Analysis | | Sample Design | | | |
|---|---|---|---|---|---|---|---|---|
| Estimate needed | | Data Collected | Estimation Method | Assumptions | Stratification | Sample Size | Uncertainties | Sample Methods |
| **CWT Based Method** | | | | | | | | |
| | Non-Retention legal and sub-legal mortalities | | For encounter estimation see cohort analysis methods used by CTC | Size and Fishery specific Release Mortality Rate | Fishery, tag group (=stock/age), period | | Potential bias is dependent on bias in release mortality rate and estimates of encounters | |
| | Unmarked mortalities in mark-selective fisheries (MSF) | Marked Fish in MSF | Landed mortalities of marked DIT fish in MSF times the unmarked to marked ratio of the DIT group estimates encounters | Fishery specific Release Mortality Rate | Fishery, tag group (=stock/age), period | | Potential bias is dependent on bias in release mortality rate and estimates of encounters | Electronic sampling in all fisheries |
| ***Natural Mortalities*** | | | Apply natural mortality rates to cohort before fisheries. | Assume age-specific natural mortality <u>rates</u>. Same for all stocks within species. | | | Potential bias depends on accuracy of natural mortality rates used. | |
| ***Post fishery, pre-spawning mortality*** | | Mortality losses of returning adults due to non-fishing, anthropogenic factors (e.g., interdam passage loss) | Mortality rates provided by agencies (e.g., dam counts) | Usually expressed in terms of mortality <u>rates.</u> All ages of fish returning in a given year are affected equally | | | Potential biases due to straying, unreported fishery mortality losses, age-specific differences in loss rates | |
| ***Spawning Escapement*** | Of tagged fish | **Hatchery returns plus strays to spawning grounds** | | | | | | |
| | | Tags observed in hatchery return | Observed tags / proportion of hatchery return that was sampled | Random sample of hatchery escapement | Indicator stock hatchery return by tag group | 20-100% | Precision is dependent on number of tagged fish recovered, therefore release tag group size, sample fraction. | Visual or electronic sampling in hatchery |

| *Data Matrix* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Data Items** | | | **Analysis** | | **Sample Design** | | | |
| **Estimate needed** | | **Data Collected** | **Estimation Method** | **Assumptions** | **Stratification** | **Sample Size** | **Uncertainties** | **Sample Methods** |
| **CWT Based Method** | | | | | | | | |
| | | Tags observed on spawning grounds | Observed tags /proportion of escapement in stratum that was sampled | Random sample of natural spawning escapement | Spawning locations with hatchery strays by tag group | 0-50% | Precision is dependent on number of tagged fish recovered, therefore release tag group size, sample fraction. | Visual or electronic sampling on spawning grounds |
| | | | Sample fraction = Number sampled / Total Escapement to stratum | | | | | |
| | | | Total Hatchery escapement is counted | | Indicator stock hatcheries | | | |
| | | | Total natural escapment to stratum is estimated using : Stratified random expansion, mark-recapture, change in ratio, weir, Area-under-the-Curve methods, Index area method. | Varies with Estimation Approach (see attachment xxx) | Spawning locations with hatchery strays | Varies with Estimation Approach (see attachment xxx) | Precision and bias depends on methods used. | Varies with Estimation Approach (see attachment xxx) |
| | of associated natural populations (required for estimation of fishery-age specific impacts) | Age (and preferably sex) composition of natural spawning escapement less hatchery strays | Total natural escapment to stratum is estimated using : Stratified random expansion, mark-recapture, change in ratio, weir, Area-under-the-Curve methods, Index area method. | Varies with Estimation Approach (see attachment xxx) | Strata for estimation of natural spawning escapements | Varies with Estimation Approach (see attachment xxx) | Precision and bias depends on methods used. | Varies with Estimation Approach (see attachment xxx) |

| Data Matrix | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Data Items | | | Analysis | | Sample Design | | | | |
| Estimate needed | | Data Collected | Estimation Method | Assumptions | Stratification | Sample Size | Uncertainties | Sample Methods |
| CWT Based Method | | | | | | | | |
| ***Number of outmigratants*** | Of tagged fish (required for estimation of survival rates to first age of recruitment to fisheries) | Total fish tagged by tag code | Various methods to estimate outmigrating tagged fish, accounting for mortalities between tagging and release. | Number of tagged fish outmigrating is known | All indicator tag groups | | Potential bias depends on methods of accounting for pre-release mortalities | |

(1) Contribution rate is the proportion of the total spawning ground escapement that is of hatchery origin, while stray rate is the proportion of the total hatchery run to the river that strays to spawning ground.

*Process Matrix*

| Process | What? | Who? | Costs | Coordination |
|---|---|---|---|---|
| **CWT Based Method** | | | | |
| Identification of major production areas and stocks | | CTC, CoTC, Domestic managers | | |
| Identify discrete, well-defined groups of fish to represent stocks of interest. | Selection of appropriate CWT release groups | CTC, CoTC, Domestic managers | | Unique codes identify release agency and tag group |
| | Ad-hoc guidelines for tag group size | CTC, CoTC | | |
| | Report release group data to PSMFC coast wide database | Domestic agencies | | |
| Fishery landed mortalities and hatchery or spawning escapement | Sample fisheries, hatcheries and spawning grounds | Domestic agencies | | Guidelines for sampling rates, stratification into fisheries and time periods. |
| | Recover and read tags. Tag code provides information on release group and age | Domestic agencies | | Methods standardized |
| | Estimation of tags in harvest by tag code | Domestic agencies | | Standardized mehtods to account for lost heads, no pins, unreadable tags, miss ids in tag recovery process |
| | Report sampling and tag recovery information to PSMFC coast wide database | Domestic agencies | | PSMFC standards for reporting data |
| Estimate non-landed fishing and natural | See data matrix | CTC, CoTC, Domestic agencies | | |

***Process Matrix***

| Process | What? | Who? | Costs | Coordination |
|---|---|---|---|---|
| | | **CWT Based Method** | | |
| mortalities | | | | |
| Estimate cohort sizes | Sum all mortalities and escapement of tagged fish | CTC, CoTC, Domestic agencies | | Standard methods using agreed parameter estimates. |
| Estimate exploitation rates by stock, age and fishery | All mortalities for each age and fishery divided by cohort size for a tag group | CTC, CoTC, Domestic agencies | | Standard methods using agreed parameter estimates. |
| Estimate survival rate by stock and brood | Cohort size at first age of recruitment divided by number released for a tag group | CTC, CoTC, Domestic agencies | | Standard methods using agreed parameter estimates. |
| Estimation of impacts on natural populations or stocks of interest | In the absence of MSF, then assume that estimates of age and fishery specific exploitation rates for CWT indicator stocks can be applied to age-specific estimates of natural escapement (or terminal run) to estimate total recruitment and impacts. | CTC, CoTC, Domestic agencies | | Standard methods using agreed parameter estimates. |
| | With MSF it may be possible to use the unmarked DIT group to provide the estimates of exploitation rates for unmarked natural populations. This capability is uncertain for chinook salmon. | CTC, CoTC, Domestic agencies | | Standard methods using agreed parameter estimates. |