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METHODOLOGIES TO MONITOR THE PERFORMANCE OF INDIVIDUAL STOCK-BASED MANAGEMENT FISHERIES

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

The 2008 Pacific Salmon Treaty (PST) describes an Individual Stock Based Management (ISBM) fishery regime that is abundance-based and constrains to a numerical limit the total catch or the total adult equivalent mortality rate for specific stocks within a jurisdiction's fisheries. ISBM management regimes apply to all Chinook salmon fisheries subject to the PST that are not AABM fisheries or terminal exclusion fisheries. Several fisheries within British Columbia (BC) are under ISBM fishery management and all PST fisheries south of the border between BC and Washington State are under ISBM fishery management.

This report focuses on three assignments to the Chinook Technical Committee (CTC) listed in Appendix A to Annex IV, Chapter 3, of the 2008 Agreement:

(7) Individual Stock Based Management Improvements

a) Individual Stock Based Metric Improvement: The CTC will explore alternative metrics to be used to monitor ISBM fishery impacts, and report to the Commission on the utility of these metrics or approaches by 2011. The non-ceiling index referenced in paragraph 8(d) has not proven to be useful for many stocks as a means to monitor or evaluate the performance of ISBM fisheries relative to the obligations.

b) Paragraph 13 Obligations for ISBM fisheries: The CTC will develop methods to estimate the savings of mature fish expected to result from further reductions to AABM fisheries under paragraph 13 and determine adjustments in ISBM fisheries required to ensure that such savings accrue to escapements.

c) Evaluate 1991 to 1996 ISBM Average Criteria: The CTC will provide estimates of the 1991 to 1996 average impacts in ISBM fisheries relative to the 1979 to 1982 base period for the stock groups listed in Attachments IV and V.

In addition to these assignments, this report reviews the ISBM component of the stock performance evaluation defined in Paragraph 13 of Chapter 3 of the 2008 Agreement. The inclusion of this material was considered appropriate as part of the additional criteria used to monitor performance of ISBM fisheries.

The report is organized into five primary sections:

- Section 1 provides the introduction and background for the ISBM assignments, describes the limitations of the current ISBM indices, and introduces the desirable attributes for an ideal ISBM metric.
- Section 2 addresses assignment 7(a) of Appendix A in the Agreement by introducing seven alternative ISBM metrics grouped into five categories. This section also provides examples of the application of alternative metrics for select PST Chinook salmon stocks, and includes an evaluation of these alternative metrics and the current indices across the list of desirable attributes.

- Section 3 addresses assignment 7(b) of Appendix A in the Agreement by developing methods to quantify the number of mature fish saved for each stock in Attachments IV and V of Chapter 3 of the Agreement after reducing SEAK and NBC AABM catches by 10%, and determining reductions required to ISBM fisheries to "pass-through" the savings into escapement.
- Section 4 addresses assignment 7(c) of Appendix A in the Agreement by computing the average post-season ISBM index for years 1991 to 1996 (using the current metric) and comparing it with index values corresponding to the general obligation specified in Paragraph 8(c) of the Agreement: 63.5% and 60% of the exploitation rate that occurred during the base period (1979-1982) for Canada and the U.S., respectively. This section also includes an evaluation of the ISBM component of stock performance specified in Paragraph 13 of the Agreement, and describes a methodology to evaluate these provisions.
- Section 5 provides a summary and conclusions.

Section 1. Four limitations have been identified with the current method calculating the non-ceiling index (i.e., pre-season ISBM index) used for fishery planning and the post-season assessment of compliance relative to ISBM obligations:

1. *Instability*: The computed values for ISBM indices change (i.e., are not stable) for several years until all age classes from contributing broods have matured and died. Assumed age-specific maturations rates (e.g., values averaged over some historical period) must be used to estimate cohort sizes and incidental mortalities for brood years that are incomplete. The adult equivalent (AEQ) values used in the calculation of ISBM indices are also subject to change because they depend on maturation rates. This instability can lead to incorrect interpretation of compliance with ISBM obligations and poses challenges for pre-season planning and for post-season assessment performance evaluations.

2. *Partial base period coverage*: The indices are unreliable for any stock where the average stock, age, and fishery-specific exploitation rates for the base years 1979-1982 were estimated using incomplete or poor data. CWT-based indices require CWTs in base period fisheries from one or more broods, reliably estimated CWTs for all fisheries (not just ISBM fisheries), and reliably estimated CWTs for the spawning escapement. This means that programs for estimating fishery catches and spawning escapements, as well as programs for sampling CWTs from fishery catches and spawning escapements, had to be fully operational during those years. This was often not the case. For some data deficient stocks, data from surrogate stocks are used to represent the base period exploitation rates, assuming both stocks have the same fishery distribution and maturation patterns.

3. *Delayed data availability:* The data needed to calculate the post-season ISBM CWT-based index for several stocks caught in U.S. ISBM fisheries are not available at the time the index must be computed for timely use. Catch estimates from some U.S. ISBM fisheries may not be available until at least one year after a fishery has occurred, either because the catch data are unavailable or because multiple agencies have not reached timely agreement on the 'final' catch estimates needed to generate expansion factors for CWT recoveries. Because these recoveries are needed to estimate cohort sizes, the consequence of these delays in the availability of CWT data

from some U.S. fisheries is that the ISBM indices for both countries may not be computed within a timeframe for ISBM evaluations and to inform fishing plans for the upcoming season.

4. *Different pre-season and post-season modeling methods*: Pre-season fishery planning is made more uncertain because numerous differences exist between the pre-season and post-season versions of the index. Fundamental differences may exist in the sources of data used in the calculations and the assumptions necessary to compute ISBM indices. This means that the two different versions of the index often do not correspond well. It is preferable for the pre-season and post-season indices to be calculated using the same approach and data.

<u>Section 2.</u> Seven alternative ISBM metrics, grouped into five categories defined by the following analytical approaches, were explored: (1) generalized linear models based on tag contributions and catch projections; (2) an effort-based catch-at-age model; (3) mortality distribution across fisheries as generated by cohort analysis of CWT data; (4) a composite-index approach based on exploitation rate analysis of CWT data; and, (5) methods using the Pacific Fisheries Management Council's (PFMC) Chinook Fishery Regulation Assessment Model (FRAM).

No single alternative metric corrected all the limitations of the current indices or exhibited all the identified desirable attributes. The analytical approaches were not evaluated in terms of their ability to calculate ISBM indices for adipose mark selective, mixed bag, or other atypical fishery regulations. Methods that allow for the computation of pre-season and post-season indices under a common analytical framework are highly desirable (currently, pre-season indices are produced by the PSC Chinook Model while post-season indices are based on the analysis of CWT data, thus producing indices that often track each other poorly). Methods 1a, 1b, 2, and 5a have this attribute but only methods 1a and 1b can be currently applied coastwide. In terms of parsimony and simple usage, the mortality distribution ISBM indices (Method 3) may do an adequate job of evaluating whether some ISBM obligations were met and has the ability to fill base period data gaps Under data-rich situations, as in the case of some stocks (Columbia Upriver Brights: URB), a more comprehensive assessment could be conducted using Method 2. Method 2 requires projections of cohort survival and effort data that are available only for a few U.S. stocks in U.S. ISBM fisheries. Finally, method 4 could remove information gaps in ISBM evaluations given our existing data and coverage but it would require a restructuring of the Attachment tables in the Agreement to have regional based composites for different areas.

The CTC recommends Methods 1a and 1b as approaches deserving further investigation towards their usage in ISBM performance evaluations. Future investigations should be based on the application of these methods to other stocks listed in attachments IV and V and on assessment of their accuracy through computer simulations. Although Method 1a has the advantage of using the current algorithm, thus facilitating a transition to a new metric, it still suffers from instability of post-season computations under incomplete broods. In contrast, Method 1b does not suffer from this limitation but it uses an alternative algorithm for post-season computations. ***From the point of view of simplicity, Method 3 could be applied after a clear representation of terminal fisheries to facilitate the computation of post-season estimates for stocks currently not evaluated due to lack of base period data.*** New analytical effort would have to be invested by CTC members in order to fully implement the use of a new approach for the computation of pre- and post-season ISBM indices.

The CTC recommends several improvements to the reporting of CWT data for U.S. ISBM fisheries to improve the utility of the current metric and alternative metrics using CWT data. Some of the delayed data availability issues with the current metric can be addressed by the CTC and southern U.S. agencies reporting CWT data. In the 1985 Memorandum of Understanding, Canada and the United States agreed to "develop the capability to use current season coded-wire tag data, fishing data, spawning escapement data, and age composition data for the pre-season management process for the next season". Currently, CWT data are available from Alaska, BC, Columbia River, Oregon and outside fisheries in Washington in time for the pre-season management process for the next season. However, estimated CWT recoveries are typically not available in time for other inside fisheries in Washington. The delay in reporting the U.S. ISBM fishery CWT data delays the reporting ISBM indices for U.S. ISBM stocks, and several Canadian ISBM stocks.

Several approaches have been identified to improve timeliness of the ISBM indices, including: (1) report the ISBM Indices for Canadian stocks that are far north migrating and rarely have any CWTs recovered in U.S. ISBM fisheries (e.g. ISBM stocks using data from Kitsumkalum, Atnarko, and Quinsam CWT stocks); (2) southern U.S. agencies review, identify, and reconcile impediments to late CWT reporting to the extent feasible; (3) for U.S. ISBM fisheries where pre-terminal fishery CWT samples have been decoded, but cannot be expanded due to delays in catch data, agencies can report observed CWT recoveries without estimated numbers via the data exchange procedures. Reporting of observed CWT recoveries that have not been estimated enables the CTC to use alternative methods to estimate ISBM indices. Complete indices can be reported in time for the pre-season management process for the next season; and, (4) where incomplete or unreported CWT data exist for U.S. ISBM fisheries, the CTC should develop and apply estimation models to impute the missing data and calculate the U.S. ISBM fishery indices to use in the pre-season management process for the next season. These approaches are consistent with the way the CTC currently makes use of the best available data or imputes missing data in order to prepare critical pre-season fishery management information, such as the AABM Abundance Indices for the next season.

<u>Section 3.</u> Based on two modeled scenarios, ***the savings of mature fish resulting from 10% reductions in SEAK and NBC AABM fisheries and accruing to terminal run varied among stocks. Proportional increases in escapement were less than 4% in all stocks, except for Upper Georgia Strait (6.4%-8.2%) and North/Central BC (4%-4.8%).*** The magnitude of the savings for a specific stock is influenced by its cohort size and exploitation in the AABM fisheries. All savings from catch reductions in AABM fisheries do not accrue into terminal run and escapement the same year because some of the saved fish are immature. ***The absolute reductions required to ISBM harvest rates were less than or equal to 1%, with the exception of Columbia River Summers in 2007 with 1.7% (2.4% relative reduction).*** In terms of relative changes, Oregon Coast in 2007 required the largest reductions to ISBM harvest rates (3.7%), followed by WCVI Naturals in 2008 (3.5%). This means that all the savings could be passed into escapement with relatively little reduction in ISBM harvest. ISBM harvest rate reductions would be necessary in several consecutive years (e.g., 3 years) to pass through all savings from a reduction in AABM catch. These scenarios are suitable to evaluate impacts on the stock groups included in the PSC Chinook Model. In most instances these stock groups include mixtures of hatchery and

wild stocks; consequently, the estimates reported may not necessarily represent savings for individual natural stocks. The scenarios were retrospective analyses using observed data. The capacity to project impacts as a result of reductions to AABM and ISBM catch is affected by limitations of the current Model (e.g. one time step, inadequate representation of natural stocks), uncertainties regarding where and when these reductions would occur, and the short timeframe available for timely assessments that could influence management decisions.

Section 4. ***The CTC concludes the additional obligation, using the 1991-1996 average exploitation rate, is more restrictive for Canadian ISBM fisheries than for U.S. ISBM fisheries.*** The general obligation is lower than the 1991-1996 average for most U.S. ISBM stocks, whereas the 1991-1996 average is lower than the general obligation for most Canadian ISBM stocks. Given that the lesser of these obligations applies when stocks do not meet their escapement goal, the additional obligation would apply for the Canadian ISBM stocks that were evaluated (several could not be evaluated), except for Upper Strait of Georgia, and for the Deschutes and Lewis River Wild in the Columbia for the U.S. ISBM stocks. Many of the U.S. ISBM stocks exceeded their escapement goals during 1991-1996, which corresponds to current conditions when ISBM restrictions would not apply. However, ISBM adult equivalent mortality rates were greater in years when the escapement goals were not met for the Hoh, Quillayute, and Siuslaw.

Also in Section 4, the conditions described in Paragraphs 13(d) and 13(e) are new components of the 2008 Agreement, relative to the 1999 Agreement, that are additional criteria for management of ISBM fisheries. These components evaluate the effect of ISBM fisheries on observed spawning escapements and determine if the stock would have exceeded the escapement threshold of 85% of a CTC-accepted escapement goal under the ISBM obligations. Paragraph 13(d) describes a situation when a stock can be identified as meeting the criteria to trigger additional management action under Paragraph 13, even if escapement exceeded the threshold, whereas Paragraph 13(e) describes a situation when a stock can be excluded from triggering additional management action under Paragraph 13, even if escapement is less than the threshold. ***The CTC demonstrated that Paragraph 13(d) and 13(e) can be quantitatively evaluated using a common method since both require estimation of the spawning escapement that would have occurred if a jurisdiction's ISBM fishery impact was the same as the obligation level.*** This method is illustrated with applications to the Harrison River in 2009 and the Nehalem River in 2008.

1 INTRODUCTION

1.1 BACKGROUND INFORMATION

The original 1985 PST established a Chinook management regime that was intended to rebuild depressed Chinook stocks through a combination of catch ceilings on highly mixed-stock fisheries and pass-through provisions for other fisheries. Fisheries not limited by catch ceilings were limited by a general obligation to pass the bulk of savings of depressed stocks through to spawning escapement. This obligation became referred to as the “pass-through” obligation. After 13 years of the Chinook rebuilding program established by the 1985 Treaty, only 50% of the naturally spawning populations monitored to assess rebuilding had achieved their agency established escapement goals (Gaudet et al 2003). A significant cause for this is believed to have been major reductions in ocean productivity for Chinook stocks since the late 1980’s. In addition, many agency escapement goals were not biologically based. Consequently, the fixed catch ceilings that were implemented and that assumed ocean productivity would remain constant, were too large for some stocks and in some cases allowed for continued overfishing. In other cases, the agency escapement goals may not have been biologically achievable. Given the extreme variability of Chinook survival and the non-biological establishment of escapement goals, fixed catch ceilings were no longer considered an appropriate management approach to achieve PST objectives. A more integrated program to manage overall exploitation rates for restoring production and sharing future benefits was essential.

In the 1999 Agreement, the Parties to the Pacific Salmon Treaty (PST) initiated an abundance-based, coastwide Chinook salmon management regime that established three types of fisheries: aggregate abundance-based management (AABM[1]), individual stock-based management (ISBM), and terminal exclusion regimes. The introduction of ISBM commitments was a new feature of the 1999 Agreement that represented a significant change from the 1985 PST. The major changes included: (1) all fisheries not included as AABM fisheries will be managed as ISBM fisheries, resulting in more fisheries being designated as ISBM (“pass-through) fisheries[2]; (2) each Party has an overall responsibility to reduce the harvest rate on depressed naturally spawning Chinook stocks such that Chinook Technical Committee (CTC) agreed escapement goals are achieved for each indicator stock; (3) the overall obligation provides increased flexibility for management so long as the general obligation for harvest rate reductions are met by the Party and impacts are not unduly transferred onto other stocks; (4) each Party has quantitative management goals to meet (until agreed escapement goals are met). The general obligation for ISBM harvest rate reductions by Party are: Canada 36.5% below base period (1979-82) average exploitation rate, and United States 40% below base period average; (5) and, the non-ceiling index developed by the CTC (CTC 1996) will be used as the assessment tool, unless otherwise recommended by the CTC.

[1] Aggregate Abundance-Based Management (AABM) fisheries include southeast Alaska sport, net, and troll (SEAK), northern British Columbia troll and Queen Charlotte Islands (NBC), and west coast Vancouver Island troll and outside sport (WCVI).

[2] There were fewer AABM fisheries under the 1999 Agreement than Ceiling Fisheries under the 1985 Agreement. Central BC and Georgia Strait became ISBM fisheries.

In addition to the general obligation, the 1999 Agreement introduced an additional obligation consisting of additional reductions as necessary to meet the agreed escapement objectives. From the 2008 Agreement language in Paragraph 8 (c):

"For those stocks for which the general obligation is insufficient to meet the agreed MSY or other biologically-based escapement objectives, the Party in whose waters the stock originates shall further constrain its fisheries to the extent necessary to achieve the agreed MSY or other biologically-based escapement objectives, provided that a Party is not required to constrain its fisheries to an extent greater than the average of that which occurred in the years 1991 to 1996"

and in Paragraph 6(b(ii)):

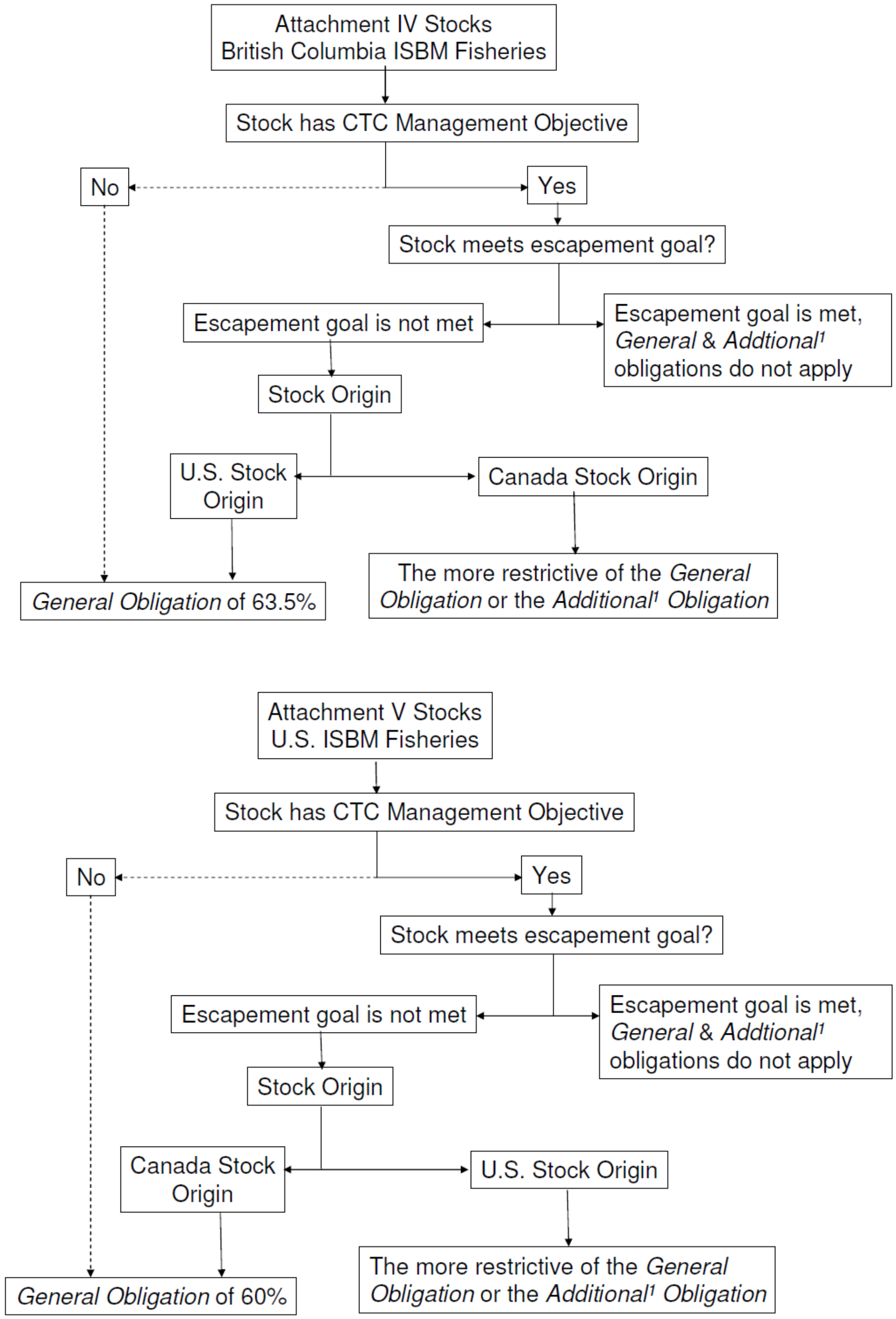
" an additional obligation as set out in paragraph 8(c) for those stock groups for which the general obligation is insufficient to meet the agreed escapement objectives".

These paragraphs indicate the lesser of the two rates, general obligation or additional obligation, would be recommended to meet escapement goals if stocks were not meeting their escapement objectives, and that the additional obligation applies to the Party in which the stock originates, as depicted in Figure 1.1.

The first assessment of ISBM obligations was completed in April 2001 (CTC 2001). The report contained both predictions of the ISBM indices for 2001and post-season estimates of indices in 1999 and 2000. The CTC noted that various datasets and analyses may be required for assessments of specific stocks because the indices are applicable only to wild stocks listed in the Agreement (Chapter 3, Attachment IV and V), and exploitation rates of some CWT indicator stocks may not accurately represent terminal harvest rates on those natural stocks (CTC 2001).

The ISBM fishery management regime, the focus of this report, is abundance-based and constrains to a numerical limit the total adult equivalent mortality rate[3] within the fisheries of a jurisdiction for a naturally spawning Chinook salmon stock or stock group (Paragraph 6(b), Chapter 3, 2008 Agreement). ISBM management regimes apply to all Chinook salmon fisheries subject to the PST that are not AABM fisheries. No PST fisheries in Alaskan waters are under ISBM management as these all contribute to the Southeast Alaska (SEAK) All Gear AABM fishery or terminal exclusion fisheries. Several fisheries within British Columbia (BC) are under ISBM fishery management and all PST fisheries south of the border between BC and Washington State are under ISBM fishery management (Table 1.1).

[3] The CTC has defined an AEQ as the probability that a fish of a given age would survive to reach its stock's terminal area in the absence of fishing, thus taking into account the age and stock-specific maturation schedule.



[1] The additional obligation is the average ISBM exploitation rate during 1991-1996

Figure 1.1 Flow diagram depicting the sequence of decisions leading to the implementation of ISBM general and additional obligations for stocks in Attachments IV and V of Chapter 3 of the 2008 Agreement according to Paragraph 8. The dashed path shows an alternative decision sequence per the 1999 Agreement. Clarification has been requested to the PSC by the CTC regarding the interpretation of Treaty language in the 2008 Agreement (see Appendix 1).

Table 1.1 U.S. and Canadian ISBM fisheries used in the CTC exploitation rate analysis and PSC Chinook Model.

U.S. ISBM Fisheries	Canadian ISBM Fisheries
Washington/Oregon Troll	Central Troll
North Puget Sound Net	Strait of Georgia Troll
South Puget Sound Net	Northern.Net
Washington Coastal Net	Central Net
Columbia River Net	WCVI Net
Terminal Net in freshwater	Juan de Fuca Net
Washington Coastal Sport	Johnstone Strait Net
North Puget Sound Sport	Fraser Net
South Puget Sound Sport	Terminal Net in freshwater
Juan de Fuca Sport	Northern Sport (Areas 3-5)
Columbia River Sport	Central Sport
Terminal Sport in freshwater	Strait of Georgia (including Juan de Fuca) Sport
	Terminal Sport in freshwater
	WCVI Inside Sport

1.2 OBJECTIVES

The conceptual framework for the types of fishery management agreed to through the 1999 PST was continued under the 2008 PST Agreement. Deficiencies were explicitly recognized with the ISBM index annually calculated for pre-season fishery planning purposes, and especially with the index calculated for assessing compliance by Canada and the U.S. with respect to specific ISBM provisions. Appendix A to Annex IV, Chapter 3, of the 2008 Agreement lists several assignments to the CTC. This report addresses the three tasks included in assignment 7 of Appendix A:

(7) Individual Stock Based Management Improvements

a) Individual Stock Based Metric Improvement: The CTC will explore alternative metrics to be used to monitor ISBM fishery impacts, and report to the Commission on the utility of these metrics or approaches by 2011. The non-ceiling index referenced in paragraph 8(d) has not proven to be useful for many stocks as a means to monitor or evaluate the performance of ISBM fisheries relative to the obligations for a variety of reasons, including:

(i) unreliable base period data;

(ii) mismatched and incomplete information between different stock groups;

(iii) instability in the metric until all brood years affected by a fishery have completed their life cycles; and

(iv) delays in the availability of CWT data.

b) Paragraph 13 Obligations for ISBM fisheries: The CTC will develop methods to estimate the savings of mature fish expected to result from further reductions to AABM fisheries under paragraph 13 and determine adjustments in ISBM fisheries required to ensure that such savings accrue to escapements.

c) Evaluate 1991 to 1996 ISBM Average Criteria: The CTC will provide estimates of the 1991 to 1996 average impacts in ISBM fisheries relative to the 1979 to 1982 base period for the stock groups listed in Attachments IV and V.

In addition to the above assignments, this report includes a review of the ISBM component of the stock performance evaluation defined in Paragraph 13 of Chapter 3 of the 2008 Agreement. The inclusion of this material was considered appropriate as part of the additional criteria used to monitor performance of ISBM fisheries (see Chapter 4).

1.3 THE CURRENT INDEX AND ITS PROBLEMS

For ISBM fisheries, the Agreement requires the CTC to compute an ISBM exploitation rate index by country for several stocks or stock groups. The ISBM index is computed using the formula defined by the CTC (CTC 1996, CTC 2005) as a non-ceiling index. The term non-ceiling dates back to the period when some of the large mixed-stock fisheries were managed to a fixed annual catch ceiling under the PST, and all other fisheries were called non-ceiling fisheries. However, in the 1999 Agreement, some of the ceiling fisheries became AABM fisheries and the others became ISBM fisheries along with the existing non-ceiling fisheries.

The ISBM index represents the ratio of the total mortalities (in adult equivalents or AEQs) of a stock in a country's ISBM fisheries in the current year divided by the total mortalities that would have occurred under base period exploitation rates:

$$ISBMIdx_{s,y} = \frac{\sum_{i=1}^{F}\sum_{a=2}^{5}(TM_{s,i,a,y} * AEQ_{s,i,a,y})}{\sum_{i=1}^{F}\sum_{a=2}^{5}(BPER_{s,i,a} * Cohort_{s,i,a,y})} \qquad (1.1)$$

where $ISBMIdx_{s,y}$ is the ISBM index for stock *s* in year *y*; $AEQ_{s,i,a,y}$ stands for adult equivalents for stock *s* at age *a*, and fishery *i* in year *y*; $Cohort_{s,i,a,y}$ is the cohort size for stock *s* by age *a* in year *y* and fishery *i* after natural mortality has occurred at that age; and, $TM_{s,i,a,y}$ is the total mortality (i.e., the sum of landed catch and incidental mortality). The term $BPER_{s,i,a}$ is the average total mortality exploitation rate that occurred in the base period 1979-1982 for stock *s*, at age *a*, in fishery *i* in AEQ terms.

$$BPER_{s,i,a} = \frac{\sum_{y=79}^{82}\frac{(TM_{s,i,a,y}) * AEQ_{s,i,a,y}}{Cohort_{s,i,a,y}}}{4} \qquad (1.2)$$

This index compares an 'expected' AEQ mortality (assuming base period exploitation rates and current stock abundance), with the observed (post-season) or projected (pre-season) AEQ mortality on a stock within a calendar year, over all ISBM fisheries of a country (see Table 1.2). Index values less than 1.0 indicate that the exploitation rates have decreased relative to the base period. The Agreement obligates Canada and the U.S. to reduce the exploitation rate from the base period by 36.5% and 40%, respectively, in fisheries on specific stocks, identified in Attachments IV and V, that are not meeting their escapement objective or that do not yet have an escapement objective (Paragraph 8c, Chapter 3). This provision is referred to as the "general obligation". The general obligation does not apply to stocks that have achieved or are projected to achieve their CTC agreed escapement objective. A total of eight and seven stock groupings were identified for Canada and the U.S., respectively, to monitor ISBM provisions (PST attachments IV and V, Chapter 3). The indices are applicable only to wild stocks. However, some ISBM terminal fisheries target hatchery indicator stocks and adjustments are necessary to terminal fishery impacts to represent mortalities of the natural stock as accurately as possible.

Timeliness of availability of the computed ISBM indices is important in the pre-season planning process. All of the data for the U.S. pre-season ISBM indices must be available and the calculations completed by mid-April. During this time, the Pacific Fisheries Management Council (PFMC) evaluates various harvest options for all U.S. coastal fisheries south of the Washington State–British Columbia Border. PFMC must choose the option that meets the management objectives and provisions of the Pacific Coast Salmon Plan under the Magnuson-Stevens Act, the obligations under the PST as well as the consultation standards for salmon stocks listed under the U.S. Endangered Species Act. To date, ISBM indices have not been considered in the pre-season fishery planning process in Canada.

Since the completion of the 1999 Agreement, it was noted that despite the specification of the above index as the means for assessing compliance with the ISBM obligations, the actual application of this formula proved problematic because the values of the index are inherently unstable (see below). Although alternative ways of computing an index for ISBM fisheries, including modifications of the PSC Chinook Model code and development of a new index, have been suggested (Gaudet et al. 2003), only recently has Sharma (2005, 2006) evaluated the current index and explored alternative approaches. Sharma (2005) identified numerous problems with the current ISBM index stemming from the fact that model and CWT-based indices do not track each other satisfactorily and the fact that many of the natural stocks are not CWT indicator stocks and therefore they are represented by surrogates that in many cases have different fishery distributions and maturation rates.

Four limitations have been identified with the current method of calculating the pre-season ISBM index used for fishery planning and the post-season index used for assessing compliance relative to ISBM obligations:

1. *Instability*: The computed values for ISBM indices change (i.e., are not stable) for several years until all age classes from contributing broods have matured and died. Assumed age-specific maturations rates (e.g., values averaged over some historical period) must be used to estimate cohort sizes and incidental mortalities for brood years that are incomplete. The adult

equivalent (AEQ) values used in the calculation of ISBM indices are also subject to change because they depend on maturation rates. This instability can lead to incorrect interpretation of compliance with ISBM obligations and poses challenges for pre-season planning and for post-season assessment performance evaluations.

2. *Partial base period coverage*: The indices are unreliable for any stock where the average stock, age, and fishery-specific exploitation rates for the base years 1979-1982 were estimated using incomplete or poor data. CWT-based indices require CWTs in base period fisheries from one or more broods, reliably estimated CWTs for all fisheries (not just ISBM fisheries), and reliably estimated CWTs for the spawning escapement. This means that programs for estimating fishery catches and spawning escapements, as well as programs for sampling CWTs from fishery catches and spawning escapements, had to be fully operational during those years. This was often not the case. For some data deficient stocks, data from surrogate stocks are used to represent the base period exploitation rates, assuming both stocks have the same fishery distribution and maturation patterns.

3. *Delayed data availability:* The data needed to calculate the post-season ISBM CWT-based index for several stocks caught in U.S. ISBM fisheries are not available at the time the index must be computed for timely use. Catch estimates from some U.S. ISBM fisheries may not be available until at least one year after a fishery has occurred, either because the catch data are unavailable or because multiple agencies have not reached timely agreement on the ‘final’ catch estimates needed to generate expansion factors for CWT recoveries. Because these recoveries are needed to estimate cohort sizes, the consequence of these delays in the availability of CWT data from some U.S. fisheries is that the ISBM indices for both countries may not be computed within a timeframe for ISBM evaluations and to inform fishing plans for the upcoming season.

4. *Different pre-season and post-season modeling methods*: Pre-season fishery planning is made more uncertain because numerous differences exist between the pre-season and post-season versions of the index. Fundamental differences may exist in the sources of data used in the calculations and the assumptions necessary to compute ISBM indices. This means that the two different versions of the index often do not correspond well. It is preferable for the pre-season and post-season indices to be calculated using the same approach and data.

In addition, issues with data quality are ignored while computing the current index. The index is always computed relative to the 1979 to 1982 base period. However, insufficient recoveries or tags from some key stocks and production programs (and fisheries) are missing from the base period. Furthermore, fishing patterns have changed significantly from the base period, thus making a direct comparison difficult. Problems with sampling issues in recent fisheries (e.g., use of electronic CWT detectors or downgrading or elimination of monitoring and evaluation programs) also contribute to the difficulty in obtaining the data necessary to compute the ISBM index.

Table 1.2 Attachments IV and V pre- and post-season stock representation in ISBM fisheries.

Stock Group	ISBM Stock	Attachment		Pre- and post-season index representation	
		IV	V	Pre-season Model stock	Post-season CWT stock
Lower Strait of Georgia	Cowichan	X	-	GST[3]	Cowichan [3]
	Nanaimo	X	-		Nanaimo [3], Big Qualicum
Fraser Late	Harrison	X	X	FRL[2]	Chilliwack [3]
Upper Strait of Georgia	Klinaklini	X	-	GSQ	Quinsam
	Kakaweikan	X	-		
	Wakeman	X	-		
	Kingcome	X	-		
	Nimpkish	X	-		
Fraser Early (springs and summers)	Upper Fraser	X	-	FRE[1]	Dome [3]
	Mid Fraser	X	-		
	Thompson	X	-		Nicola [3], Lower Shuswap
West Coast Vancouver Island Falls	Artlish	X	-	RBT	Robertson
	Burman	X	-		
	Gold	X	-		
	Kaouk	X	-		
	Tahsis	X	-		
	Tashish	X	-		
	Marble	X	-		
North/Central BC	Yakoun	X	-	NTH[1]	
	Nass	X	-		
	Skeena	X	-		Kitsumkalum [3]
	Area 8	X	-		Atnarko
North Puget Sound Natural Springs	Nooksack Spring	X	X	NKS	Nooksack Spring [3]
	Skagit Spring	X	X		N/A
Puget Sound Natural Summer/Falls	Skagit	X	X	SKG	N/A
	Stillaguamish	X	X	STL	Stillaguamish Fall Fingerling [3]
	Snohomish	X	X	SNO	N/A
	Lake WA	X	X	PSN	N/A
	Green River	X	X	PSN	South Puget Sound Fall Fingerlings [3]
Washington Coastal Fall Naturals	Hoko	-	X	WCN	Hoko
	Grays Harbor	-	X		Queets
	Queets	-	X		
	Hoh	-	X		
	Quillayute	-	X		
Columbia River Falls	Upriver Brights	-	X	URB	Upriver Brights
	Deschutes	-	X	URB	Upriver Brights
	Lewis	-	X	LRW	Lewis River Wild
Columbia River Summers	Mid-Columbia River Summers	-	X	SUM	Columbia Summers
Far North Migrating Oregon Coastal Falls	Nehalem	-	X	SRH	Salmon River Hatchery
	Siletz	-	X		
	Siuslaw	-	X		

[1]Model superstock: several CWT indicator stocks combined
[2]Out-of-base procedure used
[3]Other CWT stock used to represent base period.

The ISBM index has an implicit assumption that the fisheries or fishing structure should not have changed substantially relative to the base period. This assumption is not valid as overall harvest rates for Canada and U.S. fisheries have been reduced significantly in the last few decades in response to conservation concerns (Sharma 2005; Morishima and Henry 2000). Stocks included in new tagging programs have no base period data and assumptions need to be drawn from other tag codes or stock groupings to fill the data gaps. Moreover, in some cases the terminal harvest rates for several stocks are derived assuming the terminal harvest rate from a single stock adequately represents many other stocks (e.g., Queets represents most of Washington coast; Salmon River represents all of Oregon coast). This may be problematic since these are all independent stocks. In addition, terminal harvest rates of representative hatchery tag groups may differ significantly from harvest rates on nearby natural stocks if there are intensive "hatchery-zone" fisheries designed to target surplus hatchery fish. Differential harvest rates between hatchery and natural stocks also occur in fisheries that are managed under adipose mark selective regulations. CWTs recovered from adipose clipped fish will incorrectly measure fishery impacts on the natural stocks unless analytical mechanisms are designed to account for this difference. Mark selective fishing regulations for Chinook salmon were first implemented in U.S. ISBM terminal sport fisheries in 2002 and in pre-terminal fisheries in Puget Sound in 2003. Currently, the majority of the Puget Sound marine area sport fishery on Chinook is under mark selective fishing regulations.

1.4 DESIRABLE ATTRIBUTES OF ISBM INDEX METRICS

Paragraph 7 of Appendix A to Annex IV, Chapter 3 of the 2008 PST Agreement instructs the CTC to develop methods to address problems with the existing ISBM index. The CTC identified the following desirable attributes of an ideal ISBM metric:

1. Measures changes in total catch or total AEQ mortality required to attain agreed escapement for natural stocks;

2. Solves base period coverage issues in terms of fisheries, stock representation, and escapement data;

3. Able to generate pre-season and post-season estimates;

4. Uses the same analytical framework for pre-season and post-season computations;

5. Meets timelines for pre-season and post-season estimates;

6. Post-season estimates are stable under incomplete broods;

7. Uses current CWT data;

8. Uses data provided by existing programs;

9. Feasible to compute with available staff and time constraints;

10. Able to accommodate differences in terminal impacts between CWT indicator and natural stocks;

11. Be capable of comparing impacts of ISBM fisheries on individual stocks relative to 1979-1982 under the general obligation, and to the 1991-1996 average under the additional obligation; and,

12. Can be applied to all stocks in Attachments IV and V of the Agreement.

In addition, the ISBM index should, to the maximum extent practicable, possess the following characteristics:

1. Rely upon historical data sets collected using comparable methods;

2. Be suitable for planning and evaluating the ISBM fishery pass-through provisions that increase spawning escapements by the number of fish expected to be saved from additional restrictions on AABM fisheries;

3. Use the best available scientific information to generate pre-season projections based on abundance forecasts and fishing plans for the set of stocks identified in Attachments IV and V;

4. Use the best available scientific information to annually report post-season estimates for the set of stocks identified in Attachments IV and V; and,

5. Be available in time to evaluate ISBM fishery performance in the previous year and to plan fisheries for the upcoming year.

The above desirable attributes and characteristics were used to qualitatively evaluate alternative ISBM metrics as well as the current indices. This evaluation is presented in Section 2.7.

2 ALTERNATIVE ISBM METRICS

The first task of the ISBM assignment refers to the evaluation of alternative metrics to monitor ISBM fishery performance. In 2003, a U.S. CTC review of the implementation and application of the ISBM provision identified several limitations with the existing ISBM index (Sharma 2005). Subsequently, Sharma (2006) explored alternative approaches to the current methods, including approaches that used the existing structure along with newer techniques. These alternative ISBM metrics are grouped in 5 categories: index derived from Generalized Linear Models (GLM) forecasting CWT contributions from catch predictions (Method 1); index derived from effort or exploitation-rate data using a catch-at-age model (Method 2); index derived from CWT-based mortality distribution across fisheries (Method 3); a composite-index that would require redefinition of current ISBM obligations (Method 4); and methods that use an alternative model framework to the PSC Chinook Model used to derive the current pre-season ISBM index (Method 5). Some of these methods allow for pre-season and post-season computations (Methods 1, 2, and 5) while others only allow the computation of post-season indices (Methods 3 and 4). Additional documentation on methods 1-4 can be found in Sharma (2006).

A summary of alternative approaches described by Sharma (2006) (methods 1 – 4) and new techniques (methods 5a and 5b and application of Method 3 to stocks without base period data) are presented in the rest of this section followed by examples and an evaluation summary.

2.1 APPROACHES USING GLM METHODS

Method 1: forecasting CWT contributions based on catch predictions (pre-season and post-season)

Two methods, 1a and 1b, are based on predictions of CWT recoveries using the general formulation of the current pre-season ISBM index (Method 1a), and a simplified index that compares CWT recoveries projected across all fisheries accounting for recoveries, releases, and survival and compares it to base period recoveries (Method 1b). One of the problems with the existing pre-season ISBM index (based on PSC Chinook Model projections) is that it corresponds poorly with the post-season analysis of CWT data. Method 1a replaces PSC Chinook Model projections of ISBM indices with an independent projection based on survival rates, CWT recoveries, and anticipated catch levels. This method uses the ISBM index equation 1.1. A variant of this approach, Method 1b, entails the same independent projection in Method 1a, but takes the generalized linear model based parameters (the projection-based model) to compute the number of CWTs encountered by age using pre-season data. A post-season estimate is generated using observed catches, and survivals, and dividing this by the base period values.

Since the current pre-season ISBM index is evaluated post-season using CWT data, it seems appropriate to estimate the CWT contributions based on fishery regulations for the ISBM strata of fisheries. Historical time series of catch can be used to predict CWT contribution rates of fisheries using simple binomial models, log-linear models, or Poisson-count models.

Historical recovery distributions of CWTs could serve as a predictor of future recovery and exploitation rates if assumptions are made about the recoveries by various strata (e.g., stock, age, gear and fishery strata) using a binomial probability model. Presently this and other log-linear models have been developed to analyze recovery data (Green and Macdonald 1987, Cormack and Skalski 1992). However, the use of these models is limited if fishing, sampling effort, and environmental variability are not taken into account (Bernard and Clark 1996).

It is possible to forecast three fishery categories, namely Canadian ISBM fisheries, U.S. ISBM fisheries, and other ocean fisheries by age and use the CTC program COSHAK[4] to estimate the cohort size and apply base period ERs on this stock using the current ISBM equations (Sharma 2005). However, there are still some stability problems with this technique if the current algorithm is used because of the incomplete-broods effect.

Since the data are counts, a Poisson model can be used with the log-link function to test age, effort, survival and age-survival, age-effort interactions and dynamics. The general structure for any one fishery or groups of fisheries is given by the equations below:

$$\mu_{a,t} = \exp\left(\beta_0 + \sum_{f=1}^{3}\beta_f(S_{t-a}) + \sum_{f=4}^{6}\beta_f(R_{t-a}) + \sum_{f=7}^{9}\beta_f(C_t) + \varepsilon\right) \qquad (2.1)$$

$$LP_{a,t} = \beta_0 + \sum_{f=1}^{3}\beta_f(S_{t-a}) + \sum_{f=4}^{6}\beta_f(R_{t-a}) + \sum_{f=7}^{9}\beta_f(C_t) + \varepsilon \qquad (2.2)$$

where *LP* is the linear predictor, *a* is the age of recovery in a particular fishery or group of fisheries, *S* is the survival of the brood year associated with that age of recovery (*t-a*), *R* is the release associated with that brood, *C* is catch in the year *t* that the fishery was observed (effort can be used to derive expected catch), and the $\mu_{a,t}$*'s* (i.e., the mean number of recoveries observed by age in a fishery) are Poisson distributed. These methods are similar to those used by Cormack and Skalski (1992).

For example if fishery 1 is the Canadian ISBM group of fisheries, then there will be one relationship between survival, release, and catch (or effort) by age for that fishery. The other fisheries will have other relationships primarily because of the fishery interaction with other fisheries.

Under the null hypothesis, H_0: $\beta_1 = \beta_2 = \beta_3 = \ldots\ldots \beta_n = 0$. And under H_A: $\beta_1 \neq 0$ and/or $\beta_2 \neq 0$ and/or $\beta_3 \neq 0$……..and/or $\beta_n \neq 0$. Once the estimates are generated the current index (equation 1.1) can be used.

While method 1a uses the general formulation of the ISBM index (equation 1.1), method 1b uses a simplified index that compares CWT recoveries projected across all fisheries

[4] The primary purpose of COSHAK is to perform virtual population analyses and to calculate a set of statistics including exploitation rates, maturation rates, survival rates, and AEQ rates.

accounting for CWT releases and survival and compares it to base period CWT recoveries. Method 1b uses the Poisson-model estimates to compute the ISBM index as:

$$ISBM = \frac{\sum_{a=2}^{5} \mu_{a,t} \mid S_{t-a}, R_{t-a}, C_t}{\sum_{a=2}^{5} \mu_{a,t} \mid S_{base}, R_{base}, C_{base}} \tag{2.3}$$

2.2 EFFORT-BASED INDEX

Method 2: effort based indices or exploitation-rate (ER) based management using a catch-at-age model (pre-season and post-season)

This alternative index is based on relative changes in catchability coefficients and effort using a continuous catch equation and an age-structured model. The result is an ISBM index that is insensitive to cohort sizes and is based on catchability and effort relative to base period levels. This method also can address variations in fishery structure. However, it assumes that the effort data represent fishing effort that targets Chinook salmon. Thus, the inclusion of other effort (e.g., effort targeting other salmon species, shellfish, groundfish, etc.) will require additional filtering to maintain a robust performance of this method.

Fournier and Archibald (1992) describe a statistical catch at age model. A slight modification of their approach could be used to model Chinook salmon. In essence, different components of ocean catch, and terminal catch data by stock and age in conjunction with escapement data, can be used to estimate parameters such as recruitment to age 2, fishing mortality by fishery, stock and age, maturation and vulnerability schedules by age for fisheries. This method can be extremely useful in cases where escapement data are not meeting CTC data standards.

The method uses a forward projection algorithm that is based on estimation of certain key parameters in the backwards run reconstruction. The model uses an optimization function to find the parameters that minimizes the difference between model projections and observed ocean catches of the stock by age and fishery of concern (Deriso et al 1985) by maximizing the likelihood functions between observed and predicted catches in ocean and terminal fisheries and escapements. The prototype model that has been developed is tuned to ocean catches, terminal catches and escapement.

For the ocean component the equations are shown below:

$$N_{2,t} = Recruitment \tag{2.4}$$

Recruitment to age 2 and time *t* is estimated as a function of the model projected catches and escapement.

$$N_{a+1,t+1} = N_{a,t} e^{-(F_{a,t}+M_a)} - N_{a,t} \times MR_{a,t} \tag{2.5}$$

Essentially, population size at time *t*, is a function of population size at time *t*-1, and is a function of both fishing mortality at that age and time, and natural mortality at that age as well as the fraction of the population that matured at the previous age (*MR*) and entered the terminal area.

In order to project catch, a catchability coefficient (q_0) as a function of effort needs to be estimated:

$$Ffull_t = q_O \times E_t \tag{2.6}$$

Fishing mortality at age is then estimated as a function of age specific vulnerability ($V_{a,t}$) and *Ffull*:

$$F_{a,t} = V_{a,t} \times Ffull_t \tag{2.7}$$

Catch at age and time is then projected as a function of ocean cohort at a particular age, and fishing mortality and natural mortality at that age:

$$C_{a,t} = N_{a,t} \times (1 - e^{-(F_{a,t}+M_a)}) \times \frac{F_{a,t}}{F_{a,t} + M_a} \tag{2.8}$$

This process is repeated sequentially for groups of ISBM fisheries and other pre-terminal ocean fisheries, followed by maturation and a terminal fishery catch.

For terminal fisheries, another set of equations is used. They are similar to the ones used above but have the added component of estimating maturation from the ocean cohort to the terminal area.

$$N_{a,t_T} = (N_{a,t} - C_{a,t}) \times MR_{a,t} \tag{2.9}$$

where $N_{a,t\,(T)}$ is the age *a* abundance at time *t* in terminal area *T*, and *MR* is the maturation rate at age a (time *t*). This is a function of the ocean cohort at time *t*.

Similarly, terminal catch can be projected as:

$$Ffull_{t\,T} = q_T \times E_{t\,T} \tag{2.10}$$

where the subscript *T* indicates terminal effort (*E*) and catchability (*q*).

$$F_{a,t_T} = V_{a,t_T} Ffull_{t\,T} \tag{2.11}$$

and where $F_{a,t,(T)}$ is fishery specific mortality by age and is a function of vulnerability by age. $C_{a,t(T)}$ is then the projected catch in the terminal area (assuming loss due to natural mortality is zero):

$$C_{a,t_T} = N_{a,t_T} \times (1 - e^{-(F_{a,t_T})}) \quad (2.12)$$

and escapement at age is then calculated as :

$$Esc_{a,t} = N_{a,t_T} - C_{a,t_T} \quad (2.13)$$

The likelihood equation used in fitting these different data sources is:

$$L(Model \mid C_{a,t,f}) = \prod_{f=1}^{n} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{\left(C_{a,t,f}) - (\hat{C}_{a,t,f})\right)^2}{2\sigma^2} \right] \quad (2.14)$$

If the continuous catch equation model works then a direct fishing mortality rate can be computed assuming catchability (q) across all fisheries can be estimated. Harvest can thus be limited based on effort and catchability across a group of fisheries.

Finally, using a base set of effort scalar years projected indices as a ratio of effort in the different ISBM fisheries can be computed using the equation below:

$$ISBM_t = \frac{\sum_{i=1}^{n} q_{i,t} E_{i,t}}{\sum_{i=1}^{n} q_{i,base} E_{i,base}} \quad (2.15)$$

where i is the fishery and the variables in the denominator represent the base period. Note the catchability coefficient remains the same in this index and only projected effort and the actual effort obtained in the fishery vary. Retrospectively, performing an exercise to assess this may be difficult, and therefore a variant of method 1(b) could be used where CWTs are projected in an index based on expected values and observed values:

$$ISBM_{f,t} = \frac{\sum_{a=2}^{5} \mu_{a,f,t} \mid q_{f,t}, v_{a,f,t}, E_{f,t}}{\sum_{a=2}^{5} \mu_{a,f,t} \mid q_{fbase}, v_{abase,fbase}, E_{fbase}} \quad (2.16)$$

where $\mu_{a,f,t}$ is the number of CWTs predicted by stock, age and time in an ISBM fishery, $q_{f,t}$ is the catchability coefficient by fishery and time, $v_{a,f,t}$ is the vulnerability by age, fishery and time, and $E_{f,t}$ is the effort by fishery and time. This statistical catch-at-age (SCAA) model can be used in retrospective and prospective mode by evaluating what happened and what would have been predicted based on the CWT projections.

2.3 MORTALITY DISTRIBUTION-BASED INDEX

Method 3: mortality distribution index (post-season)

This ISBM index uses total mortality tables that the CTC annually reports for CWT indicator stocks by fishery and escapement. This metric represents the ISBM fishery impacts by country as extracted from the data that are used to construct the mortality distribution tables. Total mortality distributions are reported for all ages in the fisheries by catch year using:

$$CYDist_{CY,F} = \frac{\sum_{a=Minage}^{Maxage} \sum_{f \in \{F\}} Morts_{CY,a,f} * AEQ_{BY=CY-a,a,f}}{\sum_{a=Minage}^{Maxage} \left(\sum_{f=1}^{Numfisheries} Morts_{CY,a,f} * AEQ_{BY=CY-a,a,f} + Esc_{CY,a} \right)} \quad (2.17)$$

where $CYDist_{CY,F}$ is the proportion of total stock mortality (or escapement) in a catch year *CY* attributable to a fishery or a set of fisheries *F*, $Morts_{CY,a,f}$ is landed or total fishing mortality in year *CY* and age *a* in fishery *f* , $AEQ_{BY=CY-a,,a,f}$ is the adult equivalent factor in brood year *BY*, age *a*, and fishery *f* (for terminal fisheries, *AEQ* = 1.0 for all ages), and $Esc_{CY,a}$ is the escapement past all fisheries for either brood year *BY* or catch year *CY* and age *a*.

Distribution tables are generated annually in the CTC Calibration and Exploitation Rate Analysis Report. These tables summarize catch data divided by all recoveries from catch and escapement by jurisdiction. These tables could be used to generate a relative index of exploitation by fishery or group of fisheries as an alternative ISBM metric. The approach uses the CWT data, which is already generated by the CTC, to calculate a simple ratio to generate an alternative mortality distribution rate-based index.

An ISBM mortality distribution rate (*ISBMMD*) can be computed as a function of total ISBM mortality and escapement:

$$ISBMMD_y = \frac{\sum_{a=2}^{5} \sum_{f=1}^{n} TM_{a,f}}{\sum_{a=2}^{5} \sum_{f=1}^{n} TM_{a,f} + \sum_{a=2}^{5} Esc_a} \quad (2.18)$$

where $TM_{a,f}$ represents the portion of the adult equivalent total mortality (i.e., $\Sigma CYDist_{CY,F}$) by the ISBM fisheries in a jurisdiction. The ISBM index is computed as $ISBMMD_y$ / $ISBMMD_{79\text{-}82\ average}$. ISBM mortality distribution rates can be scaled to any period with CWT mortality distribution data to generate an index measured in units comparable to those in the current post-season ISBM index.

2.4 COMPOSITE INDEX

Method 4: alternative approaches that restructure the current obligation (post-season)

Alternative approaches can be developed such as composite indices that identify when multiple stocks fail to meet their escapement goals or targets. These composite indices could be implemented with catch or exploitation rate limits.

Indices are constantly used in the PST process (e.g., HRI; CTC 2005). This alternative entails an average composite index across stocks in a group of fisheries and the overall relationship with escapement. Given an escapement objective, the index based on a retrospective analysis might display a certain ER index value *x* over which that objective is always met. If, on the other hand, the corresponding index is *y* when there is an escapement of *b*, then the allowable index should not exceed a certain value (*x*) and should cause a reduction (*y*-*x*) in the fishery to meet that objective (Figure 2.1).

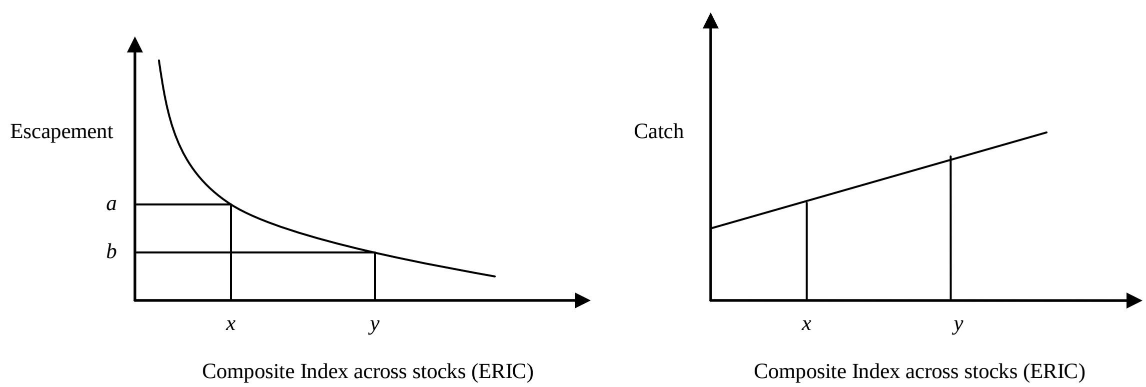


Figure 2.1 Relationship between escapement and composite index (left), and catch and composite index (right).

The equation used to assess the ER index (ERI) for a particular stock (s) is shown below:

$$ERI_{s,t} = \frac{\sum_{i=2}^{5} C_{s,i.f}}{\sum_{i=2}^{5} A_{s,i,f}} \qquad (2.19)$$

where *C* is the catch in an ISBM fishery (by age *i*) and *A* is the abundance in the fishery (either terminal or pre-terminal). Since the cohorts vary by ocean and freshwater areas (due to mature and immature cohorts), the ERI is averaged over the two fisheries to assess overall ERI's for that stock. For the overall ERI's the CWT tag data from a set of stocks in the Exploitation Rate Analysis (CTC 2005) is used. In addition, an overall composite is computed for the stocks and the fishery by aggregating that information over all stocks to create an Exploitation Rate Indicator Composite (ERIC).

$$ERIC_t = \frac{\sum_{s=1}^{n} ERI_{s,t}}{n} \tag{2.20}$$

Alternative formulations of the index could be weighted by the cohort size (A; equation 2.21) or exploitation rate (ER; equation 2.22) by the stocks encountered in the fishery.

$$ERICA_t = \frac{\sum_{s=1}^{n} A_s ERI_{s,t}}{n\sum_{s=1}^{n} A_s} \tag{2.21}$$

$$ERICE_t = \frac{\sum_{s=1}^{n} \left(ERI_{s,t}\right)^2}{n\sum_{s=1}^{n} ERI_{s,t}} \tag{2.22}$$

Certain criteria can be used to include or exclude data (as behavior of the composite index (ERIC) around the escapement target or below it is the important consideration), ignoring points that exceed target escapement by large amounts:

1. Ignored if greater than x% of the average escapement (or goal).
2. Evaluate the index value at the point where the goal is being met.
3. Use the exponential relationship to set reductions in harvest rate that might cause a consequential reduction in catch.

The model describing the relationship between the index and the escapement is then

$$E_t = \alpha e^{-\beta(ERIC)} \tag{2.23}$$

which can be linearized by log-transforming both sides:

$$\ln(E_t) = \ln(\alpha) - \beta(ERIC) + \varepsilon \tag{2.24}$$

In addition, ERIC can be related to overall catch for a particular stock by the following expression:

$$ISBMCatch = \eta e^{\lambda(ERIC)} \tag{2.25}$$

or $\ln(ISBMCatch) = \ln(\eta) + \lambda(ERIC)$ (2.26)

and $ERIC = \dfrac{\ln\left(\dfrac{ISBMCatch}{\eta}\right)}{\lambda}$ (2.27)

For simplification purposes, it is appropriate to look at common fisheries that affect all stocks (i.e. the pre-terminal fisheries by jurisdiction) and try to estimate a relationship between that and the overall catch.

2.5 FRAM-BASED INDICES

Method 5a: FRAM-based ISBM index (pre-season and post-season)

Pre- and post-season estimates of ISBM indices can be produced through the use of the PFMC's Chinook Fishery Regulation Assessment Model (FRAM). It is the primary tool employed for detailed U.S. domestic planning processes for fisheries south of the Washington-Canadian border throughout the migratory range of stocks originating in Washington and the Columbia River. FRAM is a single pool deterministic fishery model similar to the PSC Chinook Model[5] covering many of the same stocks and fisheries in somewhat different aggregations (Appendix 2, 3). FRAM is based on much of the same CWT data, fishery catches, and age-specific stock abundances that are part of the PSC Chinook Model base period data. Both models use cohort analysis from many of the same 1974-79 brood CWT release groups to represent "base period" stock size and exploitation rates during the 1979-82 fishing years. Calculation of an ISMB index from FRAM follows the general form shown in equations 1.1 and 1.2 with the caveat that the values for the variables would be in terms of FRAM units for stock cohort size, fishery exploitation rate, and adult equivalency factors for each age class across three time periods per year. Documentation of FRAM can be found at http://www.pcouncil.org/salmon/background/document-library/fishery-regulation-assessment-model-fram-documentation/.

FRAM has a higher degree of stock-fishery-temporal resolution in southern U.S. ISBM fisheries than the PSC Chinook Model, and is thus better suited to estimation of U.S. ISBM indices for U.S. stocks. FRAM generates detailed estimates of fishing mortality for individual stocks covering a 15-month planning cycle. FRAM has the capacity to evaluate modest mark-selective fishery impacts on individual marked and unmarked stock components and incorporates algorithms to estimate incidental fishing mortalities under a variety of fishing regulations. For AABM fisheries north of the Washington-Canadian border, FRAM employs effort scalars that produces the landed catch ceilings associated with the AIs for the pre-season runs and the

[5] The primary uses of the PSC Chinook model are estimating abundance indices (AIs, relative abundance compared to 1979-1982) for implementation of Aggregate Abundance Based Management (AABM) fishing regimes, providing data for models used in domestic fishery planning processes (e.g. Pacific Fishery Management Council, ESA recovery planning), and providing data for pre-season Individual Stock Based Management (ISBM) fisheries.

observed catches for the post-season model runs. The Canadian ISBM fisheries in FRAM have been modeled as recent year average observed catches for pre-season runs or the observed catch for post-season runs. The U.S. ISBM fisheries are modeled as effort scalars or expected catch for pre-season runs and observed catch for post-season runs.

The FRAM also has the capability for run reconstruction in “backwards” mode to generate post-season estimates of exploitation rates based on observed terminal run sizes and reported fishery catches. Backwards FRAM was developed to address uncertainties in pre-season abundance forecasts and to provide data employed for run reconstruction. Backwards FRAM employs an iterative procedure to estimate initial cohort sizes that best fit observed catch and terminal run size data, assuming base period patterns of fishery exploitation.

The main advantages of a FRAM-based ISBM index are that FRAM can estimate impacts of some types of mark-selective fisheries on both marked and unmarked stock components, provides a consistent method for generating pre- and post-season estimates of ISBM indices (pre-season estimates of ISBM indices are currently produced for U.S. stocks and fisheries during domestic planning processes; timely post-season estimation of ISBM indices, including those for 1991-96, can be easily generated from data produced by Backwards FRAM), and provides fine-scale stock and fishery resolution that is needed to estimate ISBM indices for several stocks. The limitations of a FRAM-based ISBM index are that stocks from rivers north of the Strait of Georgia are not represented, Canadian impacts in terminal areas cannot be evaluated, and this model may not be suitable for calculating ISBM indices for stocks that have a high proportion of fishery impacts in northern fisheries because of the absence of stock representation from northern areas. In addition, this metric introduces a new model into PSC processes and would require some effort to familiarize CTC members with capabilities and limitations. This alternative must assume base period to run-year relationship in FRAM can satisfactorily portray the intent of the ISBM provisions.

Method 5b: Harvestable surplus-based ISBM index (pre-season and post-season)

Pre- and post-season estimates of ISBM indices can be based on harvestable surplus (i.e., the proportion of the non-AABM harvest attributed to ISBM fisheries) from the PFMC and Columbia River TAC pre-season planning process (Figure 2.2). A simplified diagram of the PFMC pre-season planning process is shown below, namely if the proposed harvest results in meeting the escapement goal, then no further action is required of the U.S., state, and tribal fishery management agencies. If escapement is projected to be below the goal but the general obligation is projected to be met, then no further action is required regarding the general obligation. If the general obligation is not expected to be met, then the state and tribal fishery management agencies adjust their proposed harvest level and begin the process again.

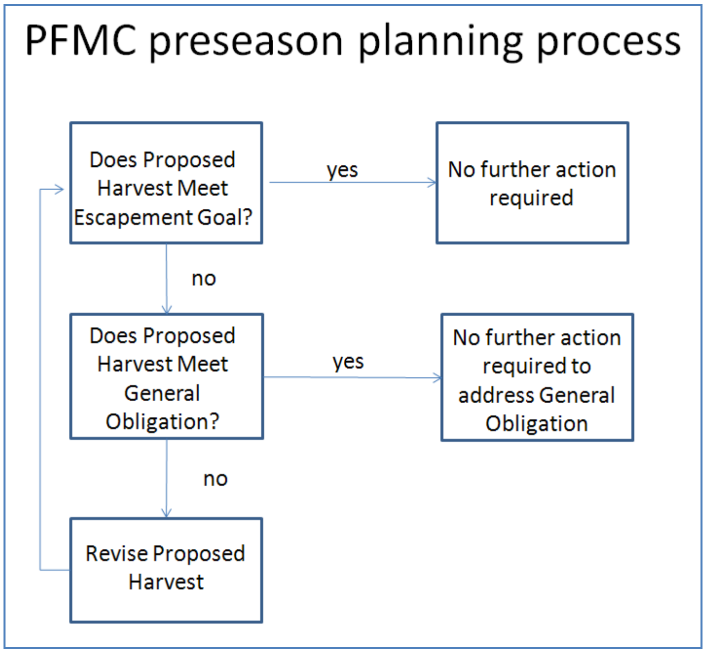


Figure 2.2 Simplified schematic of PFMC pre-season planning process to account for escapement goals and general obligation.

The pre-season version of the harvestable surplus method follows. Harvestable surplus is the projected number of fish available for harvest, after escapement goal has been met, based on the forecast.

$$\textit{Projected harvestable surplus} = \textit{terminal run forecast} - \textit{escapement goal} \qquad (2.28)$$

Convert harvestable surplus to percentage of total run so it is dimensionless and comparable with catch distribution obtained from the Exploitation Rate Analysis of CWT recoveries to get around scaling issues. If harvestable surplus is zero or negative, then the harvestable surplus distribution would be a small number, e.g. 0.001, but not zero to avoid a division by zero in Equation 2.31 and 2.32.

$$\textit{Harvestable surplus distribution} = \frac{\textit{Projected harvestable surplus}}{\textit{Terminal run forecast}} \qquad (2.29)$$

Calculate expected stock and fishery catch distribution from harvest projections. This includes the AABM and the ISBM fisheries (from the PFMC FRAM total mortality report), the terminal fisheries and escapement (from TAC pre-season harvest model). Divide catch projection by forecast run to get projected ISBM catch distribution

$$\textit{ISBM catch distribution} = \frac{\textit{Catch projection}}{\textit{Terminal run forecast}} \qquad (2.30)$$

Dividing the ISBM catch distribution by harvestable surplus distribution produces a metric of the proportion of harvestable surplus removed by the ISBM fisheries. The results should not exceed 1.0 if there is a harvestable surplus. If there is no harvestable surplus, the metric greatly exceeds 1.0. In which case, the metric is log-transformed.

$$Proportion\ of\ harvestable\ surplus\ removed = \frac{ISBM\ catch\ distribution}{Harvestable\ surplus\ distribution} \tag{2.31}$$

$$Proportion\ of\ harvestable\ surplus\ removed = ln\left(\frac{ISBM\ catch\ distribution}{Harvestable\ surplus\ distribution}\right) \tag{2.32}$$

if ratio ≥ 1.0. Dividing the proportion of harvestable surplus metric by a base period average ISBM catch distribution /harvestable surplus distribution will produce a pre-season ISBM metric:

$$ISBM\ metric = \frac{Proportion\ of\ harvestable\ surplus\ removed}{Base\ period\ average\ proportion\ of\ harvestable\ surplus} \tag{2.33}$$

The post-season methods would be similar except reported or observed catch and terminal run sizes would be used instead of projected catch and terminal run forecasts in equations 2.28 to 2.33. These methods would use catch distribution obtained from the Exploitation Rate Analysis of CWT recoveries or estimates from FRAM post-season run (available by the spring of the following year). The main advantage of a FRAM-based ISBM index is that post-season runs are available in the year after the harvest while CWT data is not available until two years after the harvest. Although FRAM is already used in the PFMC process to evaluate U.S. stocks and fisheries, the PSC Chinook Model would be needed for Canadian stocks. In addition, this metric is not suitable for stocks without escapement objectives or/and agency forecasts.

2.6 EXAMPLES

Examples of applications of the aforementioned alternative methods to particular stocks or stock composites are provided in the following sections. These examples are designed for illustration purposes and should be considered as preliminary in the best of cases, and no conclusions should be drawn about the performance of the ISBM fisheries relative to obligations based on these examples. The following applications of ISBM methods do not include both Canada and U.S. examples in all instances since specific stocks and fisheries were selected based on readily available data. Although up-to-date data have been used when possible, index values could change as a result of new information or alternative groupings. Also note that comparisons between the current index and the alternative metrics were not possible in all cases due to the different nature of index units (e.g., when using composite indices).

Method 1: forecasting tag contributions based on catch predictions

In this example, we used CWT data for the Columbia Upriver Brights stock (URB) and aggregated all ISBM fisheries in Canada and the U.S. to estimate what the predicted catch estimates would be versus the observed estimates.

As stated before, methods 1a and 1b rely on the ability to estimate CWT contributions across fisheries. The schematic below (Figure 2.3) shows the proposed method to estimate the CWTs along with the actual observations in those groups of fisheries. The left half of this figure indicates predictions for survival and expected catch rates in the fisheries using a set of coefficients estimated with the GLM techniques in the R software (R Development Core Team 2011), which are then used to predict CWT contributions by age (Table 2.1 shows the coefficients of the variable used). Note all the simulated values shown assume survival and effort are known without error. In reality these projections will vary as these quantities are not known with certainty and therefore the accuracy may be less compared to the scenarios presented.

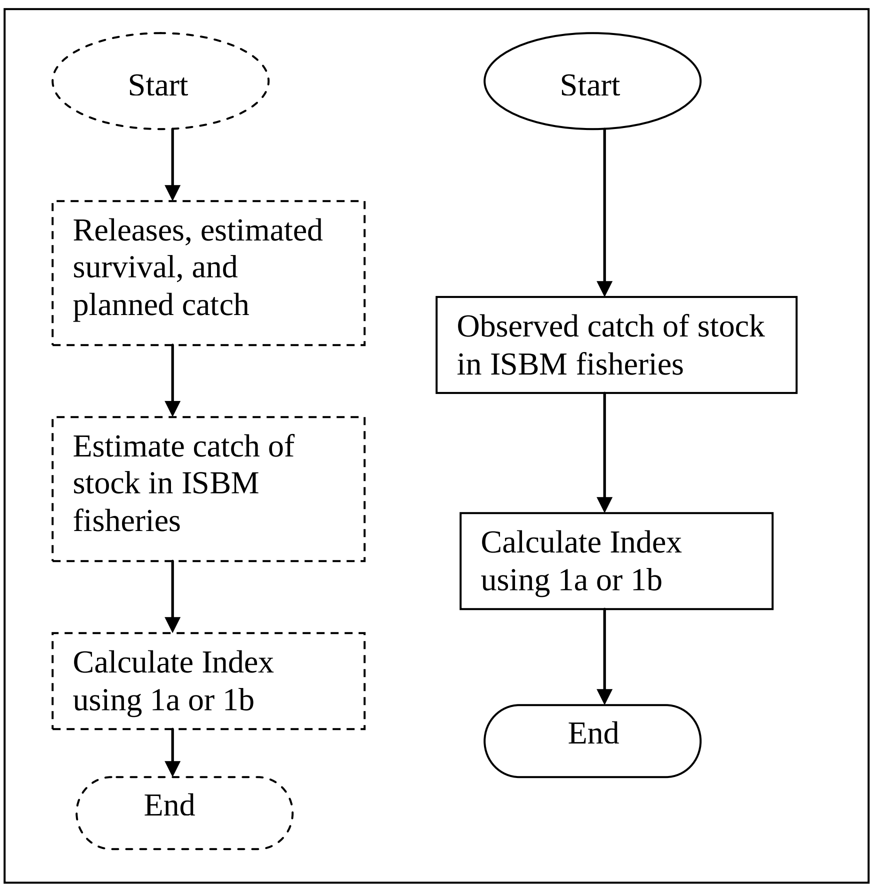


Figure 2.3 Schematic displaying the sequence of events to estimate pre-season (left) and post-season (right) indices using the GLM approach.

Table 2.1 Parameter estimates obtained from fitting the GLM to the CWT data for the URB stock using effort, survival, and tag release estimates for the following strata: escapement, Canadian ISBM fisheries, U.S. pre-terminal ISBM fisheries, U.S. terminal ISBM fisheries, and other ocean fisheries.

Escapement

Parameters	Estimate	SE	Z-value	Pr(>|z|)
β_0	2.09E+00	1.19E-01	17.621	<2.00E-16
β_1	2.20E+00	1.36E-01	16.174	<2.00E-16
β_2	2.20E+00	1.27E-01	17.239	<2.00E-16
β_3	1.38E+00	1.36E-01	10.106	<2.00E-16
β_4	1.60E-03	1.37E-03	1.172	<2.00E-16
β_5	-1.58E-02	8.63E-04	-18.355	0.24138
β_6	-7.47E-03	7.20E-04	-10.371	<2.00E-16
β_7	-3.32E-03	1.13E-03	-2.926	<2.00E-16
β_8	1.39E-06	1.74E-07	7.981	0.00344
β_9	2.34E-06	9.55E-08	24.497	1.46E-15
β_{10}	3.07E-06	8.17E-08	37.567	<2.00E-16
β_{11}	1.58E-06	1.69E-07	9.337	<2.00E-16
β_{12}	5.02E+01	1.49E+00	33.694	<2.00E-16
β_{13}	2.75E+01	9.76E-01	28.138	<2.00E-16
β_{14}	2.26E+01	5.19E-01	43.478	<2.00E-16
β_{15}	2.93E+01	9.66E-01	30.286	<2.00E-16

Canadian ISBM Fisheries

Parameter	Estimate	SE	Z-value	Pr(>|z|)
β_0	-1.60E+00	2.56E-01	-6.25	4.11E-10
β_1	1.33E+00	3.03E-01	4.379	1.19E-05
β_2	1.86E+00	2.86E-01	6.494	8.36E-11
β_3	1.31E+00	3.55E-01	3.692	0.000222
β_4	3.74E+00	2.25E-01	16.616	<2.00E-16
β_5	2.54E+00	1.55E-01	16.386	<2.00E-16
β_6	2.23E+00	1.54E-01	14.425	<2.00E-16
β_7	-2.92E-01	3.58E-01	-0.813	0.416004
β_8	2.98E-06	4.40E-07	6.766	1.33E-11
β_9	2.89E-06	3.47E-07	8.334	<2.00E-16
β_{10}	2.98E-06	3.38E-07	8.811	<2.00E-16
β_{11}	3.95E-06	6.32E-07	6.251	4.07E-10
β_{12}	1.89E+01	2.43E+00	7.796	6.40E-15
β_{13}	2.79E+01	1.85E+00	15.118	<2.00E-16
β_{14}	2.43E+01	2.18E+00	11.131	<2.00E-16
β_{15}	3.25E+01	4.85E+00	6.703	2.04E-11

Terminal ISBM Fisheries

Parameters	Estimate	SE	Z-value	Pr(>|z|)
β_0	-5.67E-01	2.89E-01	-1.96	0.05003
β_1	2.51E+00	3.07E-01	8.163	3.26E-16
β_2	3.58E+00	2.95E-01	12.151	<2.00E-16
β_3	2.39E+00	3.08E-01	7.776	7.48E-15
β_4	8.10E-03	3.12E-03	2.6	0.00932
β_5	-3.32E-03	1.07E-03	-3.093	0.00198
β_6	1.04E-02	7.27E-04	14.342	<2.00E-16
β_7	2.21E-02	1.45E-03	15.246	<2.00E-16
β_8	1.90E-06	4.45E-07	4.264	2.01E-05
β_9	3.87E-06	1.43E-07	27.013	<2.00E-16
β_{10}	3.20E-06	8.94E-08	35.763	<2.00E-16
β_{11}	2.44E-06	1.97E-07	12.424	<2.00E-16
β_{12}	6.63E+01	3.46E+00	19.16	<2.00E-16
β_{13}	5.84E+01	1.16E+00	50.267	<2.00E-16
β_{14}	3.26E+01	4.74E-01	68.892	<2.00E-16
β_{15}	1.87E+01	1.04E+00	17.988	<2.00E-16

Other Fisheries

Parameter	Estimate	SE	Z-value	Pr(>|z|)
β_0	-1.35E+00	8.08E-01	-1.674	0.0941
β_1	1.54E+00	8.18E-01	1.883	0.0597
β_2	4.23E+00	8.10E-01	5.22	1.79E-07
β_3	4.44E+00	8.11E-01	5.48	4.25E-08
β_4	1.10E+00	9.42E-01	1.162	0.2451
β_5	3.13E+00	1.38E-01	22.643	<2.00E-16
β_6	1.39E+00	7.70E-02	18.056	<2.00E-16
β_7	-1.13E-01	1.02E-01	-1.106	0.2688
β_8	-2.64E-06	1.37E-06	-1.926	0.0541
β_9	2.90E-06	1.61E-07	18.031	<2.00E-16
β_{10}	3.05E-06	8.70E-08	35.012	<2.00E-16
β_{11}	2.37E-06	1.56E-07	15.218	<2.00E-16
β_{12}	4.47E+01	7.97E+00	5.603	2.11E-08
β_{13}	3.36E+01	8.71E-01	38.553	<2.00E-16
β_{14}	2.86E+01	6.32E-01	45.176	<2.00E-16
β_{15}	3.55E+01	9.29E-01	38.172	<2.00E-16

US ISBM Pre-terminal Fisheries

Parameters	Estimate	SE	Z-value	Pr(>|z|)
β_0	-4.49E+00	1.48E+00	-3.031	0.00244
β_1	4.13E+00	1.51E+00	2.746	0.00604
β_2	4.70E+00	1.49E+00	3.146	0.00165
β_3	3.76E+00	1.52E+00	2.479	0.01317
β_4	1.76E+00	1.12E+00	1.569	0.11659
β_5	1.45E+00	2.48E-01	5.846	5.03E-09
β_6	7.25E-01	2.93E-01	2.474	0.01337
β_7	-3.99E-02	5.90E-01	-0.068	0.94608
β_8	1.59E-06	1.81E-06	0.883	0.3774
β_9	3.69E-06	3.49E-07	10.586	<2.00E-16
β_{10}	3.00E-06	3.19E-07	9.394	<2.00E-16
β_{11}	4.25E-06	5.52E-07	7.699	1.37E-14
β_{12}	8.85E+01	1.39E+01	6.385	1.71E-10
β_{13}	4.07E+01	3.11E+00	13.092	<2.00E-16
β_{14}	3.46E+01	3.30E+00	10.486	<2.00E-16
β_{15}	3.06E+01	5.97E+00	5.124	3.00E-07

For example, based on values for parameters in Table 2.1, estimates of escapement for this stock are produced using the following equations:

For age 2, 3, 4, and 5 the equations to predict escapement are respectively:

$$\mu_{t,2} = \exp\left(2.09 + 1.39(10)^{-06}(R_{t-a}) + 1.60(10)^{-03}(C_t) + 50.23S_{t-a}\right) \quad (2.34)$$

$$\mu_{t,3} = \exp\left(4.29 + 2.34(10)^{-06}(R_{t-a}) - 1.58(10)^{-02}(C_t) + 27.45S_{t-a}\right) \quad (2.35)$$

$$\mu_{t,4} = \exp\left(4.29 + 3.07(10)^{-06}(R_{t-a}) - 7.47(10)^{-03}(C_t) + 22.58S_{t-a}\right) \quad (2.36)$$

$$\mu_{t,5} = \exp\left(3.47 + 1.58(10)^{-06}(R_{t-a}) + 3.32(10)^{-03}(C_t) + 29.26S_{t-a}\right) \quad (2.37)$$

Note for age 3 the intercept term is a function of ($\beta_0 + \beta_1$), for age 4 is ($\beta_0 + \beta_2$), and for age 5 is ($\beta_0 + \beta_3$).

Based on these estimates, and using the algorithm of the current ISBM index (computed in AEQ's), Figure 2.4 displays the pre-season versus post-season performance for the index:

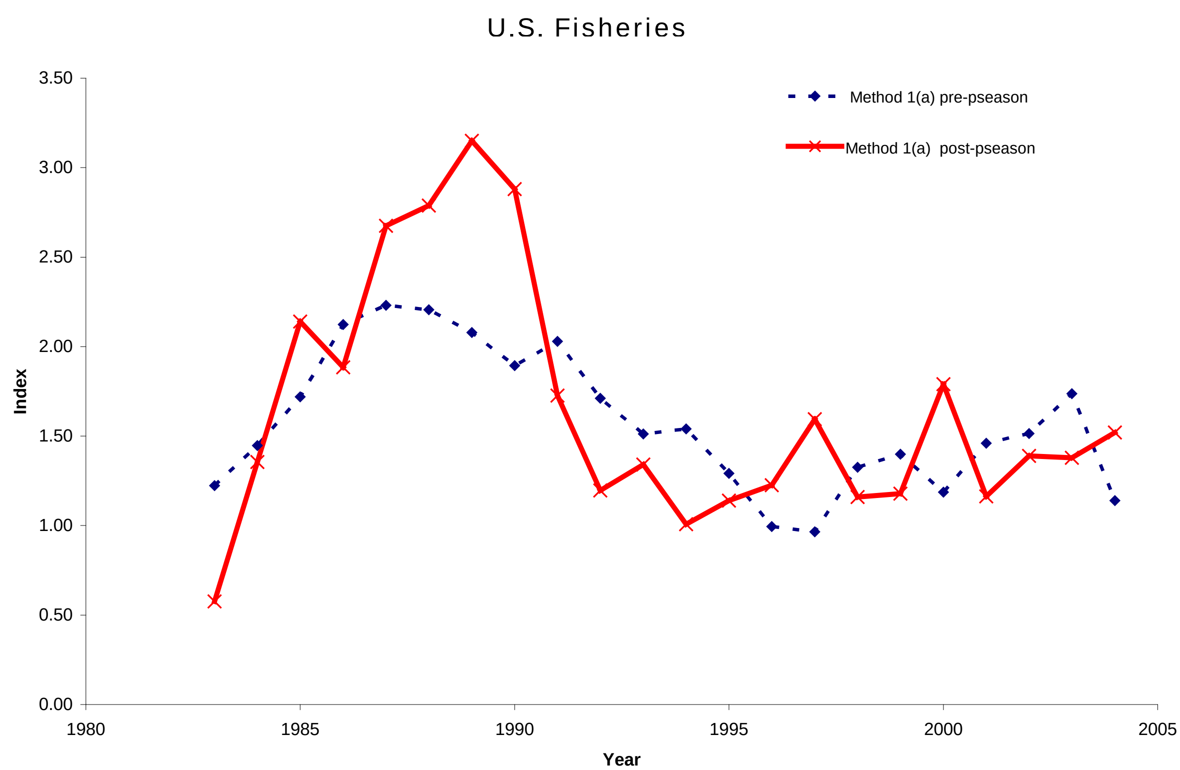


Figure 2.4 ISBM index pre- and post-season using method 1a estimating CWT contributions in all U.S. ISBM fisheries for the URB stock.

Using the same method of projecting CWTs in U.S. fisheries as shown with equations 2.34 to 2.37, an alternative index (method 1b) can be computed that is essentially a ratio of CWTs projected under current expectations versus base expectations (Figure 2.5).

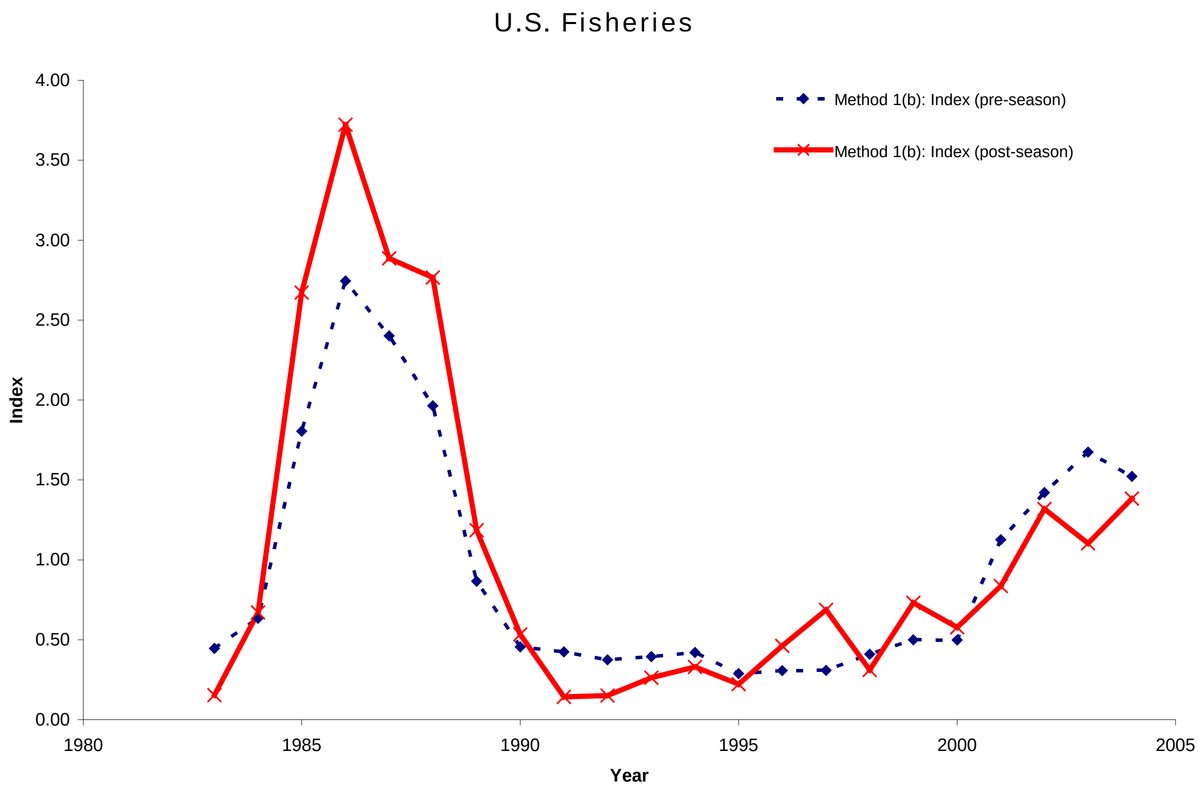


Figure 2.5 ISBM index pre- and post-season using method 1b to estimate CWT contributions in all U.S. ISBM fisheries for the URB stock.

Similar graphs are generated for the Canadian ISBM fisheries using method 1a and 1b (Figure 2.6, and Figure 2.7).

The ISBM index patterns shown for methods 1a and 1b in Figure 2.4 and Figure 2.5 for the U.S. ISBM fisheries and Figure 2.6 and Figure 2.7 for the Canadian ISBM fisheries show that these methods appear to produce different time series patterns, even though there appears to be high correspondence between the pre- and post-season indices annually. For the U.S. ISBM examples, method 1a indicates that the ISBM obligation level was not met except for the post-season value in the first year, while Method 1b indicates that the ISBM obligation level was met over several years from 1990 to 2000. At least one of the methods is not accurately representing the ISBM fisheries for evaluation purposes. The mechanism that produced these circumstances is unclear, and simulation analyses, where the true values are known, are necessary to evaluate which method accurately represents the ISBM fishery impacts.

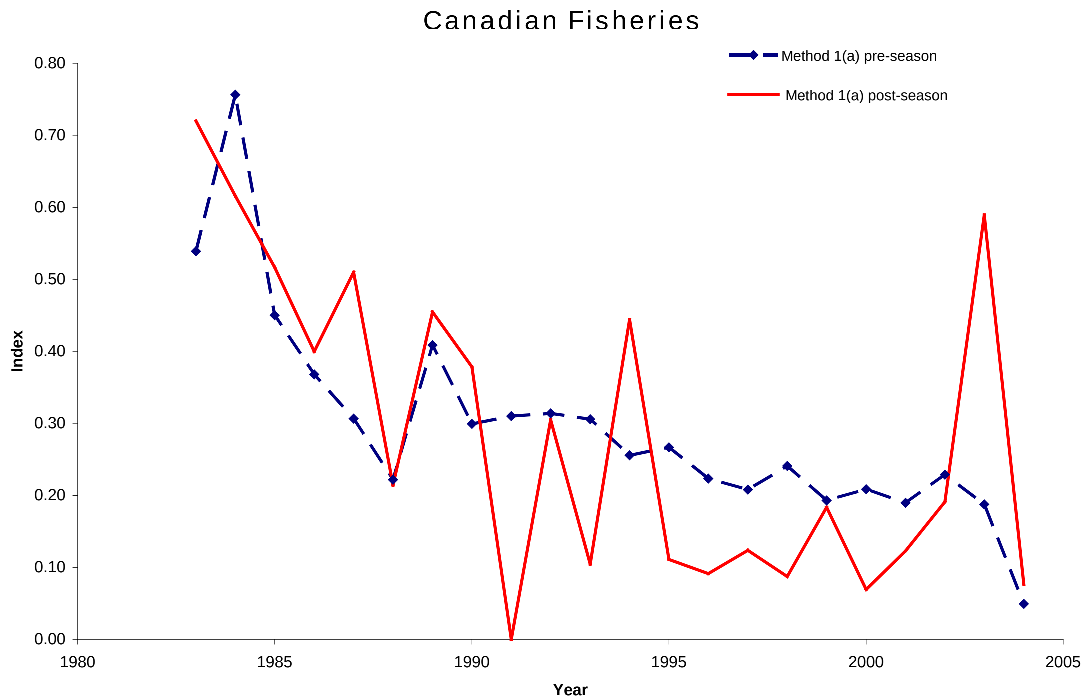


Figure 2.6 ISBM index pre- and post-season using method 1a to estimate CWT contributions in all Canadian ISBM fisheries for the URB stock.

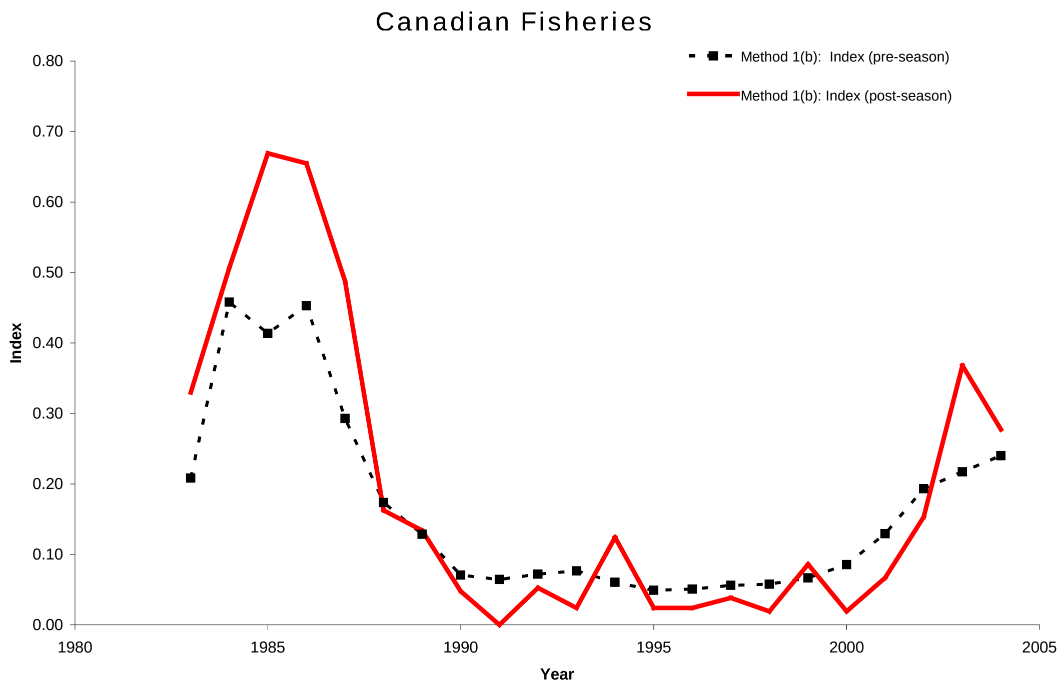


Figure 2.7 ISBM index pre- and post-season using method 1b to estimate CWT contributions in all Canadian ISBM fisheries for the URB stock.

Method 2: effort-based indices or exploitation-rate (ER) based management using a catch-at-age model

An age-structured assessment model using CWT data could be developed, which requires age-structured data collected at a fine resolution to estimate parameters such as catchability by time period, selectivity by gear and time period, and maturation rates by time period. In addition, age-2 cohort size, which depends on ocean survival and the number of CWT releases, need to be estimated as well. Hence, Figure 2.8 reproduces the diagram from the previous section for the generation of an index based on these expected parameters calculated as shown by equation 2.15 in the previous section.

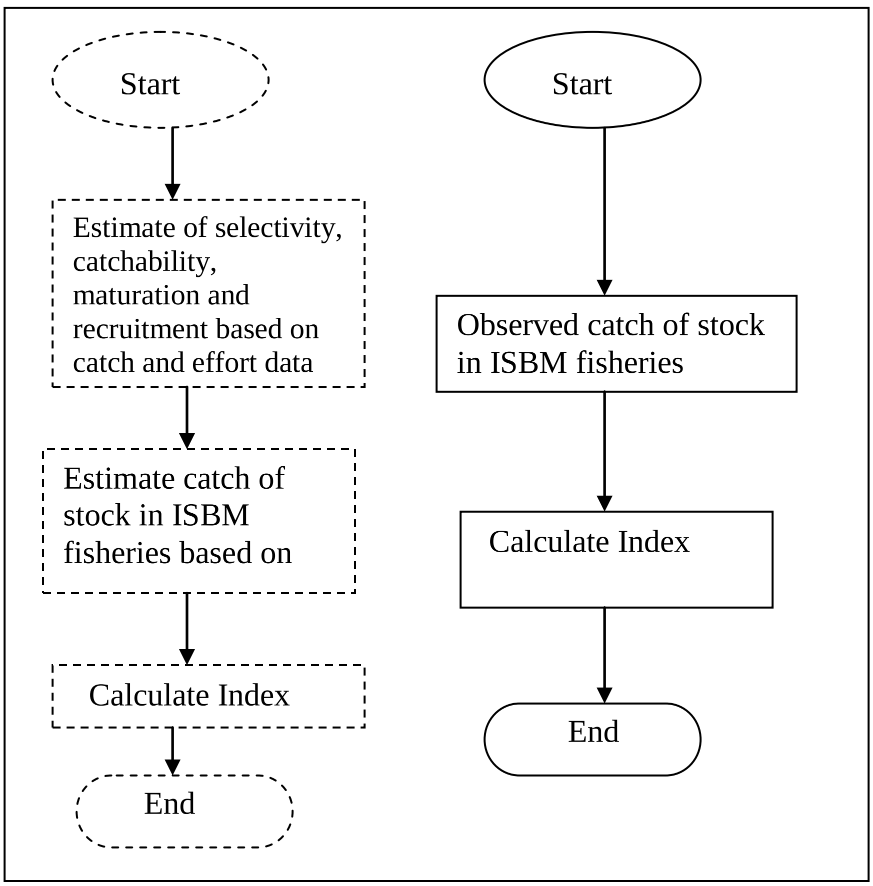


Figure 2.8 Schematic displaying the sequence of events to estimate pre-season (left) and post-season (right) indices using the age-structured modeling approach.

Based on estimated catchability and vulnerability (Table 2.2 and Table 2.3 below) from the data for the URB stock, catch by age can be projected, and an alternative index can be computed based on the two approaches.

Table 2.2 Vulnerability (selectivity) parameters for the Upriver Bright stock by fishery groups and time periods.

Fishery	Time Period	Age 2	Age 3	Age 4	Age 5
U.S. Pre-terminal ISBM	1977-1984	0.00	0.50	1.00	1.00
U.S. Pre-terminal ISBM	1985-1994	0.03	0.13	0.20	1.00
U.S. Pre-terminal ISBM	1996-2002	0.01	0.57	1.00	1.00
U.S. terminal ISBM	1977-1984	0.24	0.48	1.00	1.00
U.S. terminal ISBM	1985-1994	0.02	1.00	0.91	1.00
U.S. terminal ISBM	1996-2002	0.50	0.74	0.99	1.00
Canadian ISBM	1977-1984	0.05	0.36	1.00	1.00
Canadian ISBM	1985-1994	0.04	0.09	0.24	1.00
Canadian ISBM	1996-2002	0.00	0.07	0.21	1.00
Other fisheries	1977-1984	0.00	0.14	0.66	1.00
Other fisheries	1985-1994	0.00	0.11	0.47	1.00
Other fisheries	1996-2002	0.00	0.03	0.50	1.00

Table 2.3 Catchability (*q*) parameters for the Upriver Bright stock by fishery groups (pre-terminal U.S., terminal U.S. ISBM, Canadian ISBM, and other ocean) for three time periods.

Fishery	1977-1984	1985-1994	1996-2002
q_U.S. Pre-Terminal ISBM	0.020	0.084	0.036
q_U.S. Terminal ISBM	0.019	0.013	0.010
q_Canadian ISBM	0.060	0.142	0.259
q_Other Ocean	0.670	0.606	0.625

A comparison of the generated index values for U.S. and Canadian fisheries is shown in Figure 2.9 and Figure 2.10 below. Note all the simulated values shown assume a known effort without error. In reality these projections will vary as these quantities are not known with certainty and therefore the accuracy may deteriorate compared to the scenarios presented. Also, effort is not estimated year-round in all Canadian ISBM fisheries, which makes this method currently impractical.

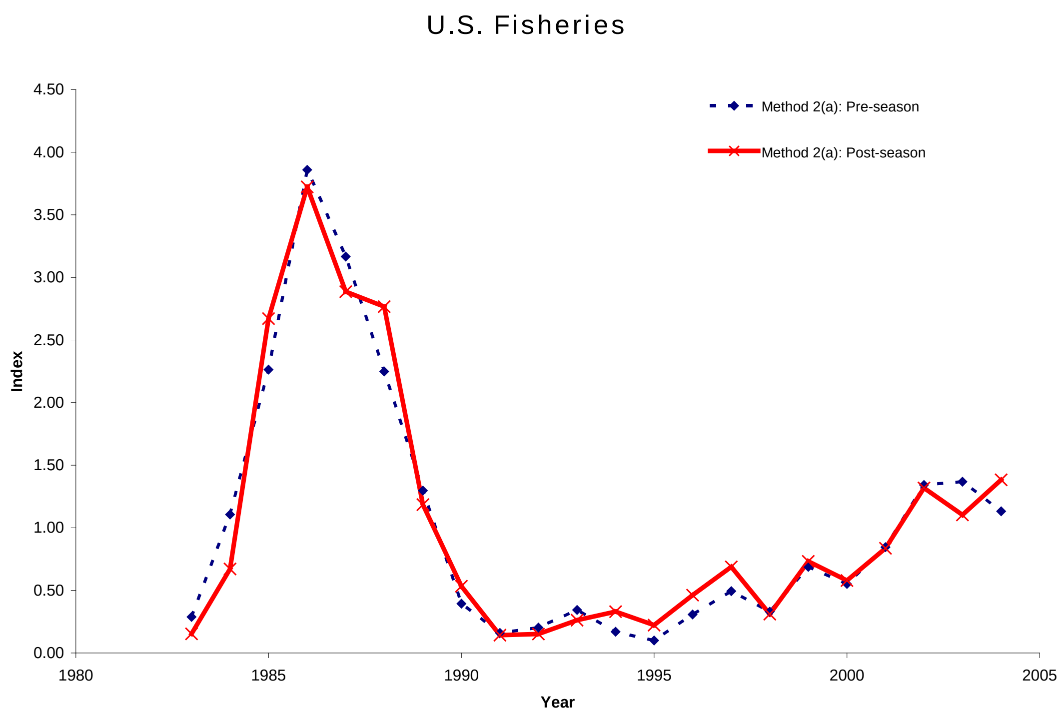


Figure 2.9 CWT-based projections on the URB stock using the age-structured model (Method 2) for U.S. ISBM fisheries.

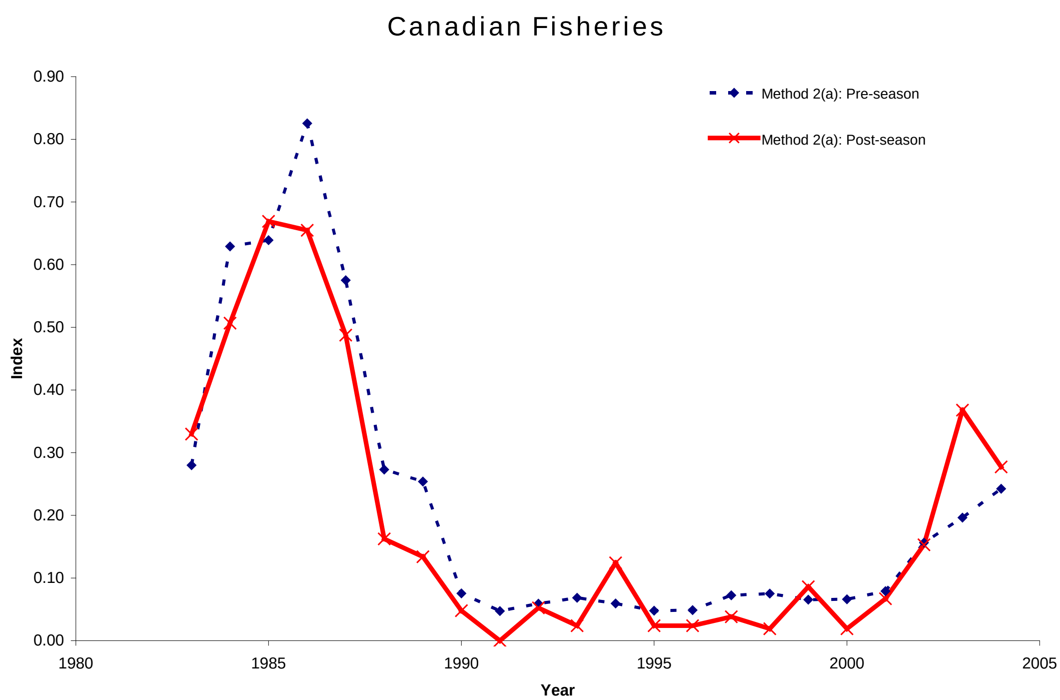


Figure 2.10 CWT based projections on the URB stock using the age-structured model (Method 2) for Canadian ISBM fisheries.

Alternatively, an effort only based index is shown in Figure 2.11, but since little knowledge is available concerning projected versus expected effort, only the post-season index is shown for illustrative purposes. This is based on the statistical catch-at-age (SCAA) method summarized in equation 2.16 in the previous section.

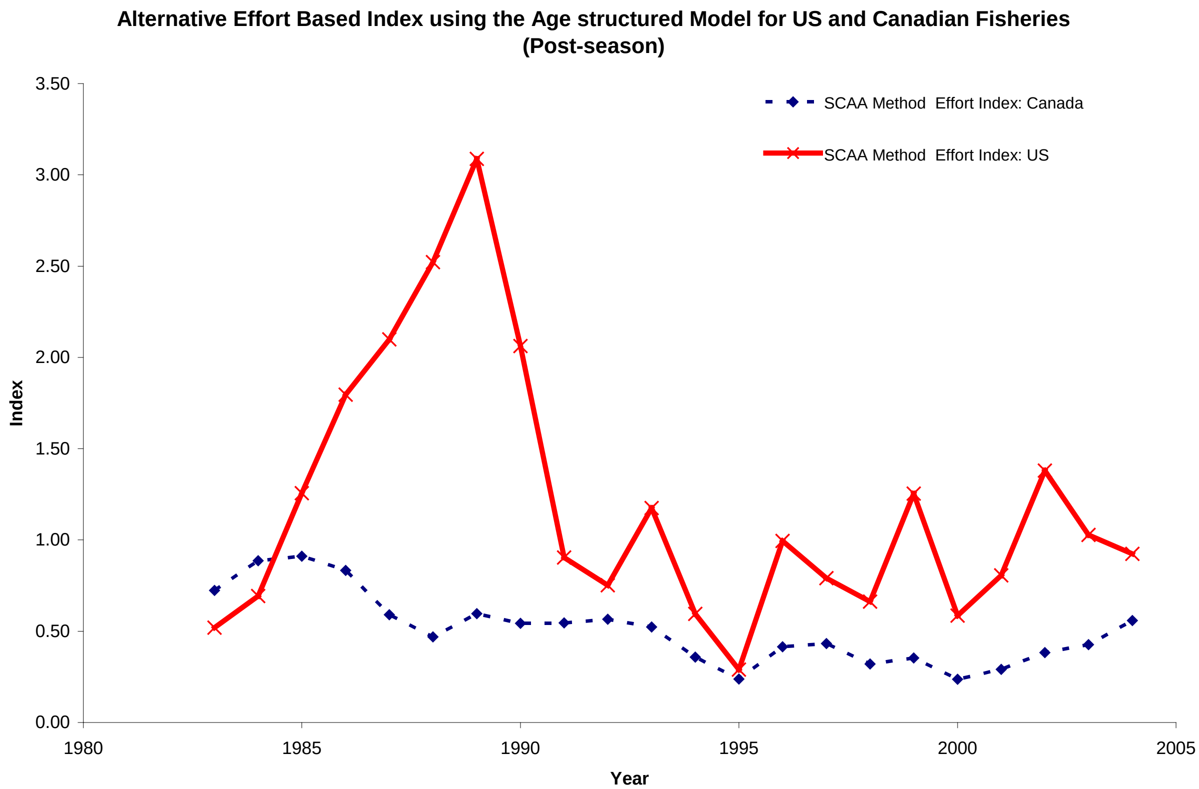


Figure 2.11 Projections of an SCAA index using only catchability and effort for Canadian and U.S. ISBM fisheries on the URB stock.

Method 3: mortality distribution index

Application of the mortality distribution index to the URB stock, a stock with complete base period data and current CWT coverage, indicates ISBM index values exceeded the general obligation and base period levels during 1984-2007; except in 1995 (Figure 2.12). The time series for the mortality distribution index depicts similar patterns to the current post-season ISBM index (r = 0.89), although the mortality distribution index produces values that are generally lower than the current index.

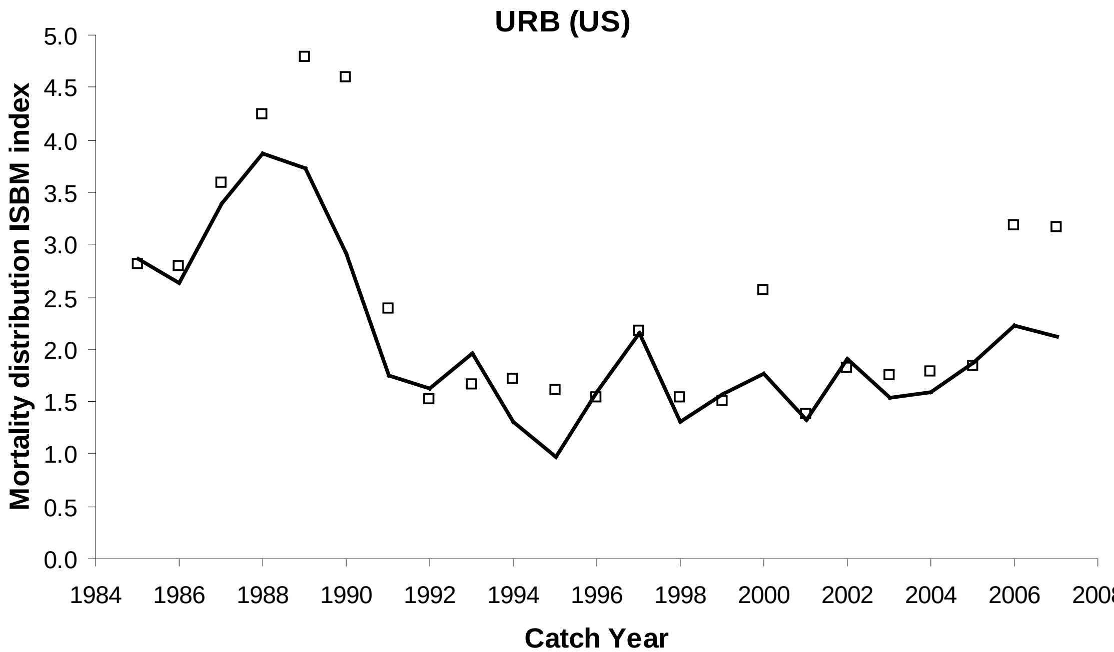


Figure 2.12 Mortality distribution-based ISBM index (solid line) for U.S. fisheries for the URB stock from 1985 to 2007. Squares identify the current post-season ISBM indices.

Other stocks listed in Attachments IV and V of Chapter 3 of the 2008 Agreement and having ISBM mortality distribution time series including the base period also exhibited mortality distribution ISBM indices similar to the current post-season ISBM indices. Robertson Creek (RBT) and Quinsam Fall (QUI), which also had complete base period data, exhibited strongly correlated (RBT r = 0.99; QUI r = 0.98) indices with similar magnitudes (Figure 2.13). Figure 2.14 shows that although Queets Fall Fingerling (QUE) and Lewis River Wild (LRW) had incomplete base period data, these stocks also showed strongly correlated indices with similar magnitudes (QUE r = 0.99; LRW r = 0.95). Lastly, Columbia Summers (SUM), which also had incomplete base period data, exhibited moderately correlated (r = 0.56) indices but dissimilar magnitudes, with the current post-season ISBM index showing generally greater values than the mortality distribution -based index (Figure 2.15). Note that currently there is incomplete separation of AABM and ISBM impacts for some stocks due to the limited number of fisheries in the mortality distribution table. Also, terminal fishery CWT recoveries from all fisheries, regardless of jurisdiction, are mapped to the terminal fishery category, which does not enable an accurate representation of ISBM fishery impacts. The CTC Analytical Work Group is currently refining the fisheries in the cohort analysis procedure to completely separate AABM and ISBM fishery impacts and to accurately report terminal fishery CWT recoveries in the appropriate ISBM fisheries.

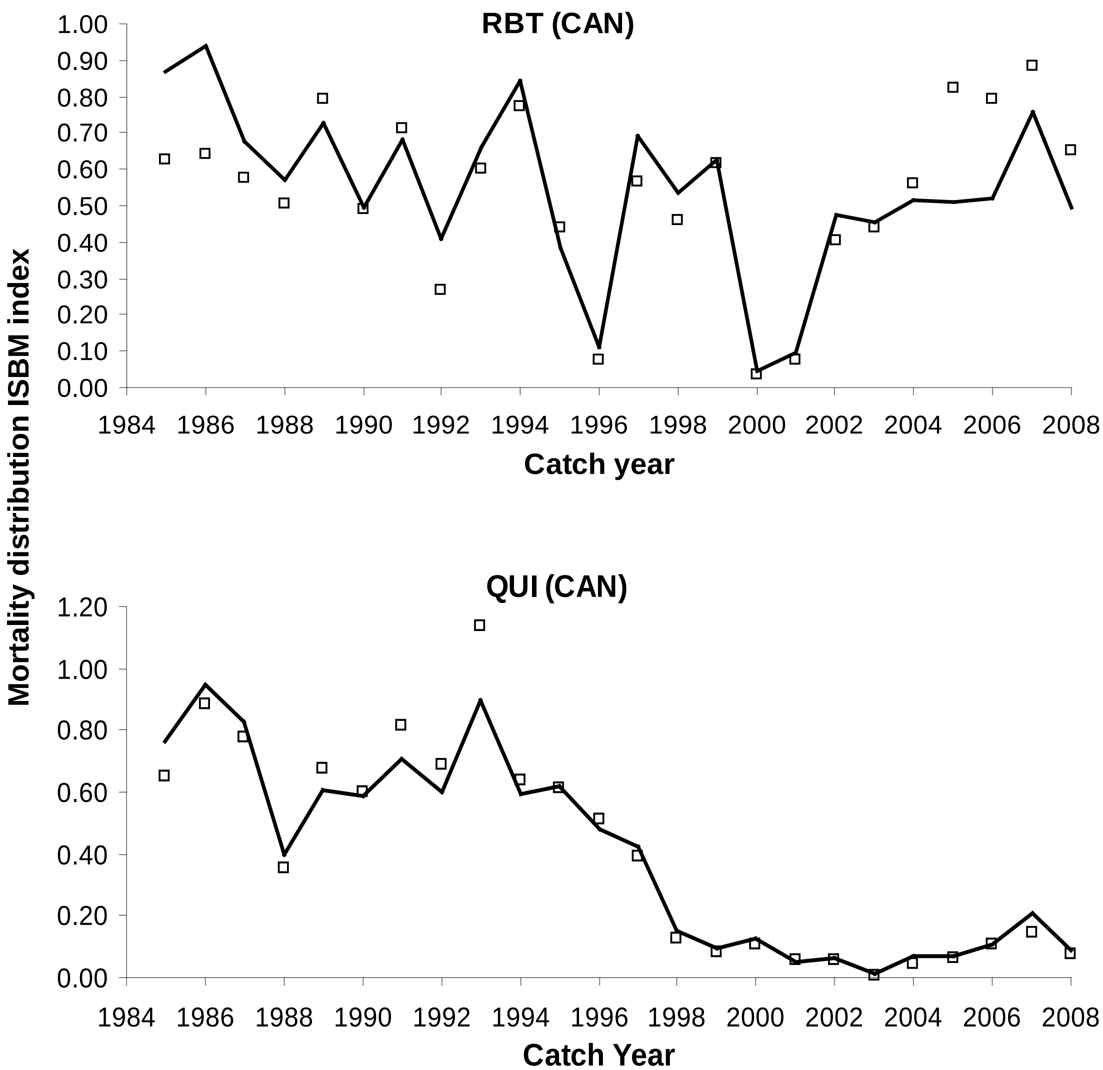


Figure 2.13 Mortality distribution-based ISBM index (solid line) for Canadian fisheries impacting on RBT and QUI stocks for years 1985-2008. Squares identify the current post-season ISBM indices. Note that both indices for RBT exclude terminal net fisheries to better represent impacts on wild fish.

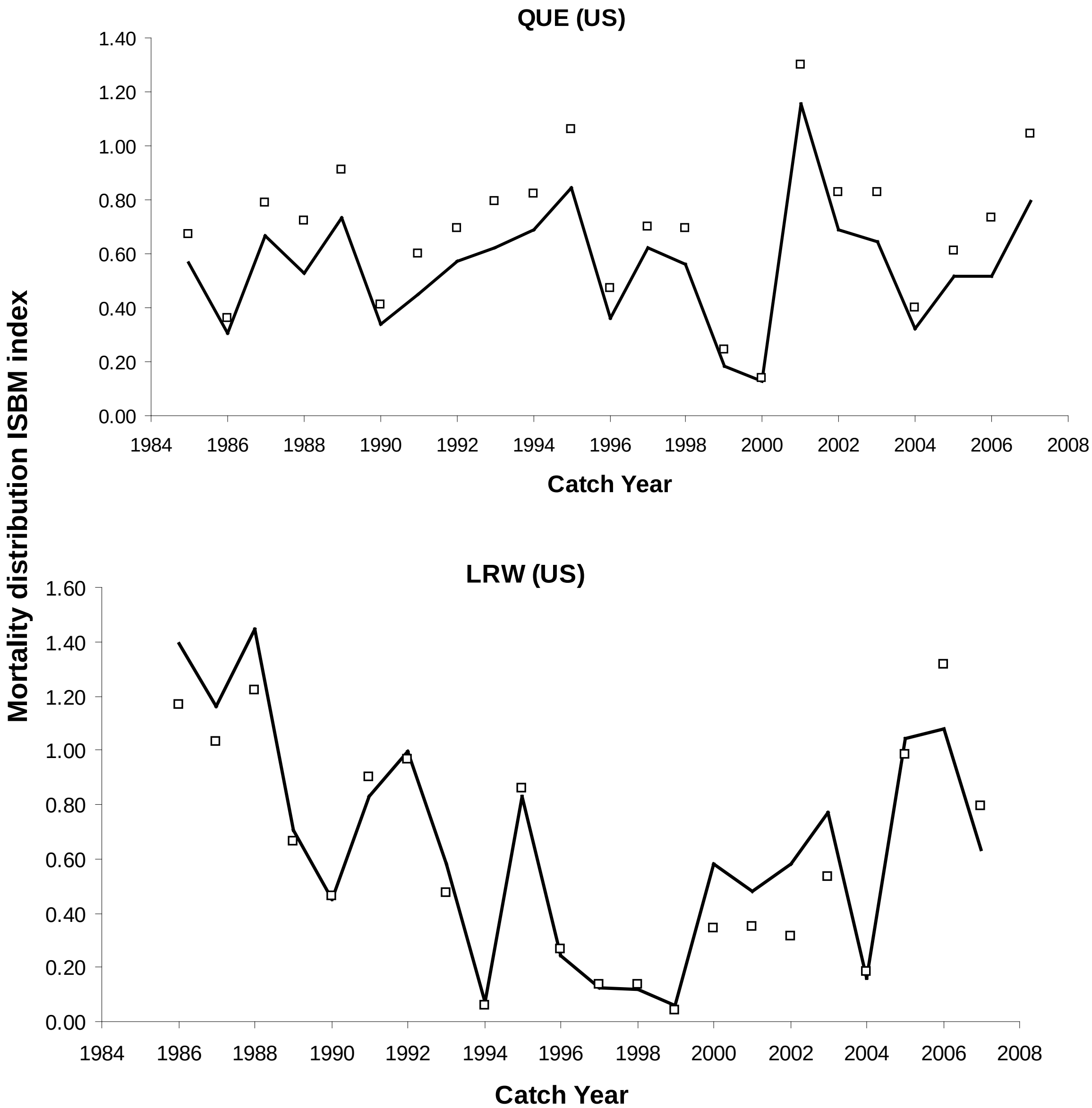


Figure 2.14 Mortality distribution-based ISBM index (solid line) for U.S. fisheries impacts on QUE and LRW stocks for years 1985-2007. Squares identify the current post-season ISBM indices.

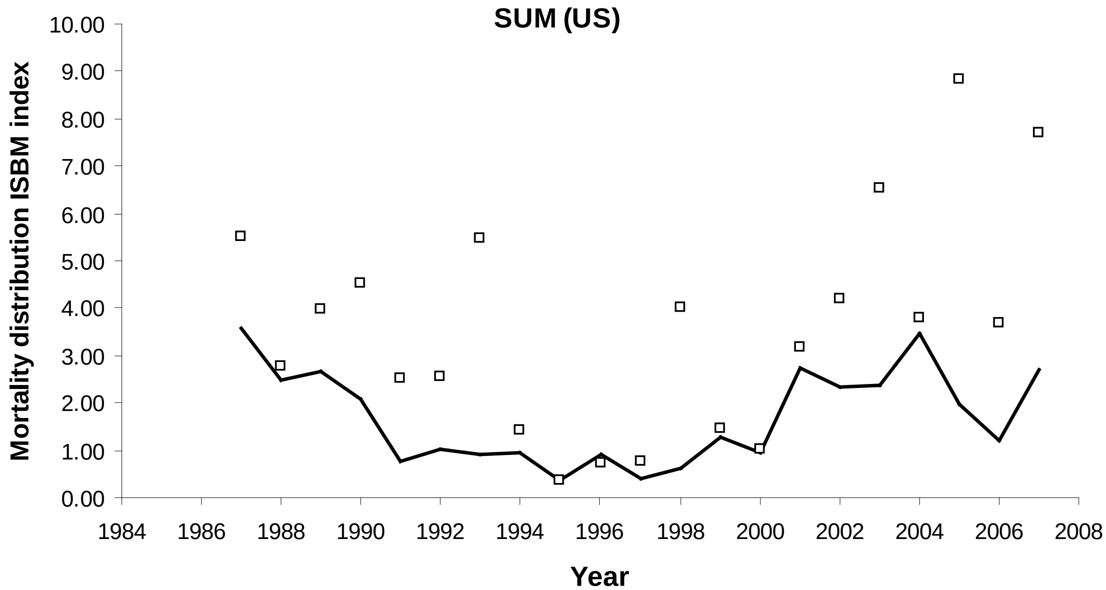


Figure 2.15 Mortality distribution-based ISBM index (solid line) for U.S. ISBM fisheries impacts on the SUM stock for 1987-2007. Squares identify the current ISBM indices.

Method 3 applied to stocks without base period data

Exploratory analyses showed that for stocks lacking base period data there is a statistical basis for inferring this information from the relationships between average ISBM mortality distributions for the base period (1979-1982) and for more recent four-year periods (e.g., 1994-1997, 1998-2001, and 2002-2005). Note that 1994 is the earliest year for which the vast majority of CWT stocks have mortality distribution and escapement data. Many of the CWT stocks with complete or partial base period coverage and their corresponding average ISBM mortality distribution rates for the aforementioned time periods are listed in Table 2.4. A few other CWT stocks, such as Nanaimo (brood years 1979 and 1980), have some CWT data during the base period that could improve the representation of the stocks and ISBM fisheries.

Average base period ISBM mortality distribution rates were positively and strongly correlated with ISBM mortality distribution rates from the more recent periods. This was evident not only for the entire data set but also for various data subsets characterized by separate Canadian and U.S. datasets and a minimum number of base period years used (Table 2.5). Separating Canadian and U.S. ISBM impacts, and selecting only stocks with at least two years of base period data improved the strength of the relationship between average ISBM mortality distribution rates, particularly for Canadian stocks. The average mortality distribution rate from 1998-2001 had the strongest association to the average base period rate for U.S. fisheries. For Canadian fisheries, 1994-1997 ($r = 0.97$) produced the strongest correlation, closely followed by 1998-2001 ($r = 0.96$). However, the former time period includes 1996, when many Canadian fisheries were reduced due to conservation concerns, thus raising questions about the relevance of using this period to predict base period rates. The rates from 1998-2001 were used for both, Canadian and U.S. ISBM fisheries. Further, removing the Willamette Spring stock (WSH was identified as an outlier) improved the relationship for Canadian fisheries (Table 2.5).

Table 2.4 Average ISBM mortality distribution rates (eq. 2.18) from base period 1979-1982 and more recent four-year periods 1994-1997, 1998-2001, and 2002-2005 for CWT stocks with time series including base period data (n = 18).

	Simple HR				
CWT stock	**79-82**	**94-97**	**98-01**	**02-05**	**Base-period years**
WSH (US)	22.55%	32.73%	27.94%	30.34%	80-82
WSH (CAN)	0.99%	0.56%	0.00%	0.00%	80-82
WRY (US)	99.02%	49.54%	43.86%	ND	82
WRY (CAN)	75.00%	3.43%	1.21%	ND	82
URB (US)	19.59%	29.61%	29.22%	33.87%	79-82
URB (CAN)	10.51%	1.04%	0.21%	0.83%	79-82
SUM (US)	15.39%	10.20%	21.55%	39.01%	79-80
SUM (CAN)	29.30%	2.79%	1.01%	0.34%	79-80
SRH (US)	39.63%	42.42%	40.10%	49.33%	81-82
SRH (CAN)	7.54%	0.40%	0.00%	0.00%	81-82
SPY (US)	92.90%	88.14%	92.69%	74.65%	82
SPY (CAN)	42.86%	21.78%	20.45%	0.00%	82
SPS (US)	84.38%	30.40%	27.85%	41.54%	82
SPS (CAN)	62.28%	8.06%	3.95%	8.59%	82
SPR (US)	81.23%	53.38%	49.43%	49.16%	79-82
SPR (CAN)	20.51%	0.80%	0.38%	0.20%	79-82
QUE (US)	57.88%	36.45%	29.35%	31.47%	81-82
QUE (CAN)	10.65%	1.52%	0.00%	0.38%	81-82
LRW (US)	38.52%	12.22%	11.94%	24.58%	81-82
LRW (CAN)	6.41%	0.72%	0.00%	0.00%	81-82
LRH (US)	69.68%	15.34%	29.46%	48.42%	80-82
LRH (CAN)	28.89%	5.98%	1.25%	0.66%	80-82
GAD (US)	72.12%	33.30%	35.11%	42.89%	82
GAD (CAN)	21.97%	13.82%	4.50%	7.75%	82
ELK (US)	78.75%	47.93%	40.46%	34.40%	81-82
ELK (CAN)	15.10%	1.67%	0.10%	0.00%	81-82
CWF (US)	59.54%	8.76%	29.20%	48.62%	81-82
CWF (CAN)	11.52%	2.18%	0.00%	0.87%	81-82
RBT (US)	2.79%	0.26%	0.07%	0.04%	79-82
RBT (CAN)	61.42%	33.36%	20.20%	42.14%	79-82
QUI (US)	0.00%	0.00%	0.20%	0.00%	79-82
QUI (CAN)	63.50%	33.59%	6.71%	3.33%	79-82
PPS (US)	0.00%	0.00%	0.00%	0.00%	79-82
PPS (CAN)	69.59%	44.83%	21.64%	10.90%	79-82
BQR (US)	4.32%	2.36%	2.48%	4.23%	79-82
BQR (CAN)	72.84%	48.38%	20.35%	15.20%	79-82

ND: No data

Table 2.5 Pearson correlation coefficients for relationships between average ISBM mortality distribution rates from the base period (1979-1982) and three more recent four-year periods for various data subsets. Rates were arcsine-transformed prior to the analysis. Bold values indicate the data subset and time period selected for regression analysis (see text for details). The term n is the number of stocks in each data set.

Data set	n	Period 1994-1997	1998-2001	2002-2005
All	36	0.81	0.76	0.74
U.S. (at least 1 year)	18	0.82	0.84	0.87
Canada (at least 1 year)	18	0.79	0.78	0.72
U.S. (at least 2 years)	14	0.81	**0.88**	0.85
Canada (at least 2 years)	14	0.95	0.94	0.79
Canada (at least 2 years; no outlier)	13	0.97	**0.96**	0.79

Regression models from selected data subsets and time periods indicated 76% and 91% of the variation in the 1979-1982 ISBM average mortality distribution rate was explained by the 1998-2001 ISBM average mortality distribution rate for U.S. and Canadian ISBM fisheries, respectively (Table 2.6). Figure 2.16 depicts these regressions, from which base period mortality distribution rates could be inferred for stocks without base period data. Since data were arcsine-transformed (AST) prior to the analysis, back-transformation was required to estimate base period rates for U.S. (equation 2.38.) and Canadian fishery impacts (equation 2.39):

$$ISBMMD_{Base\ period,\ s} = (\mathrm{Sin}_{\mathrm{Radians}}(1.233 + 1.275*\mathrm{AST}(ISBMMD_{98\text{-}01,\ s})))^2 \qquad (2.38)$$

$$ISBMMD_{Base\ period,\ s} = (\mathrm{Sin}_{\mathrm{Radians}}(19.806 + 1.422*\mathrm{AST}(ISBMMD_{98\text{-}01,\ s})))^2 \qquad (2.39)$$

Table 2.6 Parameter estimates and statistics for linear regressions (*y* = a + b*x*) between arcsine-transformed 1979-1982 (*y*) and 1998-2001 (*x*) average ISBM mortality distribution rates for U.S. and Canadian fishery impacts.

Dataset	a	SE(a)	p(a)	b	SE(b)	p(b)	Adj. R^2	n
U.S. (at least 2 years)	1.233	5.692	0.002	1.275	0.197	<0.0001	0.76	14
Canada (at least 2 years; no outlier)	19.806	1.845	<0.0001	1.422	0.132	<0.0001	0.91	13

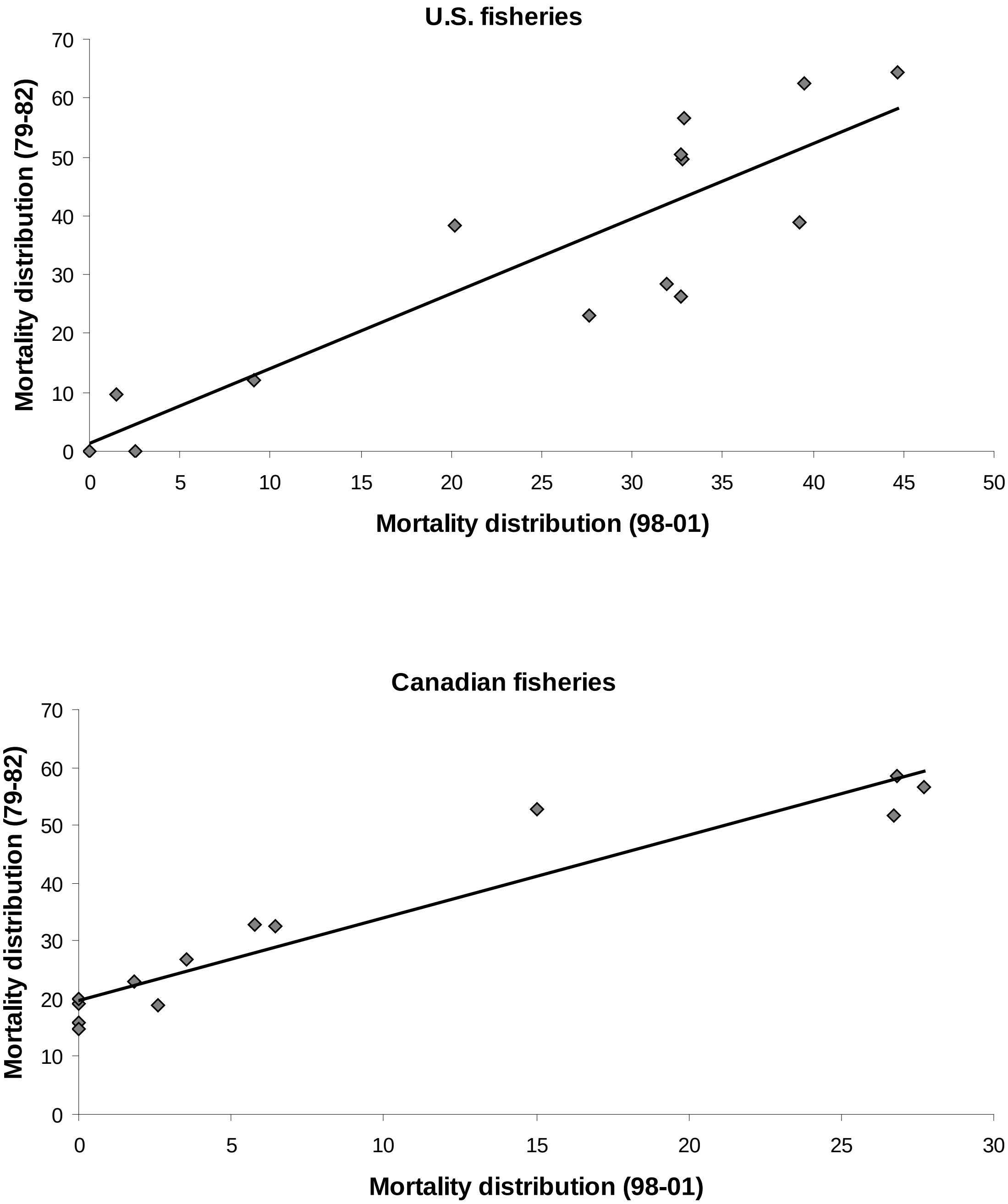


Figure 2.16 The relationship between average ISBM mortality distribution rates from 1998-2001 and the base period 1979-82 for U.S. and Canadian stocks with at least two years of base period data. Values in the plot are arcsine-transformed (AST). The solid line shows the regression line in Table 2.6.

The mortality distribution ISBM index with inferred base period average harvest rates (hereafter IBP ISBMI to distinguish from the ISBMI computed directly from mortality distribution tables) was applied to Annex stocks Cowichan (CWT stock: COW), Harrison (CWT stock: CHI), and Green River (CWT stock: SPS). Note that an ISBM index for COW is currently estimated using terminal harvest rates calculated from observed landed catch and escapement data. Using equations 2.38 and 2.39 to derive base period mortality distribution rates for these stocks, the computation of IBP ISBMI for Canadian impacts on COW and CHI, and U.S. impacts on SPS showed strong correlations with the current post-season ISBMI with IBP ISBMI values greater than the current post-season ISBMI for COW (Figure 2.17) and CHI (Figure 2.18) but generally below the general obligation for the shown time period. Conversely, the IBP ISBMI was generally lower than the current post-season ISBM for SPS (Figure 2.19).

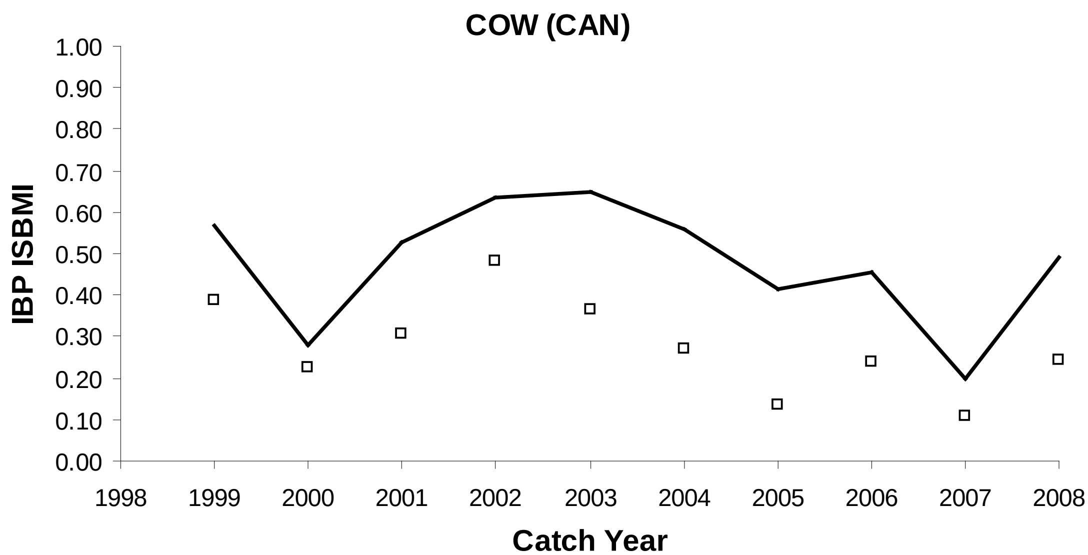


Figure 2.17 Mortality distribution-based ISBM index with base period rates inferred from the regression model (IBP ISBMI) in Table 2.6 (solid line) for Canadian fishery impacts on COW for years 1999-2008. Squares identify the current post-season ISBM indices. Note that the difference in magnitude between the two indices is not only due to the difference in methodology but also to the fact that post-season ISBM indices for this stock are based on CWT data from Cowichan but base period exploitation rates from Big Qualicum River (BQR) whereas the mortality distributions use only CWT data from Cowichan.

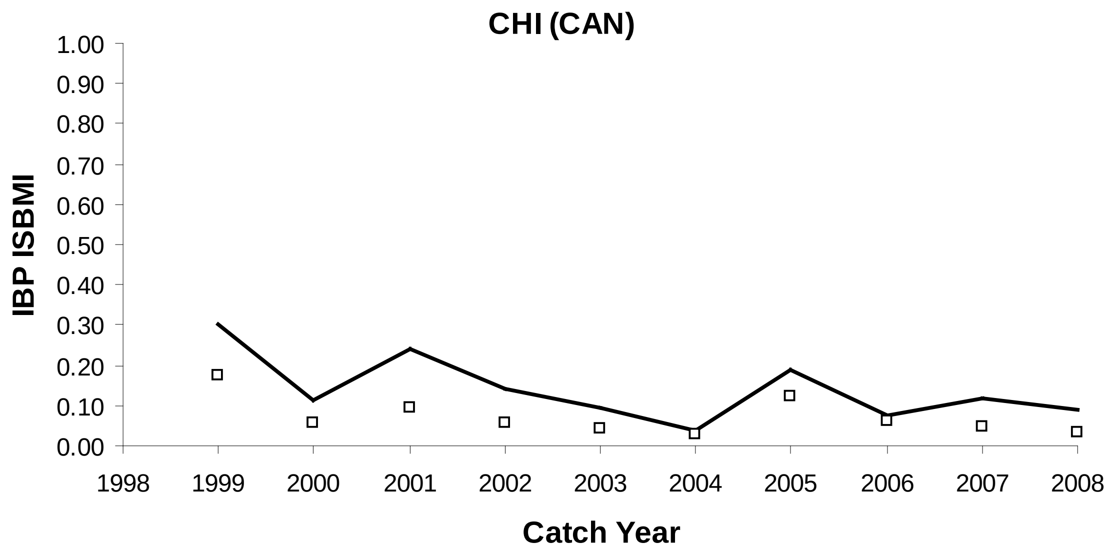


Figure 2.18 Mortality distribution-based ISBM index with base period exploitation rate inferred from the regression model (IBP ISBMI) in Table 2.6 (solid line) for Canadian fishery impacts on CHI for years 1999-2008. Squares identify the current post-season ISBM indices. Note that both indices for this stock exclude terminal sport fisheries to better represent impacts on wild fish.

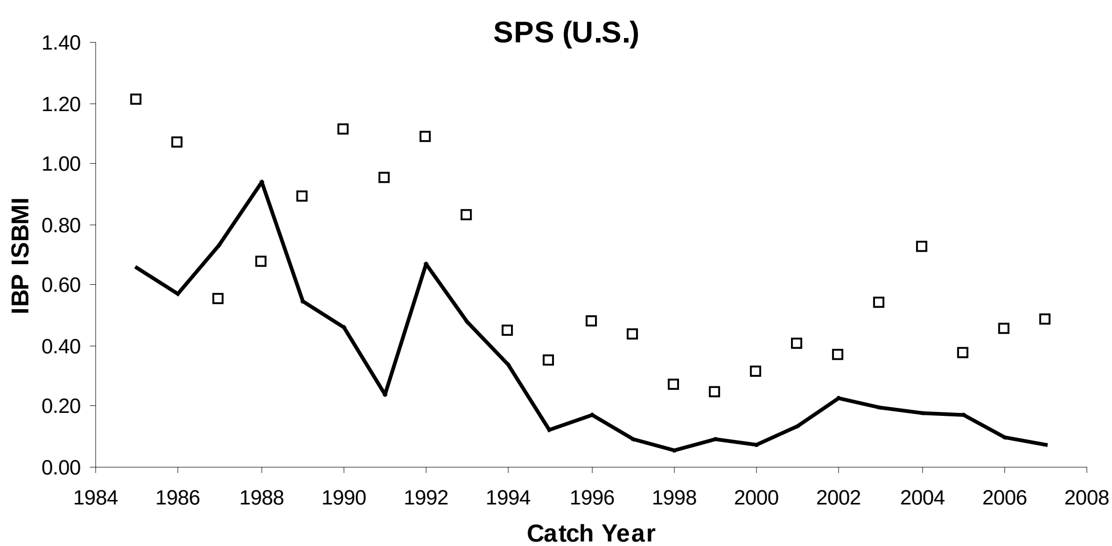


Figure 2.19 Mortality distribution-based ISBM index with base period rates inferred from the regression model (IBP ISBMI) in Table 2.6 (solid line) for U.S. fishery impacts on SPS for years 1985-2007. Squares identify the current post-season ISBM indices.

In perspective, the mortality distribution ISBM index has some of the desirable attributes identified earlier, such as measuring changes in total AEQ mortality, being capable of comparing impacts of ISBM fisheries on individual stocks relative to 1979-1982, using data provided through existing programs, and being feasible to compute within currently available resources. In addition, the strong relationship between 1979-1982 and 1998-2001 average ISBM harvest rates, as derived from mortality distribution tables, provides inferential capabilities for stocks without base period data, and with further refinement and evaluation, this could be a very useful technique to develop base period information. The ability of using the IBP ISBM index will improve after ISBM impacts are completely separated from AABM impacts in the mortality distribution tables and after correctly identifying terminal fishery impacts to jurisdiction. Allowing the evaluation of ISBM fishery impacts on more exploitation rate indicator stocks would facilitate an evaluation of ISBM Treaty provisions in a more robust fashion. In addition, some discussion has taken place within the CTC on the potential that the regression-based method used in the application of method 3 to stocks without base period data can have for out-of-base procedures involved in new base period calibrations of the PSC Chinook Model.

Method 4: alternative approaches that restructure the current obligation

Two applications of the composite index could be pursued. The first application follows a regional based CWT index that may be representative of a particular region. The Columbia River and Georgia Straits Stocks were evaluated as an example of this application. Because we are aggregating multiple codes for a region, these represent multiple rivers on Georgia Strait (Cowichan and Quinsam) and on the Columbia (Upriver Brights, Columbia River Summer Chinook, and Columbia Lower River Hatchery).

This application of the composite index would call for a reduction in the composite target if multiple stocks fail to meet their escapement goals or targets. The reduction could be implemented with catch controls or exploitation rate controls. Two examples are shown. Figure 2.20 illustrates composite indices with various weighting schemes (by stock cohort and by fishery exploitation rate) for U.S. ISBM fisheries including terminal fisheries and the URB, SUM, and LRH CWT indicator stocks in a single composite. Similarly, Figure 2.21 depicts these composite indices for Canada ISBM fisheries including terminal fisheries and the Cowichan-Quinsam composite (COW and QUI CWT indicator stocks).

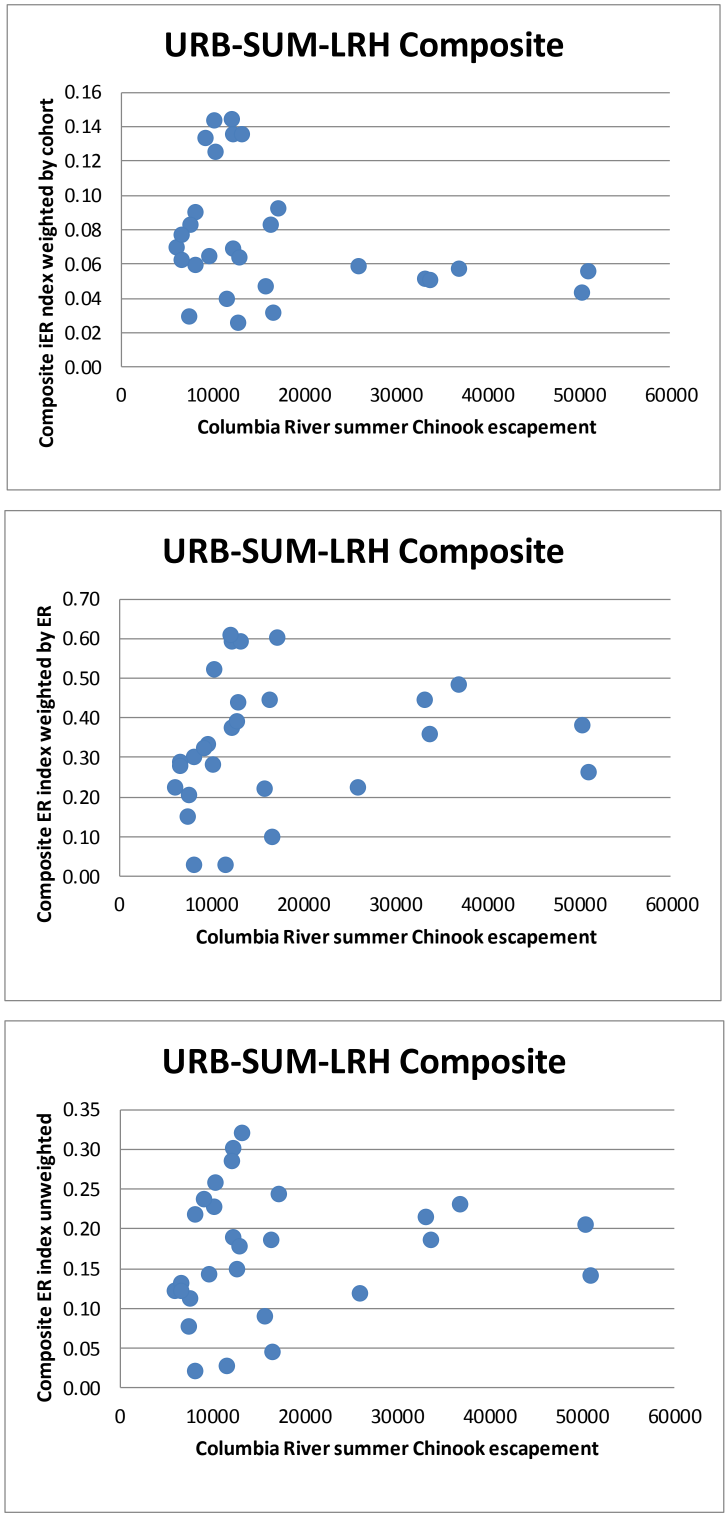
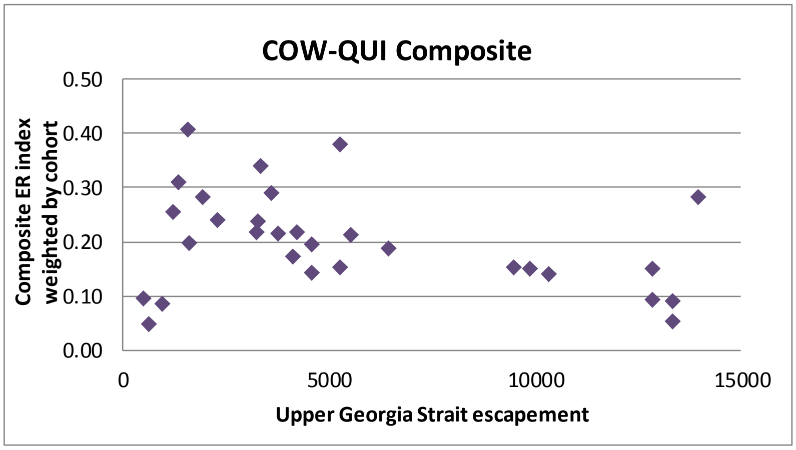
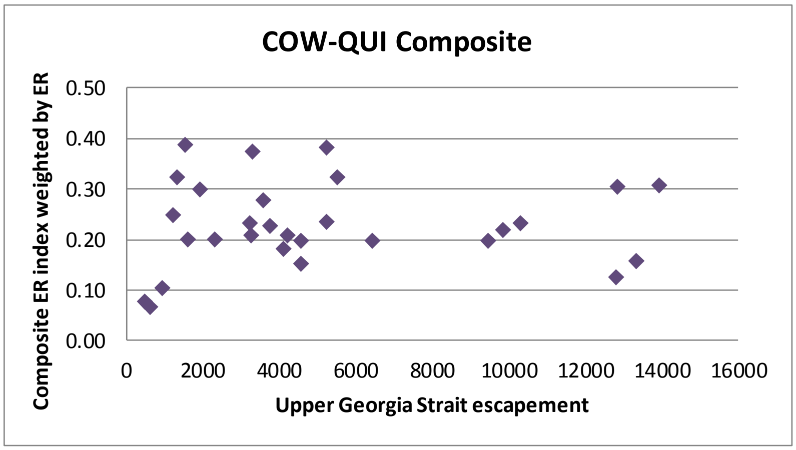


Figure 2.20 Columbia River Summer Chinook escapement and composite index (URB, SUM, & LRH) for U.S. ISBM fisheries including terminal fisheries under three weighing schemes. (Top) Weighted by stock cohort size. (Middle) Weighted by exploitation rates across fisheries. (Bottom) Unweighted composite index.





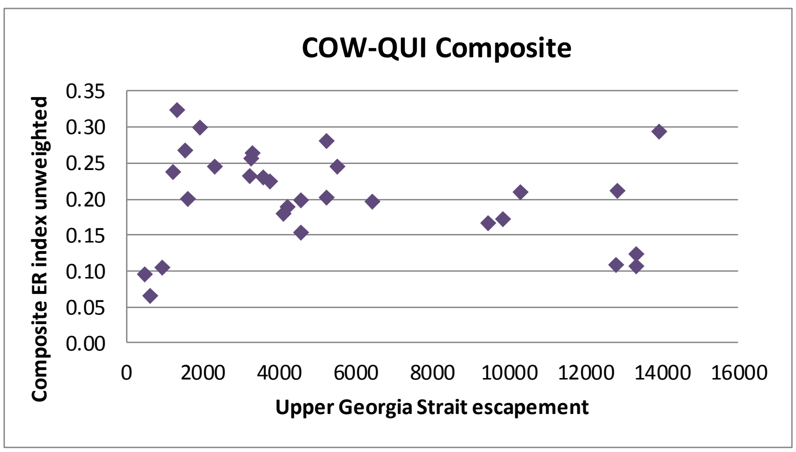


Figure 2.21 Upper Georgia Strait escapement and Georgia Strait (COW & QUI) composite index for Canadian ISBM fisheries including terminal fisheries under three weighing schemes. (Top) Weighted by stock cohort size. (Middle) Weighted by exploitation rates across fisheries. (Bottom) Unweighted composite index.

Based on results from the previous figures, the index generated does not appear to be responsive enough to escapement for the region and aggregate, though a threshold target could be used (e.g., 0.2 for Georgia Strait in Figure 2.21, which specifies a level below which fisheries allow escapement greater than 2000 fish).

An alternative application of the composite index could rely on a new framework to compute a multi-fishery, multi-stock index for pre-terminal areas by country of jurisdiction. This index would be similar to the Ratio of Means or Simple Average indices that are computed for the aggregate abundance based fisheries, but only computed for pre-terminal fisheries that affect these stocks. Because this index implies a management paradigm different to the one specified in the PST, a harvest rate approach that is agreed to by the parties that fish in terminal areas would be the basis of management. This new basis for management would be based on two separate obligations: one in the mixed-stock pre-terminal fisheries and the other in the river of origin that is mandated by the jurisdiction in which the stock originates. Example of an index by country and stock group is shown below for two stocks Upper Georgia Strait and Columbia River Summer for composite indices for all pre-terminal fisheries. For the terminal area management, regional forums could set the fishing levels so as not to overfish beyond the desired optimum spawning stock level (Figure 2.22 and Figure 2.23).

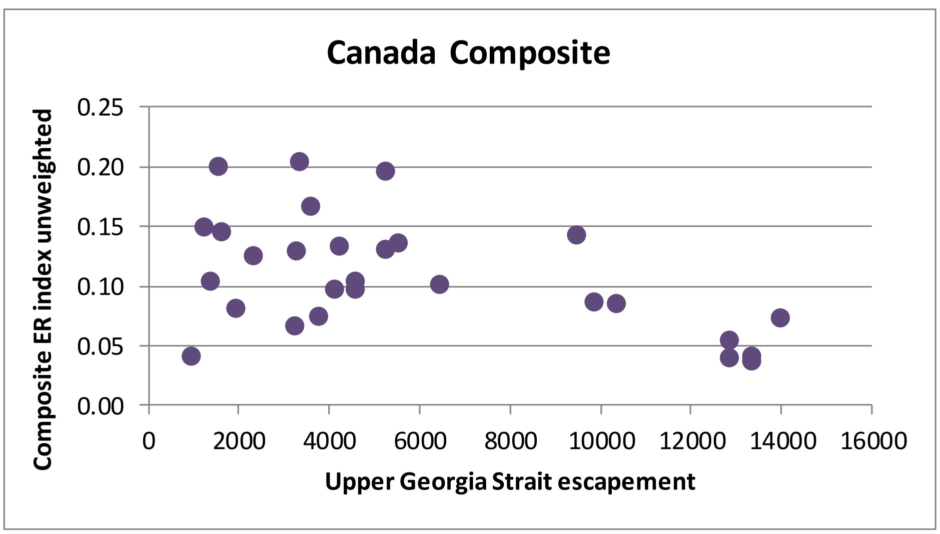


Figure 2.22 Upper Georgia Straits escapement and Canada (COW, QUI, CHI, & RBT) unweighted composite index for Canada pre-terminal ISBM fisheries excluding terminal fisheries.

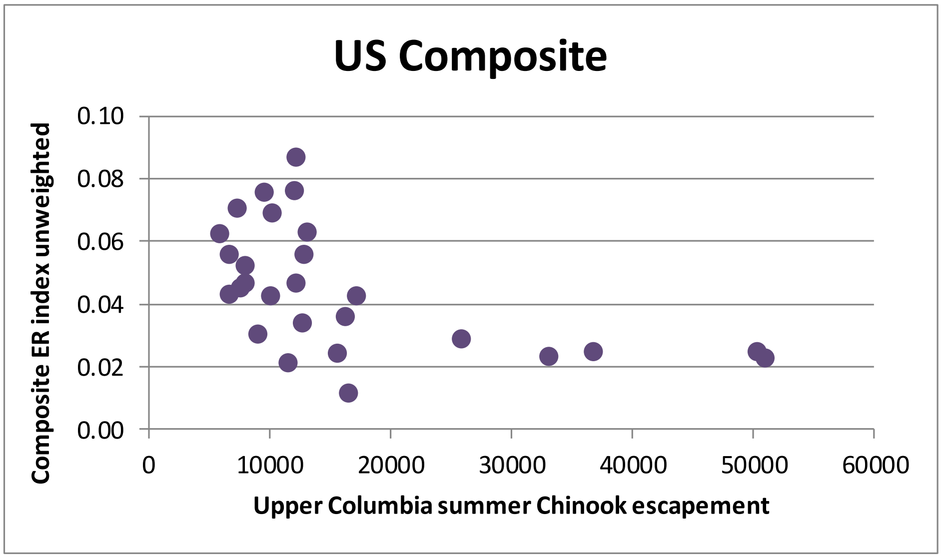


Figure 2.23 Columbia River Summer Chinook escapement and U.S. unweighted composite index (Deschutes, Grays Harbor, SPS, Hoh, Hoko, LRW, Nehalem, NKS, NKF, QUE, Quillayute, Siletz, Siuslaw, SKS, SSF, STL, SUM, & URB) for U.S. pre-terminal ISBM fisheries excluding terminal fisheries.

Method 5a: FRAM-based ISBM index

The ISBM indices for Puget Sound stocks identified in Attachment IV and V from post-season FRAM (backwards) are shown in Figure 2.24-Figure 2.29. Due primarily to the listing of Puget Sound Chinook in 1999 under the Endangered Species Act, U.S. ISBM indices have been well under 0.6 for every stock with the occasional exception of Skagit and Green River summer-fall Chinook where there can be significant terminal fisheries depending on the status of the escapement. For most Puget Sound stocks the U.S. ISBM indices have been on a slight upward trend for the recent 4 to 7years. Canadian ISBM indices generally show a similar pattern to the U.S. indices. None of the Puget Sound stocks have CTC approved escapement goals.

Table 2.7 contains ISBM estimates in U.S. and Canadian fisheries for the Puget Sound Chinook stock examples between Method 5a and those from the CWT exploitation rate analysis (ERA) conducted annually by the CTC for calibration of the Chinook Model. In no case was there a complete time series of CWT based ISBM indices for U.S. and Canadian fisheries. Lack of representative CWT groups and/or insufficient tag recoveries for all age classes were the primary reasons. For Lake Washington and Green River, significantly different terminal fishery harvest rates in these two areas do not allow for use of the aggregate collection of “south Puget Sound” CWT groups to estimate the U.S. ISBM indices. These aggregate CWT recovery groups for south Puget Sound Chinook are appropriate for making ISBM estimates for the exclusively pre-terminal fisheries in Canada where the different CWT groups from the various hatcheries are expected to experience the same level of fishing effort.

Application of a FRAM-based ISBM index is best suited to Washington and Oregon stocks that have a significant portion of their impacts in U.S. fisheries and for those stocks that do not have consistent time series of CWT releases. The FRAM based ISBM index can be calculated both on a pre-season and post-season basis without the requirement for waiting until all age classes have returned from a CWT release group. In addition, FRAM and its associated terminal fishery modules for some stocks (e.g., Puget Sound) provides the capability to stratify near-terminal and terminal fisheries where stock aggregates (either in the Chinook Model or CWT indicator groups) cannot satisfactorily account for differential harvest rates in these ISBM fisheries.

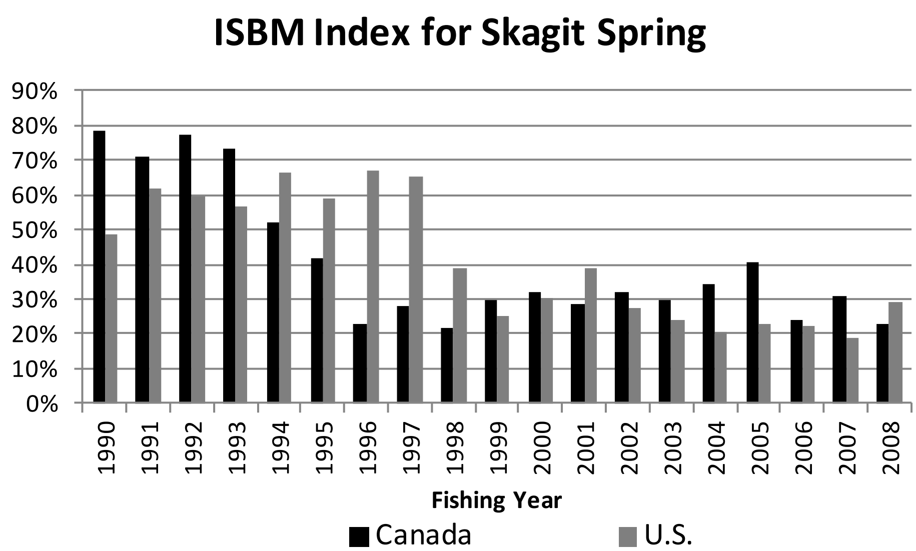


Figure 2.24 FRAM-based ISBM indices for Skagit spring Chinook in Canadian and southern U.S. fisheries.

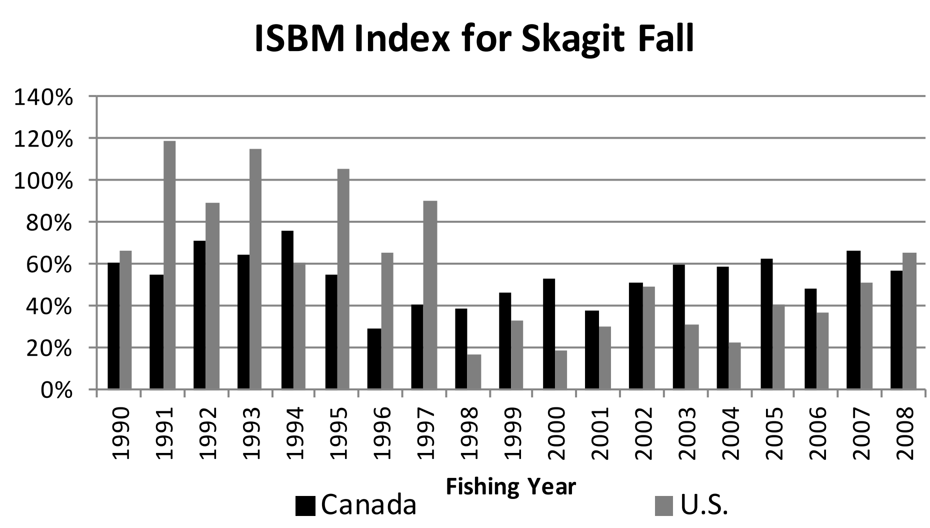


Figure 2.25 FRAM-based ISBM indices for Skagit summer/fall Chinook in Canadian and southern U.S. fisheries.

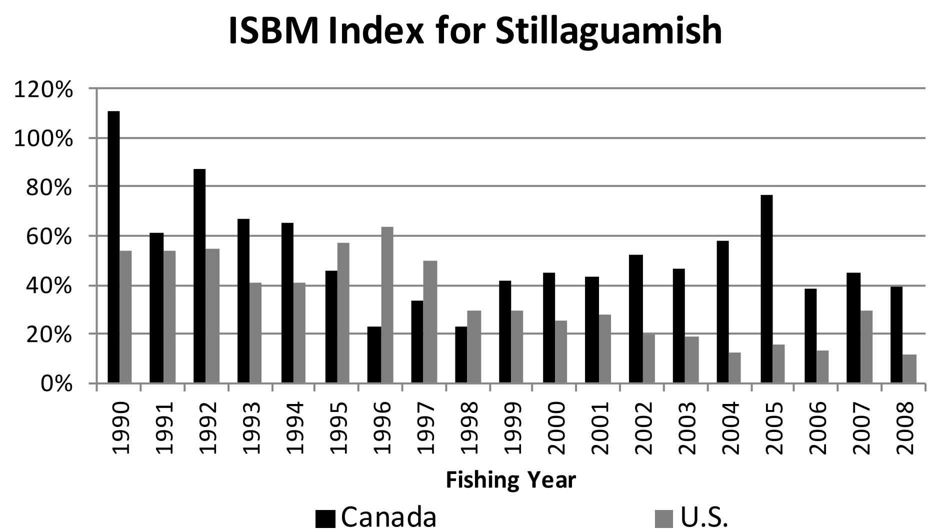


Figure 2.26 FRAM-based ISBM indices for Stillaguamish summer/fall Chinook in Canadian and southern U.S. fisheries.

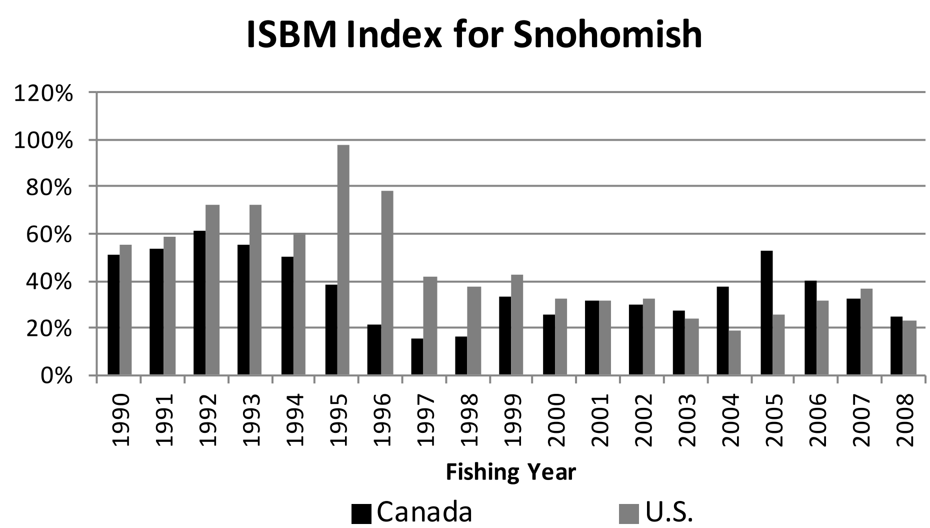


Figure 2.27 FRAM-based ISBM indices for Snohomish summer/fall Chinook in Canadian and southern U.S. fisheries.

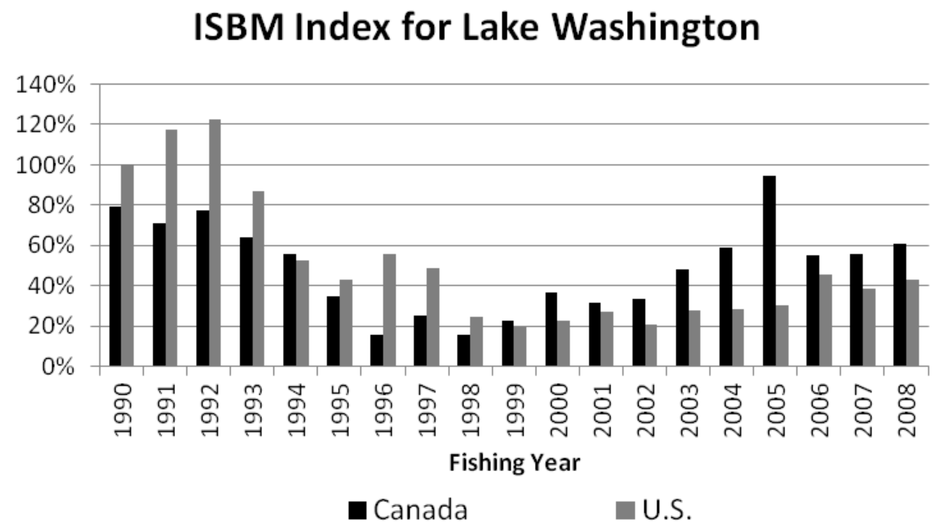


Figure 2.28 FRAM-based ISBM indices for Lake Washington summer/fall Chinook in Canadian and southern U.S. fisheries.

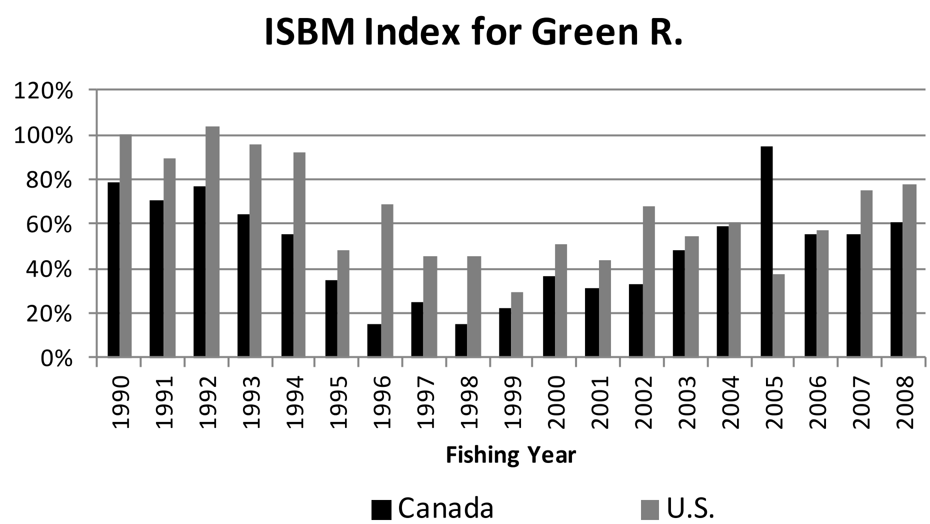


Figure 2.29 FRAM-based ISBM indices for Green summer/fall Chinook in Canadian and southern U.S. fisheries.

Table 2.7 Comparison of ISBM indices for Puget Sound Chinook stocks between Method 5a and the CWT exploitation rate analysis by the CTC.

	SKAGIT SPRING				SKAGIT SUMMER-FALL				STILLAGUAMISH			
Fishing	Canada ISBM		US ISBM		Canada ISBM		US ISBM		Canada ISBM		US ISBM	
Year	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT
1990	0.78	na	0.49	na	0.61	no ERA CWTs	0.67	no ERA CWTs	1.11	na	0.54	0.42
1991	0.71	na	0.62	na	0.55	no ERA CWTs	1.19	no ERA CWTs	0.62	na	0.54	na
1992	0.77	0.01	0.60	0.10	0.71	no ERA CWTs	0.89	no ERA CWTs	0.87	0.09	0.54	0.74
1993	0.73	na	0.57	0.92	0.64	no ERA CWTs	1.15	no ERA CWTs	0.67	na	0.41	na
1994	0.52	na	0.66	na	0.76	no ERA CWTs	0.61	no ERA CWTs	0.65	na	0.41	na
1995	0.42	0.04	0.59	0.35	0.55	no ERA CWTs	1.05	no ERA CWTs	0.46	0.09	0.57	0.27
1996	0.23	0.02	0.67	0.22	0.29	no ERA CWTs	0.66	no ERA CWTs	0.23	0.19	0.64	0.40
1997	0.28	0.06	0.66	0.24	0.40	na	0.90	0.13	0.33	na	0.50	na
1998	0.22	na	0.39	3.33	0.39	na	0.17	0.08	0.23	0.04	0.29	1.15
1999	0.30	na	0.25	na	0.46	na	0.33	0.00	0.42	na	0.29	na
2000	0.32	na	0.30	3.79	0.53	na	0.19	0.09	0.45	na	0.26	na
2001	0.29	0.03	0.39	0.33	0.38	na	0.30	0.06	0.43	na	0.28	na
2002	0.32	na	0.28	0.09	0.51	na	0.49	0.03	0.52	na	0.20	na
2003	0.30	na	0.24	0.58	0.60	na	0.31	0.06	0.46	na	0.19	na
2004	0.34	na	0.21	na	0.59	na	0.22	0.07	0.58	0.01	0.12	0.05
2005	0.41	na	0.23	na	0.62	na	0.40	0.03	0.77	na	0.16	1.65
2006	0.24	0.46	0.22	7.87	0.48	na	0.37	0.05	0.38	na	0.14	na
2007	0.31	na	0.19	na	0.67	na	0.51	0.07	0.45	0.04	0.30	0.12
2008	0.23	na	0.29	na	0.57	na	0.65	0.03	0.39	na	0.12	na

	SNOHOMISH				LAKE WASHINGTON				GREEN			
Fishing	Canada ISBM		US ISBM		Canada ISBM		US ISBM		Canada ISBM		US ISBM	
Year	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT	Method 5	ERA-CWT
1990	0.51	no ERA CWTs	0.55	no ERA CWTs	0.79	0.43	1.00	na for U.S.	0.79	0.43	1.01	na for U.S.
1991	0.54	no ERA CWTs	0.59	no ERA CWTs	0.71	0.21	1.18	na for U.S.	0.71	0.21	0.90	na for U.S.
1992	0.62	no ERA CWTs	0.73	no ERA CWTs	0.77	0.55	1.23	na for U.S.	0.77	0.55	1.04	na for U.S.
1993	0.55	no ERA CWTs	0.72	no ERA CWTs	0.64	0.43	0.87	na for U.S.	0.64	0.43	0.95	na for U.S.
1994	0.50	no ERA CWTs	0.61	no ERA CWTs	0.55	0.52	0.52	na for U.S.	0.55	0.52	0.92	na for U.S.
1995	0.39	no ERA CWTs	0.97	no ERA CWTs	0.35	0.25	0.43	na for U.S.	0.35	0.25	0.48	na for U.S.
1996	0.21	no ERA CWTs	0.78	no ERA CWTs	0.16	0.39	0.56	na for U.S.	0.16	0.39	0.69	na for U.S.
1997	0.16	no ERA CWTs	0.42	no ERA CWTs	0.25	0.19	0.49	na for U.S.	0.25	0.19	0.45	na for U.S.
1998	0.16	no ERA CWTs	0.38	no ERA CWTs	0.15	0.13	0.25	na for U.S.	0.15	0.13	0.45	na for U.S.
1999	0.33	no ERA CWTs	0.43	no ERA CWTs	0.22	0.20	0.20	na for U.S.	0.22	0.20	0.30	na for U.S.
2000	0.25	no ERA CWTs	0.33	no ERA CWTs	0.36	0.12	0.22	na for U.S.	0.36	0.12	0.51	na for U.S.
2001	0.31	no ERA CWTs	0.32	no ERA CWTs	0.31	0.21	0.27	na for U.S.	0.31	0.21	0.44	na for U.S.
2002	0.30	no ERA CWTs	0.32	no ERA CWTs	0.33	0.33	0.21	na for U.S.	0.33	0.33	0.68	na for U.S.
2003	0.28	no ERA CWTs	0.24	no ERA CWTs	0.48	0.25	0.28	na for U.S.	0.48	0.25	0.54	na for U.S.
2004	0.38	no ERA CWTs	0.19	no ERA CWTs	0.59	0.20	0.29	na for U.S.	0.59	0.20	0.61	na for U.S.
2005	0.53	no ERA CWTs	0.25	no ERA CWTs	0.95	0.25	0.30	na for U.S.	0.95	0.25	0.38	na for U.S.
2006	0.40	no ERA CWTs	0.32	no ERA CWTs	0.55	0.18	0.46	na for U.S.	0.55	0.18	0.58	na for U.S.
2007	0.32	no ERA CWTs	0.36	no ERA CWTs	0.56	0.12	0.38	na for U.S.	0.56	0.12	0.75	na for U.S.
2008	0.25	no ERA CWTs	0.23	no ERA CWTs	0.61	0.11	0.43	na for U.S.	0.61	0.11	0.77	na for U.S.

Method 5b: ISBM metric based on harvestable surplus

The URB and FRL stocks were used as examples for Method 5b. The CTC-accepted escapement goal for the URB is 40,000, which has been met since 1984. Harvests from the ISBM fisheries have never exceeded the harvestable surplus, i.e. the post-season metric was always less than 1.0, even before 1983 (Figure 2.30). The impacts from the AABM fisheries are not shown in the graph. Pre-season estimates of the proportion of harvestable surplus removed by the ISBM fisheries are available starting in 2005. These are based on projected catches and run forecasts and tend to exceed the post-season estimates based on actual catches and run sizes. Pre- and post-season estimates of the ISBM metric have exceeded the 0.6 general obligation for U.S. ISBM fisheries (Figure 2.31). However, the post-season ISBM metric does not start until 1983, when escapement goals were being met with no way to determine if the general obligation was met prior to 1983. Pre-season estimates of the ISBM metric are available starting in 2005. These are based on projected catches and run forecasts and tend to exceed the post-season estimates based on actual catches and run sizes.

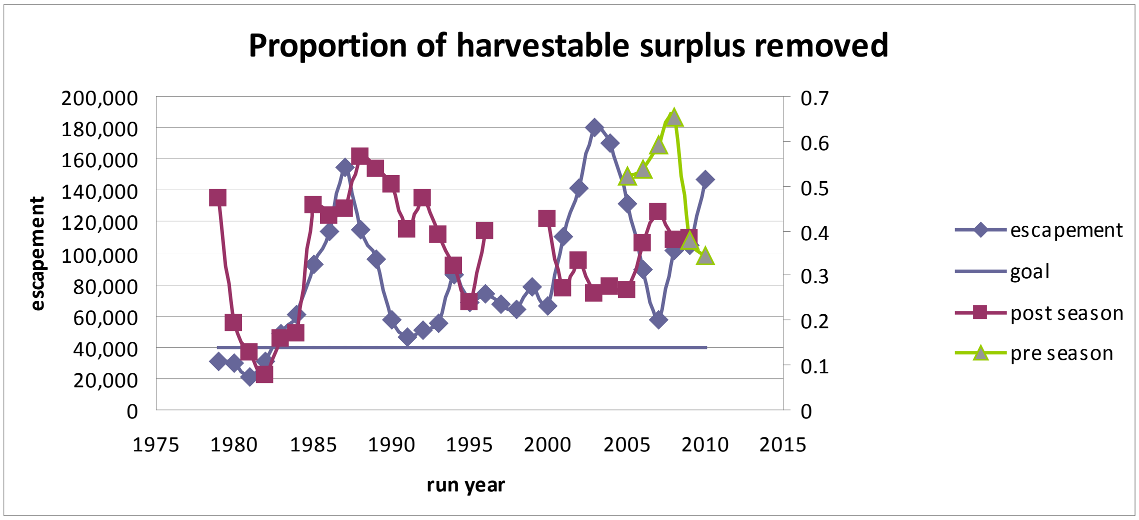


Figure 2.30 Pre- and post-season estimates of the proportion of harvestable surplus removed in the URB stock. Observed escapement and escapement goal are also shown.

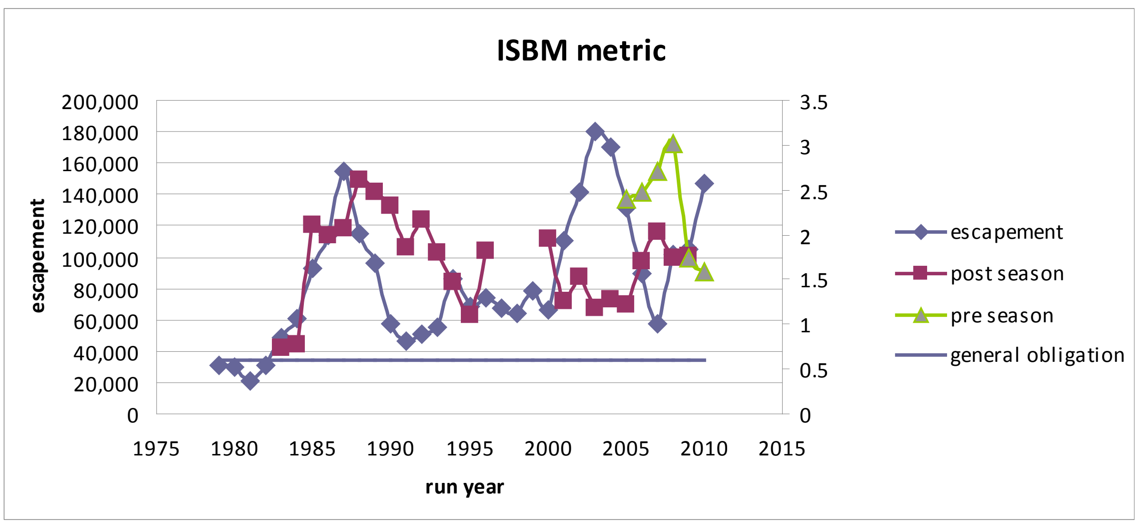


Figure 2.31 Pre- and post-season estimates of the ISBM metric in the URB stock. Observed escapement and the general obligation level are also shown.

For the FRL stock, the lower bound of the escapement goal range is 75,100 (Figure 2.32). Escapement goals were met for all years except 2006 and 2008, i.e. the post-season metric was greater than 1.0. Pre-season projected escapements were below the goal in 2005, 2006, and 2007, i.e. the pre-season metric was greater than 1.0. The impacts from the AABM fisheries are not shown in the graph. Pre-season estimates of the proportion of harvestable surplus removed by the ISBM fisheries are available starting in 2005. These are based on projected catches and run forecasts and tend to exceed the post-season estimates based on actual catches and run sizes. The general obligation metric for the years when there was no projected harvestable surplus were rescaled using logarithms (equation 2.32).

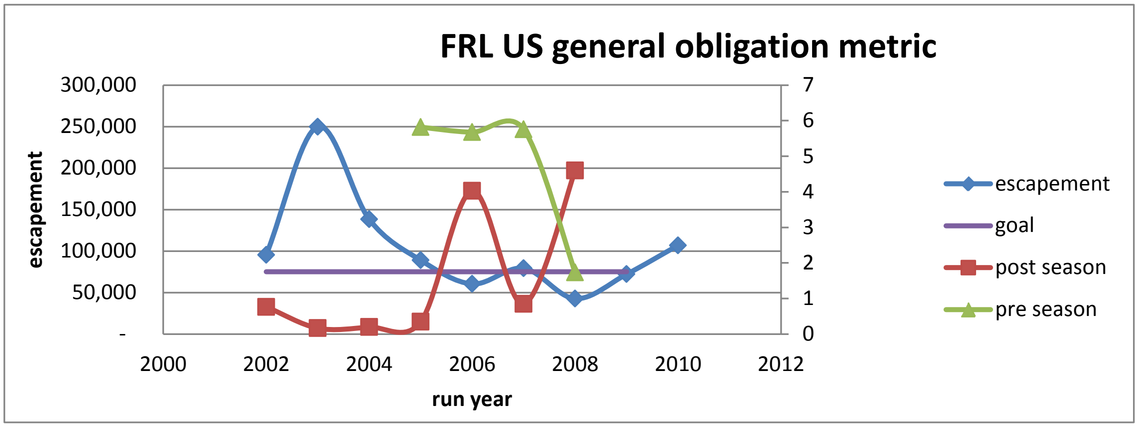


Figure 2.32 Pre-season and post-season estimates of the ISBM metric in the FRL stock. Observed escapement and the general obligation level are also shown.

2.7 QUALITATIVE EVALUATION OF CURRENT AND ALTERNATIVE ISBM METRICS

In terms of desirable attributes (as described in Section 1.4), the current approach generates indices that represent total mortality (landed catch plus incidental mortality as opposed to landed catch only), has the ability to generate pre-season and post-season indices, meets pre-season timelines, uses current CWT data, uses data provided by existing sampling programs, is feasible to compute with available staff and time constraints, has the ability to accommodate differences in terminal impacts between CWT indicator stock and natural stock, and has the ability to calculate the 1991-1996 average index. However, the current approach has gaps in base period coverage in terms of fisheries, stock representation, and escapement data, uses different analytical frameworks for pre-season and post-season computations, exhibits a two-year lag for the post-season estimate for stocks intercepted in U.S. ISBM fisheries, and post-season estimates are unstable until complete broods have returned. None of the alternative metrics solves all these limitations of the current approach but improvements can be accomplished by most of the alternative approaches (Table 2.8).

Methods using GLMs of CWT contributions based on catch projections (Methods 1a and 1b) or using an effort-based catch-at-age model (Method 2) have the ability to solve base period coverage issues in terms of fisheries and escapement, have the same analytical framework for pre-season and post-season evaluations, and have the potential to meet post-season timelines (one year after pre-season estimate). Methods 1b and 2 allow the computation of post-season estimates that are stable prior to complete broods returning. However, methods 1a and 1b are currently not feasible to compute with available staff and time constraints and would require the CTC to create computer programs to make these methods pragmatic. Method 2 requires effort data that are not available for all fisheries. An alternative post-season metric based on mortality distributions (Method 3) exhibits similar limitations to the current approach but it offers the ability to generate base period harvest rates for stocks without these data, and could also meet post-season timelines. A composite index (Method 4) could potentially solve all the limitations of the current approach, except for post-season instability under incomplete broods, but this approach requires a new ISBM paradigm allowing for an aggregate-based concept (as opposed to individual stocks) in Treaty provisions. Some alternative metrics are currently not applicable coastwide due to data limitations (Methods 1b and 2) or model structure (FRAM-based Methods 5a and 5b). Methods using the FRAM (Methods 5a and 5b) instead of the PSC Chinook Model for ISBM computations, exhibit many of the identified desirable attributes but they can be applied only to U.S. ISBM stocks. Nonetheless, only Method 5a among all metrics has the ability to evaluate the performance of some types of non-standard fisheries such as mark-selective fisheries (MSFs[6]). In MSFs, the assumption that exploitation rates derived from CWTs recovered from a hatchery indicator represent the exploitation rates of wild stocks no longer applies, and direct analysis of CWTs from adipose fin-clipped fish alone does not allow the computation of an ISBM index.

In terms of other relevant characteristics that are not desirable attributes (Table 2.9), Methods 1b, 2, and 4 require algorithms different to the one currently used for post-season computations, and only Method 2 is independent of base period data. Method 2 is deemed as potentially the most precise of all alternative approaches but it is data demanding and computationally intensive. With the exception of Methods 3 and 4, the alternative pre-season ISBM metrics can be computed independently of projections generated by the PSC Chinook Model. However, Methods 2 and 4 would require a change in Treaty provisions with explicit consideration of fishing effort as a driving factor for Method 2 and the PSC consent to assess ISBM indices in terms of stock groupings required for Method 4. Currently, fishing effort is not estimated year-round for all Canadian ISBM fisheries. Method 5b could also require changes in Treaty provisions if the index is based on achieving escapement goals instead of meeting the general obligation.

Some of the alternative approaches generate ISBM metrics that are in units not comparable to those produced by the current approach (Methods 1b, 2, and 4). The main advantage of the FRAM-based methods is that they provide fine-scale stock and fishery resolution. However, in addition to the limited application of the FRAM-based approach to U.S. stocks, additional time would be required to train CTC members how to use the FRAM. For Method 3, a requirement that is shared with the current post-season index is the need for a clear

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[6] MSFs allow retention of marked (adipose fin clipped) hatchery fish while all caught, un-marked fish (with an intact adipose fin), must be released, regardless of origin, whereas mixed-bag MSF fisheries allow limited retention of unmarked fish the daily limit or a complete limit consisting of only marked fish. Thus, the MSF fishery targets hatchery fish, whereas the mixed-bag MSF fishery targets a mix of hatchery and wild fish. This does not, however, preclude an impact to wild stocks. Unmarked and marked released fish still experience some hook and release mortality. A major consequence of these fisheries is the differential exploitation rates of marked and unmarked fish. Exploitation rates of tagged, hatchery stocks are not indicative of the unmarked, wild stocks they are intended to represent. The Selective Fisheries Evaluation Committee (SFEC) of the Pacific Salmon Commission has developed several methods to estimate MSF impacts on wild stocks, such as the use of Double Index Tag (DIT) groups; however, there can be pragmatic limitations that are irresolvable (e.g., not all indicator stocks have capacity for adequate DIT production). To date, the majority of MSFs targeting hatchery Chinook have been confined to sport fisheries conducted in limited areas of WCVI, the Strait of Juan de Fuca (BC and WA), marine and freshwater areas of Puget Sound, the Columbia River and coastal Washington and coastal Oregon.

separation of ISBM and AABM fishery impacts in mortality distribution tables. The CTC is currently working on new stratification schemes that will eventually correct this issue. In general, each alternative approach has special requirements that range from projections of catch (methods 1a and 1b) to the generation of coastwide standardized effort (Method2) and stock grouping analyses (Method 4).

Based on the evaluation of alternative ISBM metrics, the CTC recommends Methods 1a and 1b as approaches deserving further investigation for evaluating ISBM performance. Although Method 1a has the advantage of using the current algorithm, thus facilitating a transition to a new metric, it still suffers from instability of post-season computations resulting from incomplete broods. In contrast, Method 1b does not have this limitation but it uses an alternative algorithm for post-season computations. From the point of view of simplicity and immediate usage, Method 3 could facilitate the computation of post-season estimates for stocks currently not evaluated due to lack of base period data. Alternatively, equation 2.18 could include in the denominator the mortality contributions from AABM and ISBM fisheries from both jurisdictions, in which case equation 2.18 is reduced to $ISBMMD_y = \sum_{a=2}^{5} \sum_{f=1}^{n} TM_{a,f}$. Preliminary analyses showed that the differences in ISBM index values generated with either version of equation 2.18 are small and unbiased in most cases. At any rate, new analytical effort would have to be invested by CTC members in order to fully implement the use of a new approach for the computation of pre- and post-season ISBM indices.

Table 2.8 Desirable attributes exhibited by methods to compute ISBM indices.

Method	Current	Method 1	Method 2	Method 3	Method 4	Method 5a	Method 5b
Desirable attributes		GLM a) Current b) Alternative	Effort-based (catch-at-age)	Mortality distribution	Composite index	FRAM-based	Harvestable surplus
Measures total mortality	Yes	Yes if derived estimates used	Yes if derived estimates used	Yes	Yes	Yes	Yes
Solves base period issues: (a) Fisheries (CWT, sampling rates)	No	Estimates could be derived from covariates	Estimates could be derived from covariates	No	Yes (aggregate coverage)	Yes	US only
Solves base period issues: (b) Stock representation	No	No	No	Yes	Yes	Yes	Depends on stock
Solves base period issues: (c) Escapement (CWT, population estimates)	No	Estimates could be derived from covariates	Estimates could be derived from covariates	No	Yes	Yes	US only
Ability to generate pre-season indices	Yes	Yes	Yes	No	Yes (dependent on projections)	Yes	Yes
Ability to generate post-season indices	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Method	Current	Method 1	Method 2	Method 3	Method 4	Method 5a	Method 5b
Desirable attributes		GLM a) Current b) Alternative	Effort-based (catch-at-age)	Mortality distribution	Composite index	FRAM-based	Harvestable surplus
Uses the same analytical framework for pre-season and post-season computations	No	Yes	Yes	Not Applicable	Yes	Yes	Varies by stock
Meets pre-season timeline of February 1st	No	Yes if projections available	Yes if projections available	Not Applicable	Maybe	No	Yes
Meets post-season timeline (year+1)	No (year+2)	Yes if projections available	Yes if projections available	No (year+2)	Maybe	No (year+2)	Yes
Post-season estimates stable under incomplete broods	No	a) No b) Yes	Yes	Yes	No	Not Applicable	Not Applicable
Uses current CWT data	Yes	Yes	Yes	Yes	Yes	No	Yes
Uses data from existing sampling programs	Yes	Yes	No	Yes	Yes	Yes	Yes

Method	Current	Method 1	Method 2	Method 3	Method 4	Method 5a	Method 5b
Desirable attributes		GLM a) Current b) Alternative	Effort-based (catch-at-age)	Mortality distribution	Composite index	FRAM-based	Harvestable surplus
Feasible to compute with available staff and time constraints	Yes	No	No	Yes	No (requires new aggregate-based concept for ISBM fisheries)	Yes for southern U.S. stocks in FRAM (estimated for pre-season domestic process.	Yes, during PFMC process
Can accommodate terminal differences between indicator and natural stock	Yes, using external calculations	Yes	Yes	Yes using external calculations	Yes	Yes using external calculations	Yes using external calculations
Ability to calculate 1991-96 index	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Can be applied to all Annex stocks	No	a) Yes b) No	No. Data currently unavailable for several stocks	No	Yes	No	No

Table 2.9 Other relevant characteristics exhibited by methods to compute ISBM indices.

Relevant characteristics	Current Method	Method 1a GLM/Current Algorithm	Method 1b GLM/Alternative Algorithm	Method 2 Effort-based (catch-at-age model)	Method 3 Mortality distribution	Method 4 Composite index	Method 5a FRAM-based	Method 5b Harvestable surplus
Required change in current ISBM post-season index algorithm	Not applicable	No	Yes	Yes	No	Yes	No	No
Dependence on base-period data	Yes	Yes	Yes	No	Yes/No		Yes	Yes/No depending on objective
Independent from the projection by the PSC Chinook Model	No	Yes	Yes	Yes	Not applicable	Not applicable	Yes	Yes
Requires a change in Treaty provisions	No	No	Maybe	Yes	No	Yes	No	Yes, if index is based on achieving escapement goals instead of meeting general obligation
ISBMI units comparable to those of the current index	Not applicable	Yes	No	No	Yes	No	Yes for stock units covered in FRAM	Yes
Performance evaluation of non-standard fisheries	No	No	No	No	No	No	Yes for mark-selective fisheries	No
Main advantage of using this method	No changes required	No change in current algorithm	Simple to compute using projections	Highly precise using pre-and post season analysis though computationally intensive	Allows computation of post-season index for stocks without base-period harvest rate data	Target catch is based on historic relationships and limits	Provides fine-scale stock and fishery resolution for FRAM stocks	Use same model that U.S. uses for preseason planning of stock specific impacts. Directly related to escapement goals
Special requirements	Pre-season and post-season computations use different analytical framework	Requires projection of catch	Requires projection of catch	Requires coastwide standardized effort data	Requires clear separation of ISBM and AABM fishery impacts in mortality distribution tables	Requires stock grouping analyses	Requires effort to familiarize CTC members with FRAM capabilities and limitations. Not all PSC stocks covered in FRAM	Not suitable for stocks without escapement goal or/and agency forecast. Need Canada pre-season planning model with stock specific impacts by fisheries.

2.8 THE CURRENT INDEX IN PERSPECTIVE

A variety of problems have been identified with the current ISBM index. These problems are not due to mathematical formulation per se but are instead the result of data deficiencies or implementation issues. Generally, these problems concern (1) poor correspondence between the pre- and post-season ISBM indices, (2) a two-year time lag for the CWT-based index, (3) incomplete broods, (4) absence of Chinook non-retention mortalities represented in base period exploitation rates, (5) absent or incomplete base period data, (6) large changes in some ISBM fisheries since the base period, (7) representation of natural indicator stocks, (8) an inability to separate ISBM and AABM fishery impacts for WCVI and NBC fisheries, and (9) an inability to correctly identify terminal fishery impacts by jurisdiction. Since no problem-free alternative has been identified, a fresh consideration of the current index may help identify improvements which were not obvious in the past or even feasible to make. Below, some of the main problems are outlined and possible steps toward improvements are suggested.

Poor correspondence between the pre-season and post-season indices

Two different versions of the ISBM index are currently calculated on an annual basis. One version, based on data used and generated by the PSC Chinook Model, generates the forecast of the index and is considered in pre-season fishery planning. The post-season version, based on CWT data, generates a value used for assessment of compliance with the ISBM provisions of the PST. While both are based on similar mathematical formulations, the two time series often do not correspond well and this affects the perception of reliability of each version and limits their use. There are several fundamental reasons why these versions of the index may not correspond well, but the core problem is that each is based on different types of data. There is overlap in some of the data but there are substantial differences that will always be present.

The obvious solution to this problem is to adopt one version or to generate a full set of annual values including the pre-season forecast value using both approaches. The CWT-based forecast could be made by assuming average fishery impacts, cohort survival rates and maturation rates and this is what already occurs in the calculation of the pre-season forecast based on Chinook-Model generated data. Other methods of forecasting CWT data were described in this chapter, and the development of a computer program to apply Method 1a, for example, would enable pre- and post-season ISBM indices to be based on the same type of data while using the current algorithm.

Two-year time lag for CWT-based index

There is a serious impediment to calculating a full time series of CWT-based indices (including the pre-season forecast) each year in that CWT estimates are not available in the Regional Mark Information System (RMIS) for some of the most important southern U.S. fisheries until more than a year after the fisheries have occurred. Until final catch estimates are available, the observed CWT recoveries and the associated estimates are not posted to RMIS. This propagates tardiness of the CWT-based indices since they are at best two years out-of-date. Therefore the CWT index is typically of limited utility because fishery impacts will have occurred two years before fishery compliance under the PST can be assessed, and fishery managers do not have information for the most recent year to use for planning fisheries in the upcoming year. This situation impacts the current index in that the post-season values change for three years until all the broods present within them have matured (see the section below on the 'The incomplete brood problem') and well after the fisheries have occurred.

The issue of late reporting of CWT data to international databases was reviewed by the Data Sharing Committee in 2011, but reporting issues were only identified for some of the U.S. ISBM fisheries. Each agency's procedures for sampling fisheries for CWTs, decoding CWTs, and data management were all meeting the timelines necessary for the CTC to develop the ISBM indices on time. However, the catch estimates that are necessary to expand the CWT sample data are not available for some sport and net fisheries. For Puget Sound sport and net fisheries, in-season or preliminary catch estimates are available in time, e.g. via creel surveys, however final estimates are not accepted by co-managers in sufficient time. In coastal Oregon, terminal sport fishery catch is available in time for the exploitation rate indicator (CWT'd) stocks originating from both the Elk and Salmon Rivers through ongoing creel survey programs. However, for their natural production counterparts (e.g. Nehalem, Siletz and Siuslaw) estimates of terminal fishery impact are not available from state-wide self-reporting surveys until two years after the occurrence of the fishery. The exception to this limitation is when creel survey programs are in place to assess the performance of those ISBM fisheries.

Historical catch estimates can be updated and presumably improved at any time, thus, waiting to post recoveries to RMIS until catch estimates are 'final' does not seem to provide a compelling reason for delay. A possible solution could be that all agencies agree to post observed recoveries by the end of the year in which they were sampled even if actual estimates calculated from catch and sample data will not be available until some future time. Temporary estimates could be associated with these recoveries based on preliminary (e.g. in-season) catch estimates or on CWT estimates averaged across recent years in the same fishery. This latter step could be accomplished externally (e.g., by the CTC) but better estimates could likely be provided by agencies or generated through a standardized algorithm incorporated into RMIS.

At this time the two-year late reporting of U.S. ISBM fishery CWT data only affects the CWT indicator stocks caught by U.S. ISBM fisheries. Several Canadian stocks with far north migration distributions do not rely on southern U.S. CWT data (e.g., Kitsumkalum, Atnarko, and Quinsam) and their ISBM indices can be generated by the CTC on time. Other stocks that have few or occasional CWT recoveries in the southern U.S. fisheries, such as Fraser River spring-, summer-, and fall-run stocks, can have U.S. ISBM CWT recoveries estimated using recent average exploitation rates and cohort sizes, or other modeling techniques, during the interim period until the U.S. ISBM CWT data can be reported on time. For these stocks, it would be very valuable to report unexpanded 'observed' CWT recoveries, if for example the catch data or sample rates were unavailable, because that information can be used to estimate a fishery-specific sampling rate. Lastly, some stocks are exploited more heavily in U.S. ISBM fisheries, and other estimation models can assist the CTC with reporting the ISBM indices on time. Some estimation models for CWT data are described in this chapter, and new approaches can be reviewed by the CTC as time permits.

Given the availability of complete CWT estimates from the most recent fishery year, a time series of annual values could be calculated using both current versions of the index. There are valid reasons for the preference of one version compared to the other and the availability of the same time series for each version would enable the best choice of index value depending on the particular objective.

The incomplete brood problem

Within each calendar year, several age classes of Chinook originating from different spawning generations or 'cohorts' are present in the catch and escapement. The cohort analysis procedure employed in the annual exploitation rate analysis cannot produce 'final' (or stable) statistics until the oldest possible age for a cohort has passed by. The cohort analysis, however, is designed to produce 'temporary' estimates for incomplete cohorts based on assumed age-specific maturation rates. These are based on an average of all completed cohorts or on a chosen set of recently completed broods. The reliance on the assumed maturation rates allows the calculation of exploitation rates up to the most recent year of CWT recovery data included in the analysis. This seems like a small concession given the ability to produce more contemporary estimates.

The 'incomplete brood' problem is not exclusive of the current ISBM index; it exists in the calculation of other important metrics used by the CTC. These include the pre-season AI values for the AABM fisheries which are derived from the forecasts of cohort abundances based on data and rate values from incomplete broods. The CTC, however, has recently identified several improvements that can be made to the algorithms used in the cohort analysis. These changes to the cohort analysis computer program code are expected to produce more accurate statistics (e.g., maturation rates) for all cohorts, whether complete or not. These improvements are likely to increase the reliability of the current CWT-based ISBM index, even for years affected by incomplete broods.

Absence of CNR mortalities in the base period exploitation rate estimates

Chinook Non-Retention (CNR) fisheries only became a regular occurrence after the base period (1979 –1982). This means that incidental mortalities from this type of fishery are not present in the base period average exploitation rates for ISBM fisheries used in the calculation of either version of the current version of the index. The annually calculated values may thus be an underestimate of the total ISBM fishery impacts, and the effect may vary across the stocks for which the ISBM index is calculated.

This issue was discussed in the 'Technical Backgrounder' paper (Gaudet et al. 2003) produced following the signing of the 1999 PST. Several solutions to this problem were even proposed but these have not been adopted or considered since. A recommendation would be for the CTC to review how significant and widespread CNR impacts are in the ISBM fisheries and to reconsider the solutions put forward in the Technical Backgrounder. New solutions may also be devised.

Absent, incomplete or poor quality data in the base period

As long as the ISBM index is calculated relative to a historical base period such as 1979-1982, a variety of intractable problems will compromise its accuracy and reliability. The list of problems includes:

1. Insufficient or absent CWT recoveries due to lack of CWT releases made in advance of the base period;

2. Insufficient, biased or absent CWT sampling in terminal fisheries or in the escapement during the base period;

3. Poor or non-existent estimation of catch in terminal fisheries or of the escapement during the base period, i.e., the data used to estimate CWT recoveries; and,

4. Expansion of ISBM fisheries from inconsequential levels in the base period to much more substantial levels after the base period.

Improvements are now possible in data used to represent base period ISBM impacts for at least some of the CWT indicator stocks, or possibly many of them. Consideration of new approaches and inclusion of new or revisited data have not been attempted by the CTC for many years. This work will take place as the CTC proceeds with a new recalibration of the base period for the PSC Chinook Model. The improvements in the cohort analysis procedure and PSC Chinook Model calibration that have been planned or already carried out by the CTC will undoubtedly result in improved estimates of ISBM (and AABM) fishery impacts from both the CWT-based version and the Model-based method.

Large reductions in some ISBM fisheries since the base period

Certain ISBM fisheries have been dramatically reduced since the base period, mostly in response to conservation concerns for stocks caught in them. Examples of formerly substantial ISBM fisheries are Georgia Strait Troll and Sport which averaged 236,610 and 218,932, respectively, for the base period. For the period, 2005 -2009, the troll catch was 0 and sport catch averaged only 6% of the base period (CTC 2011). Such large reductions result in decreased impacts on stocks caught in the fisheries. They also result in fewer CWT recoveries available for calculation of the CWT-based ISBM index and increase the uncertainty in the calculated value. The effect of large changes in ISBM fishery magnitude and the resulting number of CWTs will vary across stocks in relation to their prevalence in the fisheries. In general, a CWT-based index calculated from a low number of estimated CWTs will have high uncertainty. Currently, there is no satisfactory solution to this problem.

Representation of natural indicator stocks

The scale of the indicator stocks in Attachments IV and V includes both individual and groups of populations, which can result in differing amounts of uncertainty in indices among indicator stocks. When only a single model stock or exploitation rate indicator stock is available to represent many populations, the indices for an individual ISBM indicator stock can have low accuracy if populations vary in biological attributes, such as ocean distribution, migration timing, and maturation rates. Generally, the accuracy of the indices will be high when there is direct one-to-one correspondence between an indicator stock and either a model stock or a CWT exploitation rate indicator stock.

There are few indicator stocks in the Attachments with a one-to-one direct correspondence between a natural indicator stock and a CWT exploitation rate indicator stock or a CTC model stock. Many of the CWT exploitation rate stocks experience a different gauntlet of ISBM fisheries, either pre-terminal or terminal. For the CWT indicator stock data, adjustments are made to best represent the indices for the natural indicator stocks. However, a comparable set of adjustments is not possible with the CTC model because the fisheries cannot be modeled at a sufficiently fine scale without representing each indicator stock as its own model stock. This situation results in reduced accuracy of the CTC model indices for natural indicator stocks.

Nearly all of the CWT exploitation rate indicator stocks for the natural stock groups in Attachment IV and V are hatchery stocks, which can have different terminal fishery exploitation rates than the natural stocks they represent. For example, several of the CWT exploitation rate indicator stocks (e.g., Robertson Creek [RBT], Chilliwack [CHI], Salmon River [SRH]) can have significant terminal fisheries that target surplus hatchery production, while other terminal fisheries for their corresponding natural stocks may be severely restricted or closed because of little or no surplus production. Furthermore, the spatial distribution of the natural indicator stocks rarely aligns well with that of the CWT exploitation rate indicator stocks, and can cause the natural indicator stocks to migrate through a different set of fisheries than the CWT indicator stock. Both differences in terminal fisheries (e.g. freshwater) and spatial distribution can create circumstances that require adjustments to CWT data.

For some stock groups, the number of populations they represent reflects the number of CWT indicator stocks that were available to represent the base period fisheries when the CTC developed the last version of the model. Variation among terminal exploitation rates for natural indicator stocks can be assessed by improved monitoring of terminal fisheries or by improving the CWT coverage of salmon production regions.

Recently, the CTC has reported CWT data for several more exploitation rate indicator stocks than was available when the last version of the model was built. This new information could potentially be used to better represent the biological attributes of natural stocks in the CTC model, for example by dividing existing model stocks into component stocks that would be better represented using recently available CWT statistics, and ultimately improve the accuracy of the indices.

Inability to separate ISBM and AABM sport fishery impacts for WCVI and NBC

The configuration of the CTC model and CWT cohort analysis do not now accurately represent the indices for the Canadian ISBM fisheries. Currently, ISBM and AABM sport fisheries are combined and reported only as WCVI sport and NBC sport. Correction of these circumstances requires revisions of the CTC model, the CTC exploitation rate analysis, and likely a unique identification of these fisheries in the CWT data. For the NBC sport fishery, the CWT recoveries can be separated easily into AABM and ISBM fisheries using the existing management areas. However, identification of AABM and ISBM CWT recoveries in the WCVI sport fishery is more complicated because the definition of the ISBM and AABM fisheries varies by time and the surfline that intersects Pacific Fishery Management Areas. Correct identification of the CWT recoveries is the responsibility of the reporting agency, and it is recommended that CDFO communicate a proposal with options to correctly identify the AABM and ISBM recoveries to the Data Sharing and Chinook technical committees.

Inability to correctly identify terminal fishery impacts by jurisdiction

Two fishery mapping errors have been identified with the cohort analysis program that affects the ISBM Indices. These errors will be corrected when standardized c-file[7] formats are used in the cohort analysis system database.

The CWT cohort analysis program incorrectly maps some of the terminal CWT recoveries to the wrong jurisdiction. The CWT cohort analysis reports all terminal CWT recoveries in terminal gear categories regardless of jurisdiction, since there is just one ‘terminal net’ and one ‘terminal sport’ fishery. This situation produces an incorrect reporting of U.S. ISBM terminal fishery impacts as Canadian ISBM fishery impacts for Canadian ISBM stocks, and vice versa for U.S. ISBM stocks. This situation causes the ISBM impacts to be overestimated for the jurisdiction where the stock originates, and causes the ISBM impacts to be underestimated in the jurisdiction where the recoveries occurred. Among all the CWT recoveries used by the CTC for the March 2011 Exploitation Rate Analysis (ERA), this happened for 27 CWT recoveries from Canadian indicator stocks in U.S. terminal net fisheries and 3 U.S. indicator stock recoveries in Canadian terminal net fisheries. Among the Canadian indicator stocks, Cowichan had the most (11) CWT recoveries in U.S. terminal fisheries occurring in 10 years and amounting to 27.99 estimated CWT recoveries (Appendix 4).

There are also situations where the terminal sport recoveries are being incorrectly omitted when they occur in the other jurisdiction’s sport fisheries. There were three U.S. indicator stock recoveries in Canadian terminal sport fisheries, and nine Canadian indicator stock recoveries in U.S. terminal sport fisheries that were omitted during the March 2011 ERA. These omissions yield biased CWT statistics, including ISBM Indices.

To correct this situation, modifications are needed to uniquely identify terminal fisheries for each CWT indicator stock in the CWT cohort analysis by using standardized c-file formats in

[7] Estimated CWT recoveries of an individual tag code are combined in a c-file. C-files from selected tag codes are used as input files in CTC exploitation rate analysis.

the cohort analysis system database. Thus, terminal fishery recoveries in the jurisdiction where the stock does not originate can be identified correctly by the fishery name and mapped to the appropriate jurisdiction's ISBM fishery.

Conclusions concerning the current indices

Modifications to base period data and improvements in the treatment of incomplete broods may improve the reliability and validity of the CWT-based index to the point that it remains a robust method for assessing post-season compliance with each country's obligations. Introduction of new techniques may also allow the current CWT-based index method to provide pre-season values useful for fishery planning. While the current CWT-based method may never be completely satisfactory in all respects, it may satisfy most objectives. The largest impediment to timely reporting of the CWT-based indices by the CTC is the two-year time lag that exists with reporting of CWT recoveries in U.S. ISBM fisheries, particularly those in Washington State. If late CWT data reporting issues are irresolvable for some U.S. ISBM fisheries, then estimation models can be applied to enable the CTC to report the ISBM indices on time, and to better inform ISBM fishery management planning. Planned improvements in the CWT data and in the input data and the structure of the PSC Chinook Model will also result in a more reliable time series of ISBM index values generated from the Model-based data.

3 ASSESSMENT OF ISBM FISHERIES UNDER PASS-THROUGH PROVISIONS

3.1 PASS-THROUGH PROVISIONS IN PARAGRAPH 13

Paragraph 13 of the 2008 Agreement contains provisions that are complementary to the general obligation specified in Paragraph 8 and are characterized by additional management actions in AABM and ISBM fisheries. According to these provisions, the catch limit of an AABM fishery identified in Table 1 of Chapter 3 of the Agreement, will be reduced by 10% if the majority of indicator stocks within each of two stock groups listed in Attachments I and II do not achieve their agreed management objectives in two consecutive years (the second year can be observed or forecasted). The Table 1 catch limit will be reduced by 20% if this situation occurs in the majority of indicator stocks within three or more stock groups. These provisions assume that Paragraph 8 obligations are met and they do not apply to the WCVI AABM fishery per Paragraph 13(g). For indicator stocks with escapement management objectives, escapements that are at least 15% below the objective meet the criteria to trigger the additional management actions. For indicator stocks with exploitation rate management objectives, exploitation rates exceeding agreed objectives meet the criteria to trigger the additional management actions. If additional management actions are required, ISBM fisheries will be reduced to increase the escapement of depressed stocks in the stock groups meeting the provisions above by the number of mature fish saved from the AABM fishery reductions.

The second ISBM assignment described in Appendix A to Annex IV, Chapter 3 is to develop methods to estimate the numbers of mature fish saved as a result of reductions to AABM fisheries and to determine adjustments required in ISBM fisheries to ensure those savings reach escapement. The core of this assignment is to estimate the number of mature fish saved for each stock in Attachments IV and V after reducing SEAK and NBC AABM catches by 10%, and to determine reductions required to ISBM fisheries to "pass-through" the savings into escapement. Impacts of reductions in AABM fisheries accrue over multiple years (i.e., reductions in an AABM fishery will affect both mature and immature fish), are stock and year specific, and depend on where and when the reductions take place (Figure 3.1).

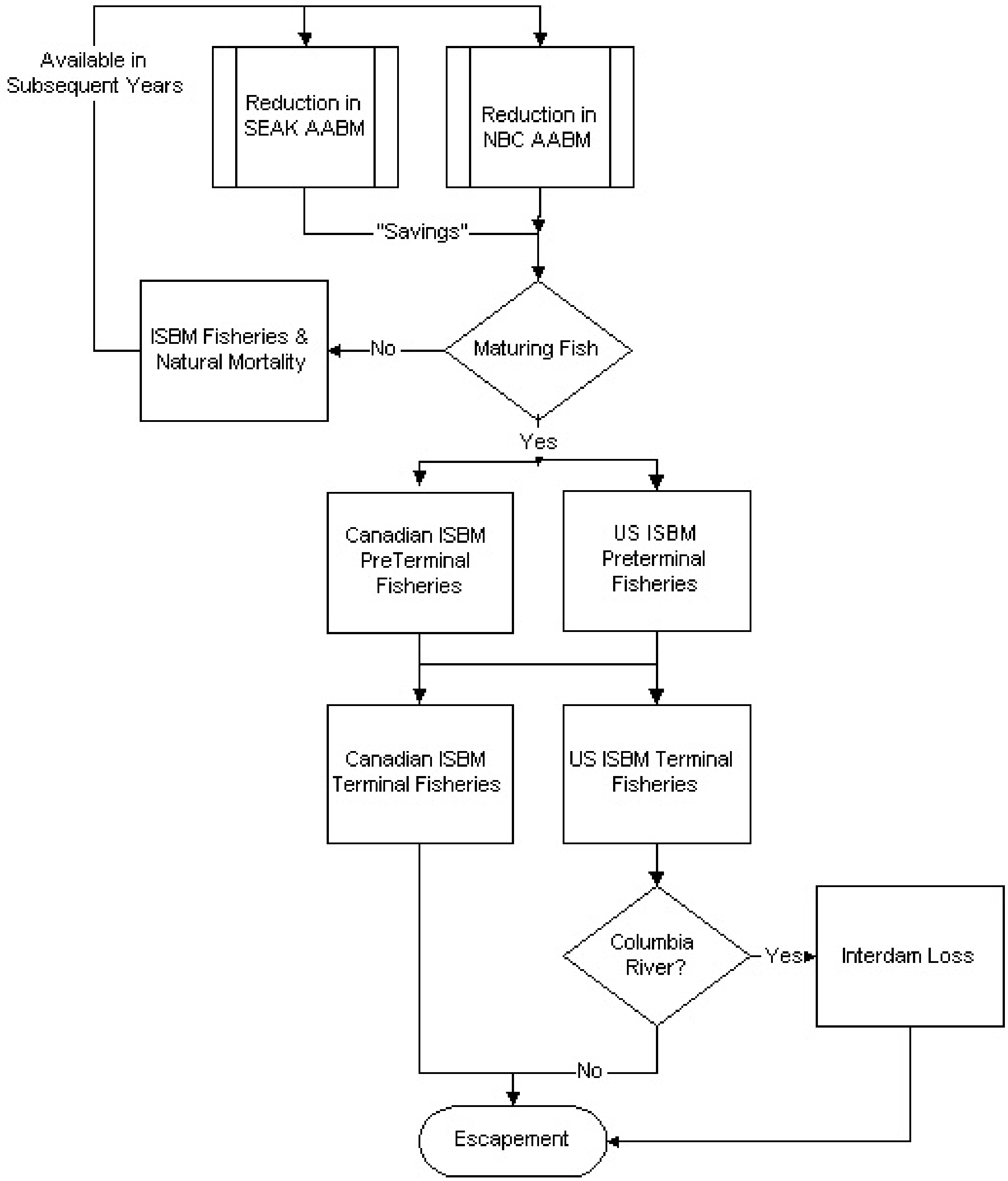

Figure 3.1 Flow diagram for fish saved as a result of AABM catch reductions.

Two scenarios using the PSC Chinook Model to estimate the savings of mature fish as a result of a 10% reduction in SEAK and NBC catch are presented in sections 3.2 and 3.3. Both sections also include the reductions necessary to ISBM fisheries to pass the savings to escapement. Scenario 1 estimates the savings resulting when the 10% reduction is taken in three consecutive years while scenario 2 estimates the savings resulting when the 10% reduction is taken in one year. Scenario 1 was chosen to illustrate the variation in savings as a function of different stock abundances. As run sizes vary annually the expected savings would vary and so would the ISBM reductions. Scenario 1 provides a range of the expected realized savings over any given year. Scenario 2 was chosen to examine the savings of mature fish in the year of the reduction and the savings of mature fish in subsequent years as a result of a one year reduction. Input files for the projection run of calibration 1007 were modified to create the scenarios and two PSC Chinook Model runs were completed for each scenario. In the first model run for both scenarios, terminal runs and escapements were computed under the ISBM general obligation using observed catch levels for the AABM fisheries. In the second model run, observed catch levels were reduced in AABM fisheries and terminal runs and escapements were computed again. Increases in terminal runs and escapements as a result of the reductions were calculated using terminal run and escapement estimates from the model runs. Additional reductions to ISBM harvest rates required to pass the savings to escapement were also calculated.

3.2 SCENARIO 1: SAVINGS RESULTING FROM A THREE-YEAR REDUCTION TO SEAK AND NBC AABM CATCH

Calibration 1007P13R1 (run 1) was used with AABM catches in the .CEI file[8] at their observed levels and with ISBM fisheries operating under the general obligation (i.e., FP[9] scalars in ISBM .FPA files were set at 0.635 and 0.60 for Canada and US, respectively) for the years 2007-2009. Calibration 1007P13R2S1 (run 2-scenario 1) included 10% reductions in catch (i.e., observed catch was reduced in .CEI files by 10%) for the SEAK and NBC AABM fisheries in years 2007-2009 while keeping the ISBM FP scalars unchanged from run 1. Terminal run and escapement estimates for 2007-2009 were extracted from the run 1 and run 2-scenario 1 output using the CheckCCC program (Ryan Briscoe 2007; Alaska Department of Fish and Game). Assumptions were made that the effects on escapements and cohort sizes were minor across these periods (large changes in AABM fisheries would have corresponding increases in escapement in terminal areas which would then have a ripple effect on subsequent years). While this bias may not be very large, some examination of its effects on pass-through provisions is recommended when this provision occurs as an additional management action. The general procedure will still be the same as outlined here, but it will be required to build a feedback mechanism into the escapement recoveries in subsequent years. In addition, if this provision does occur, it will only apply on a yearly basis and therefore these multi-year effects should be minimized.

The differences in terminal run and escapement and the proportional increase in escapement between run 1 and run 2-scenario 1 were calculated for each stock (Table 3.1). The difference between the terminal run from run 1 and the terminal run from run 2 is the savings of mature fish resulting from a 10% reduction in catch in the SEAK and NBC AABM fisheries. Additional savings would be realized in 2010 and 2011 as a result of immature fish being saved in 2008 and 2009. The proportional increase in escapement ($PIEsc_{s,y}$) was computed as:

[8] The CEI file provides parameter values related to the quotas or ceilings for fisheries.
[9] Fishery Policy (FP) is a stock and age specific scalar that determines the potential stock and age composition in the catch by fishery (i.e. fishery policy because stock composition can be changed via time and area adjustments).

$$PIEsc_{s,y} = \left(\frac{Esc2_{s,y}}{Esc1_{s,y}} \right) - 1 \tag{3.1}$$

where $Esc1_{s,y}$ is the escapement from model run 1 and $Esc2_{s,y}$ is the escapement from model run 2 for a given stock, *s* and year, *y*.

Table 3.1 Increase in terminal runs (all ages pooled), increase in escapements (all ages pooled), and proportional increase in escapements for 2007 to 2009 resulting from consecutive 10% reductions to SEAK and NBC catches in 2007 to 2009.

	Increase in Terminal Run			Increase in Escapement			Proportional Increase in Escapement			
Stock	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**Avg.**
Col R Summer	1385	1780	1923	398	1182	1269	2.5%	3.1%	2.7%	2.8%
Fraser Early	2363	2175	2189	1728	1580	1586	1.5%	1.4%	1.4%	1.5%
Fraser Late	245	372	780	209	306	738	0.2%	0.5%	0.5%	0.4%
Georgia St. Lwr Nat	85	100	94	85	100	94	1.6%	1.7%	1.9%	1.7%
Georgia St. Upper	2026	1682	1368	2026	1682	1368	9.5%	8.4%	6.7%	8.2%
Lewis R Wild	109	94	138	96	83	117	1.5%	1.3%	1.4%	1.4%
Nooksack Spring	1	1	1	1	1	1	0.2%	0.3%	0.2%	0.2%
North/Centr	4287	6533	10324	4287	6533	10324	3.0%	4.7%	6.8%	4.8%
Oregon Coast	2627	1563	1723	2325	1387	1512	3.6%	2.9%	2.8%	3.1%
Pgt Sd NatF	38	79	72	32	64	57	0.2%	0.4%	0.5%	0.4%
Skagit Wild	57	127	119	52	113	102	0.5%	0.9%	1.0%	0.8%
Snohomish Wild	35	62	61	24	41	39	0.6%	1.0%	1.0%	0.9%
Stillaguamish Wild	20	31	25	18	28	23	1.8%	2.3%	2.1%	2.1%
UpRiver Brights	2541	2822	5442	1839	1962	3774	1.9%	1.7%	2.0%	1.9%
WA Coastal Wild	843	851	1011	621	612	737	2.0%	1.8%	2.0%	2.0%
WCVI Natural	537	386	328	496	356	305	3.9%	3.8%	3.1%	3.6%

If all savings were passed into escapement, the difference in terminal run and the difference in escapement would be equal in Table 3.1. The actual ISBM harvest rate (all ages pooled) modeled in run 2 was calculated as (Table 3.2):

$$HR2_{s,y} = \frac{TR2_{s,y} - Esc2_{s,y}}{TR2_{s,y}} \tag{3.2}$$

The ISBM harvest rate (all ages pooled) required to pass all savings to escapement ($HRR_{s,y}$) was computed as (Table 3.2):

$$HRR_{s,y} = \frac{TR2_{s,y} - (Esc1_{s,y} + DTR_{s,y})}{TR2_{s,y}} \tag{3.3}$$

where $TR2_{s,y}$ is the terminal run from model run 2 for a given stock and year, $DTR_{s,y}$ is the difference in terminal run between model runs 1 and 2 for a given stock and year. Thus, the reduction required to the ISBM harvest rate ($ISBMR_{s,y}$) to pass the savings to escapement was computed as (Table 3.2):

$$ISBMR_{s,y} = HR2_{s,y} - HRR_{s,y} \tag{3.4}$$

Table 3.2 ISBM harvest rate modeled in run 2, ISBM harvest rate required to pass all savings to escapement, and absolute ISBM harvest rate reduction (with relative reduction in parentheses) required to pass-through savings to escapement for 2007 to 2009 resulting from consecutive 10% reductions to SEAK and NBC catches in 2007 to 2009.

	Run 2 Harvest Rate			Harvest Rate Required			Harvest Rate Reduction		
Stock	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
Col R Summer	71.6%	35.0%	35.1%	69.9%	34.0%	34.2%	1.7% (2.4%)	1.0% (2.9%)	0.9% (2.5%)
Fraser Early	25.3%	24.8%	25.2%	24.8%	24.4%	24.8%	0.4% (1.7%)	0.4% (1.6%)	0.4% (1.5%)
Fraser Late	8.6%	16.3%	11.8%	8.6%	16.2%	11.8%	0.0% (0.3%)	0.1% (0.5%)	0.0% (0.2%)
Georgia St. Lwr Nat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
Georgia St. Upper	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
Lewis R Wild	14.1%	13.4%	19.9%	13.9%	13.3%	19.7%	0.2% (1.3%)	0.2% (1.1%)	0.2% (1.0%)
Nooksack Spring	0.5%	1.0%	0.7%	0.5%	1.0%	0.7%	0.0% (0.5%)	0.0% (0.0%)	0.0% (0.0%)
North/Centr	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
Oregon Coast	10.7%	8.9%	12.7%	10.3%	8.6%	12.4%	0.4% (3.7%)	0.3% (3.6%)	0.3% (2.6%)
Pgt Sd NatF	22.2%	22.7%	23.2%	22.1%	22.6%	23.1%	0.0% (0.1%)	0.1% (0.3%)	0.1% (0.4%)
Skagit Wild	14.0%	12.8%	13.9%	13.9%	12.7%	13.8%	0.0% (0.3%)	0.1% (0.8%)	0.1% (1.0%)
Snohomish Wild	35.1%	35.2%	34.1%	34.9%	34.8%	33.7%	0.2% (0.5%)	0.3% (1.0%)	0.3% (1.0%)
Stillaguamish Wild	10.9%	11.3%	10.4%	10.7%	11.1%	10.2%	0.2% (1.7%)	0.2% (2.1%)	0.2% (1.9%)
UpRiver Brights	28.6%	33.3%	31.7%	28.1%	32.8%	31.1%	0.5% (1.8%)	0.5% (1.5%)	0.6% (1.8%)
WA Coastal Wild	26.9%	25.7%	26.9%	26.4%	25.2%	26.4%	0.5% (1.9%)	0.5% (2.0%)	0.5% (2.0%)
WCVI Natural	13.1%	8.1%	8.0%	12.8%	7.8%	7.8%	0.3% (2.1%)	0.3% (3.5%)	0.2% (2.7%)

3.3 SCENARIO 2: SAVINGS RESULTING FROM A ONE-YEAR REDUCTION TO SEAK AND NBC AABM CATCH

Calibration 1007P13R1 was used again as run 1 in scenario 2. Calibration 1007P13R2S2 (run 2-scenario 2) incorporated a 10% reduction in catch for the SEAK and NBC AABM fisheries in year 2007 while keeping the ISBM FP scalars unchanged from run 1. The 2008 and 2009 catches were kept at observed levels so the savings of mature fish in 2008 and 2009 as a result of saving immature fish in 2007 could be estimated. Terminal run and escapement estimates for 2007-2009 were extracted from the run 1 and run 2-scenario 2 output. The differences in terminal run and escapement and the proportional increase in escapement between run 1 and run 2-scenario 2 were calculated for each stock (Table 3.3). The difference between the terminal run from run 1 and the terminal run from run 2 is the savings of mature fish resulting from a 10% reduction in catch in the SEAK and NBC AABM fisheries in 2007.

The actual ISBM harvest rate modeled in run 2-scenario 2 was calculated using equation 3.2. The ISBM harvest rate required to pass all savings to escapement was computed using equation 3.3, and the reduction required to the ISBM harvest rate to pass the savings to escapement was computed using equation 3.4 (Table 3.4).

**Table 3.3	Increase in terminal runs (all ages pooled), increase in escapements (all ages pooled), and proportional increase in escapements for 2007 to 2009 resulting from a 10% reduction to SEAK and NBC catches in 2007.**

	Increase in Terminal Run			Increase in Escapement			Proportional Increase in Escapement			
Stock	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**Avg.**
Col R Summer	1385	1141	835	398	759	548	2.5%	2.0%	1.2%	1.9%
Fraser Early	2363	990	618	1728	753	477	1.5%	0.7%	0.4%	0.9%
Fraser Late	245	288	525	209	240	506	0.2%	0.4%	0.3%	0.3%
Georgia St. Lwr Nat	85	76	63	85	76	63	1.6%	1.3%	1.3%	1.4%
Georgia St. Upper	2026	1185	788	2026	1185	788	9.5%	5.9%	3.9%	6.4%
Lewis R Wild	109	51	62	96	45	51	1.5%	0.7%	0.6%	1.0%
Nooksack Spring	1	1	0	1	1	0	0.2%	0.2%	0.1%	0.2%
North/Centr	4287	5161	8063	4287	5161	8063	3.0%	3.7%	5.3%	4.0%
Oregon Coast	2627	818	523	2325	725	460	3.6%	1.5%	0.8%	2.0%
Pgt Sd NatF	38	68	50	32	54	39	0.2%	0.3%	0.3%	0.3%
Skagit Wild	57	108	84	52	95	71	0.5%	0.8%	0.7%	0.6%
Snohomish Wild	35	49	39	24	31	25	0.6%	0.8%	0.6%	0.7%
Stillaguamish Wild	20	23	16	18	21	14	1.8%	1.7%	1.3%	1.6%
UpRiver Brights	2541	1444	1672	1839	1008	1156	1.9%	0.9%	0.6%	1.1%
WA Coastal Wild	843	429	380	621	310	289	2.0%	0.9%	0.8%	1.2%
WCVI Natural	537	226	125	496	209	117	3.9%	2.2%	1.2%	2.5%

**Table 3.4	ISBM harvest rate modeled in run 2, ISBM harvest rate required to pass all savings to escapement, and absolute ISBM harvest rate reduction (with relative reduction in parentheses) required to pass-through savings to escapement for 2007 to 2009 resulting from a 10% reduction to SEAK and NBC catches in 2007.**

	Run 2 Harvest Rate			Harvest Rate Required			Harvest Rate Reduction		
Stock	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
Col R Summer	71.6%	35.0%	35.1%	69.9%	34.3%	34.7%	1.7% (2.4%)	0.6% (1.9%)	0.4% (1.1%)
Fraser Early	25.3%	24.7%	25.2%	24.8%	24.6%	25.1%	0.4% (1.7%)	0.2% (0.6%)	0.1% (0.4%)
Fraser Late	8.6%	16.3%	11.8%	8.6%	16.2%	11.8%	0.0% (0.3%)	0.1% (0.4%)	0.0% (0.1%)
Georgia St. Lwr Nat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
Georgia St. Upper	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
Lewis R Wild	14.1%	13.4%	20.0%	13.9%	13.3%	19.8%	0.2% (1.3%)	0.1% (0.6%)	0.1% (0.5%)
Nooksack Spring	0.5%	1.0%	0.7%	0.5%	1.0%	0.7%	0.0% (0.5%)	0.0% (0.0%)	0.0% (0.0%)
North/Centr	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% (0.0%)	0.0% (0.0%)	0.0% (0.0%)
Oregon Coast	10.7%	8.9%	12.7%	10.3%	8.7%	12.6%	0.4% (3.7%)	0.2% (2.0%)	0.1% (0.8%)
Pgt Sd NatF	22.2%	22.7%	23.2%	22.1%	22.6%	23.1%	0.0% (0.1%)	0.1% (0.3%)	0.1% (0.3%)
Skagit Wild	14.0%	12.8%	13.9%	13.9%	12.7%	13.8%	0.0% (0.3%)	0.1% (0.7%)	0.1% (0.7%)
Snohomish Wild	35.1%	35.2%	34.1%	34.9%	34.9%	33.8%	0.2% (0.5%)	0.3% (0.8%)	0.2% (0.7%)
Stillaguamish Wild	10.9%	11.3%	10.4%	10.7%	11.2%	10.3%	0.2% (1.7%)	0.2% (1.5%)	0.1% (1.2%)
UpRiver Brights	28.6%	33.4%	31.7%	28.1%	33.1%	31.5%	0.5% (1.8%)	0.3% (0.8%)	0.2% (0.6%)
WA Coastal Wild	26.9%	25.7%	26.9%	26.4%	25.5%	26.7%	0.5% (1.9%)	0.3% (1.0%)	0.2% (0.7%)
WCVI Natural	13.1%	8.1%	8.0%	12.8%	7.9%	7.9%	0.3% (2.1%)	0.2% (2.0%)	0.1% (0.9%)

The absolute reductions required to ISBM harvest rates were 1% or less, with the exception of Columbia River Summers in 2007 with 1.7% (2.4% relative reduction). In terms of relative changes, Oregon Coast in 2007 required the largest relative reductions to ISBM harvest rates (3.7%), followed by WCVI Naturals in 2008 (3.5%). This means that all the savings could be passed into escapement with little reduction in ISBM harvest. ISBM harvest rate reductions would have to occur in several consecutive years (e.g., 3 years) to pass all savings from reductions in AABM catch. ISBM harvest rate reductions were smaller for Scenario 1 than for scenario 2 to pass all savings to escapement. This occurs because scenario 2 incorporates additional reductions to AABM fisheries in 2008 and 2009 that result in larger savings to pass to escapement. The scenarios held the FP scalars constant for all stocks caught in ISBM fisheries from 2007-2009, which is equivalent to assuming the same annual ISBM harvest rate for 2007-2009.

4 ADDITIONAL CRITERIA USED TO MONITOR PERFORMANCE OF ISBM FISHERIES

4.1 1991-1996 ISBM AVERAGE EXPLOITATION RATE CRITERION

This section addresses the third ISBM assignment regarding an evaluation of the 1991 to 1996 ISBM average criterion, also referred to as the additional obligation in Paragraph 6(b(ii)) of the 2008 Agreement. This provision limits the amount of additional reductions required in U.S. ISBM fisheries where severe restrictions began in 1991 in the Columbia River as a result of Endangered Species Act listings.

Through the general obligation, Canada and the United States agreed to additional precautionary measures by limiting their adult equivalent mortality rates in the aggregate of their ISBM fisheries to no greater than 63.5% and 60.0%, respectively, relative to the mortality that occurred in the base period (Paragraph 8(c), Chapter 3, 2008 Agreement). This obligation applies to stock groups identified in Attachments IV and V that are not achieving their management objectives. For those stocks for which the general obligation is insufficient to meet the agreed MSY or other biologically-based escapement objectives, the Party in whose waters the stock originates shall further constrain its fisheries to the extent necessary to achieve the agreed MSY or other biologically-based escapement objectives, provided that a Party is not required to constrain its fisheries to an extent greater than the average of that which occurred in the years 1991to 1996. Unless otherwise recommended by the CTC and approved by the Commission, the ISBM index defined in CTC (2005) where data are available for the required time periods, the average total annual adult equivalent mortality rate that occurred in 1991 to 1996, or an alternative metric recommended by the CTC and approved by the Commission will be used to monitor performance of ISBM fisheries. A detailed description of the methods which use CWT recoveries to compute the current ISBM index for stocks with various data levels can be found in Sharma (2005). Currently, the ISBM equation (equation 1.1) can be computed for nine stocks for the U.S. ISBM index and 12 stocks for the Canadian ISBM index.

There are 41 escapement indicator stocks listed in Attachments IV and V to represent 12 stocks groups (Table 4.1 and Table 4.2). Some stock groups with multiple indicator stocks are represented by a single CWT stock while for other stock groups there is a one-to-one correspondence between an indicator and a CWT stock. There are two stock groups, Fraser Early and North/Central British Columbia that have CWT stocks but have not yet been used by the CTC to monitor the performance of the Canadian ISBM fisheries. Altogether, there are 14 CWT stocks used in ISBM index computations. Ten of the CWT stocks had all four years of base period CWT recovery data to calculate the base period exploitation rates (*BPER* in equation 1.2). For the other four CWT stocks without the requisite number of base period years, the base period terminal harvest rates come from surrogate (proxy) stocks. For stocks with terminal fisheries directed on hatchery production and not representing impacts on natural production, separate terminal area harvest rates were calculated for the hatchery and natural components. For these stocks, the natural component harvest rate was used to modify the CWT recoveries from the terminal area fisheries. The ISBM index was calculated for only 32 of the 41 indicator stocks (11 were calculated directly from terminal harvest rates estimated from CWT tag recoveries; 21 required external estimates of terminal harvest rates; Table 4.1and Table 4.2). Management agencies provided external estimates of terminal harvest.

ISBM indices for any given year were not computed if the number of estimated CWT recoveries was less than 35 or if there was no corresponding CWT stock. These indices are reported as "NA". ISBM indices with negative values (due to zero or near zero base period exploitation rates) are also reported as "NA". Post-season ISBM indices were calculated using CWT data from the 2009 exploitation rate analysis (see Appendix 5). Finally, the average 1991-1996 ISBM index was calculated for each stock and evaluated relative to the general obligation and any CTC accepted escapement goals. Unlike indices for recent years with incomplete broods, which may vary, the indices from 1991 to 1996 are based on data from complete brood years.

The 1991-1996 period was identified as the basis for the additional obligation due to the assumption that low exploitation rates in the U.S. Chinook salmon fisheries occurred during this period in response to Endangered Species Act provisions. However, an average ISBM index across stocks of 1.14 (range: 0.43-2.36) shows that ISBM exploitation rates were greater during this period than in the 1979 to 1982 base period. For comparison, the average 1991-1996 ISBM index across stocks in Canadian Chinook salmon fisheries was 0.52 (range: 0.25-0.74). Some of these averages, however, include years with escapement levels above escapement goals.

The evaluation of the average 1991-1996 ISBM index showed that the 1991 to 1996 index average is lower than the general obligation for three out of four (75%) stocks impacted by Canadian ISBM fisheries (Figure 4.1). For the fourth stock, Upper Georgia Strait (GSQ), the general obligation is more restrictive. However, since the 1991-1996 average criterion applies exclusively to stocks with CTC accepted escapement goals, this additional obligation only applies to the Cowichan (COW) and the Harrison (CHI) Chinook stocks The exclusion of 1996 from the average was explored since many Canadian fisheries were closed that year due to conservation concerns, but that had no impact on the conclusions (Figure 4.1bottom). When the average is computed only for stocks with CTC accepted escapement goals and years when the escapement goal was not met, the average index value decreased from 0.25 to 0.16 (0.13 when 1996 is excluded) for Harrison (CHI); both values are substantially lower than the general obligation.

For U.S. ISBM fisheries, the 1991-1996 average ISBM index was lower than the general obligation for three out of thirteen (23%) stocks (Figure 4.2). The 1991-1996 average criterion would have further constrained ISBM fisheries impacting the Deschutes, Lewis River Wild, and Stillaguamish Chinook stocks. However, since the 1991-1996 average criterion applies exclusively to stocks with CTC accepted escapement goals, the Stillaguamish Chinook stock was not a candidate for the implementation of the additional obligation because it has no CTC accepted escapement goal for this stock[10]. Furthermore, the additional obligation applies only during the years when the Deschutes and the Lewis River Wild Chinook stocks failed to meet their escapement objectives. When the average is computed only for stocks with CTC accepted

[10] Stillaguamish is one of eight stocks in Attachments IV and V with an exploitation-rate management objective with which the 1991-1996 average criterion does not apply.

escapement goals and years when the escapement goal was not met, the average index value increased in the Hoh (from 1.12 to 2.37), Quillayute (from 0.76 to 1.52), and Siuslaw (from 1.60 to 2.36), thus indicating that ISBM adult equivalent mortality rates for these stocks were greater in years when escapement goals were not met.

Table 4.1 Stock groups, indicator stocks whether external estimates of terminal harvest rates are required, CWT indicator, and base period data proxy for Canadian ISBM fisheries.

Stock group	Stocks in Group (Indicator stocks)	External terminal HR	CWT stock	Base period stock if number of base period years is less than four
Lower Strait of Georgia	Cowichan Nanaimo	Yes	COW	GST
Fraser Late	Harrison	Yes	CHI	FRL
North Puget Sound Natural Springs	Nooksack Skagit	No No	NSF NSF	NKS NKS
Upper Strait of Georgia	Klinaklini Kakwiekan Wakeman Kingcome Nimpkish	No	QUI	NA
Fraser Early (Spring and Summers)	Upper Fraser Mid Fraser Thompson	NA	NA	NA
West Coast Vancouver Island Falls	Artlish Burman Gold Kaouk Tahsis Tashish Marble	No	RBT	NA
Puget Sound natural Summer/Falls	Skagit Stillaguamish Snohomish Lake Washington Green River	No No NA NA No	SSF STL NA NA SPS	SKG NA NA NA NA
North/Center British Columbia	Yakoun Skeena Nass Area 8 (Atnarko,Dean)	NA	NA	NA

Table 4.2 Stock groups, indicator stocks whether external estimates of terminal harvest rates are required, CWT indicator, and base period data proxy for U.S. ISBM fisheries.

Stock group	Stocks in Group (Indicator stocks)	External terminal HR	CWT stock	Base period stock if number of base period years is less than four
Washington Coastal Fall Naturals	Hoko	Yes	HOK	NA
	Hoh	Yes	QUE	NA
	Quillayute	Yes	QUE	NA
	Queets	No	QUE	NA
	Grays Harbor	Yes	QUE	NA
Columbia River Falls	Upriver Brights	No	URB	NA
	Deschutes	Yes	URB	NA
	LRW	No	LRW	NA
West Coast Vancouver Island Falls	Artlish Burman Gold Kaouk Tahsis Tashish Marble	No	RBT	NA
Puget Sound natural Summer/Falls	Skagit	No	SSF	SKG
	Stillaguamish	No	STL	NA
	Snohomish	NA	NA	NA
	Lake Washington	NA	NA	NA
	Green River	No	SPS	NA
Fraser Late	Harrison	Yes	CHI	FRL
Columbia River Summers	Mid-Col Summers	No	SUM	NA
Far North Migrating Oregon Coastal Falls	Siletz	Yes	SRH	NA
	Siuslaw	Yes	SRH	NA
	Nehalem	Yes	SRH	NA
North Puget Sound Natural Springs	Nooksack	No	NSF	NKS
	Skagit	No	NSF	NKS

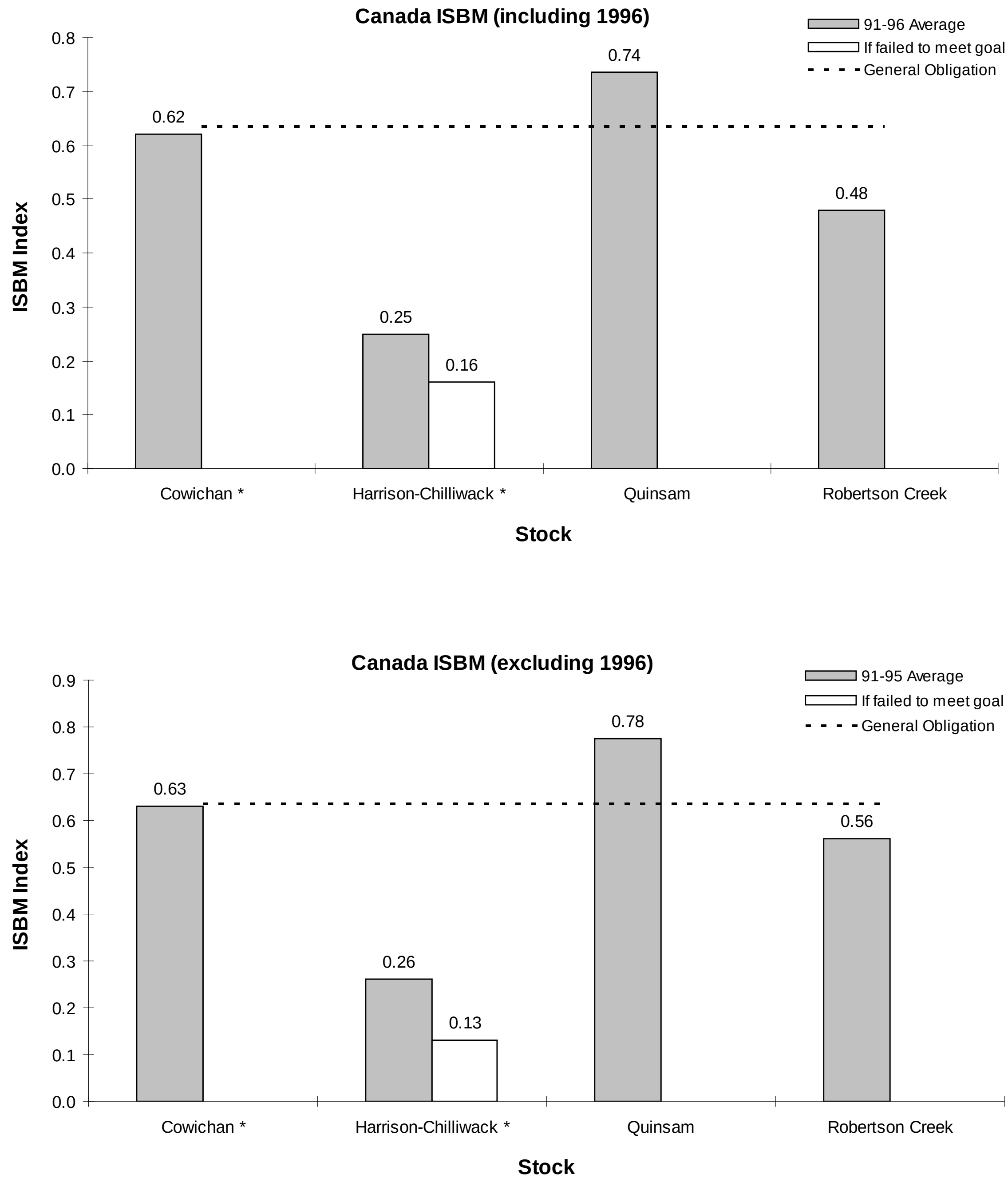

Figure 4.1 The 1991-1996 (upper) and 1991-1995 (lower) average ISBM index for Canadian stocks in Canadian ISBM fisheries. The ISBM index corresponding to the PST general obligation (63.5% for Canadian fisheries) is also shown. An asterisk indicates a CTC accepted escapement goal exists for that stock. Grey bars represent the average of all years whereas white bars represent the average for years when escapement goals were not met.

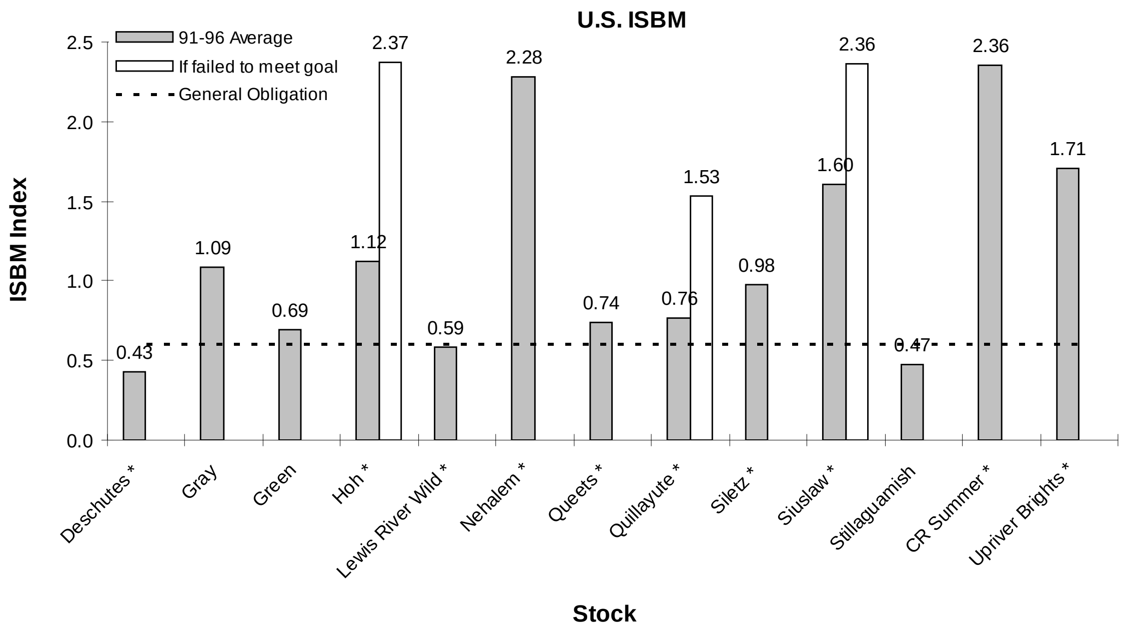

Figure 4.2 The 1991 to 1996 average ISBM index for U.S. stocks in U.S. ISBM fisheries. The ISBM index corresponding to the PST general obligation (60% for U.S. fisheries) is also shown. An asterisk indicates a CTC accepted escapement goal exists for that stock. Grey bars represent the average of all years whereas white bars represent the average for years when escapement goals were not met.

4.2 ISBM COMPONENT OF STOCK PERFORMANCE EVALUATION IN PARAGRAPH 13

In Chapter 3 of the 2008 Agreement, Paragraph 13 outlines a precautionary feature leading to further reductions in AABM and ISBM fisheries when specific conditions around management objectives occur for stocks and stock groups in Attachments I-III. Part of the evaluation of whether management objectives are met for individual stocks considers the performance of ISBM fisheries relative to their obligations and their effect on spawning escapement. The steps included in this evaluation are illustrated in Figure 4.3 and dictated in Paragraphs 13(d) and 13(e):

> *Paragraph 13. The Parties agree:*
> *(d) action will be taken consistent with (c)(i) or (c)(ii) for AABM fisheries even if escapement exceeds 85% of the agreed escapement goal as a consequence of harvest levels in ISBM fisheries in the jurisdiction in which the stock originates that were more restrictive than the obligations required pursuant to paragraph **8**;*
> *(e) action will not be taken under (c)(i) or (c)(ii) above, for AABM fisheries even if escapement is less than 85% of the agreed escapement goal as a consequence of an ISBM fishery not meeting the general obligation listed under paragraph 8;*

The conditions described in Paragraph 13(d) and (e) evaluate the effect of ISBM fisheries on observed spawning escapements and determine if the stock exceeded 85% of the escapement goal. Paragraph 13(d) describes a situation in which a stock can be identified as triggering additional management action under Para 13, even if escapement exceeded the threshold, whereas Paragraph 13(e) describes a situation in which a stock can be excluded from triggering additional management action under Paragraph 13, even if the management objective is not met (Figure 4.3).

Paragraph 13(d) evaluates if a stock that met the escapement threshold did so because ISBM fisheries in the jurisdiction that the stock originated were further constrained to a degree beyond that required in Paragraph 8. It provides an incentive to further reduce ISBM fishing rates to help achieve escapement objectives, while retaining the potential to trigger reduction of AABM fishing in response to poor stock performance and escapement.

Paragraph 13(e) evaluates if a stock would have had a spawning escapement greater than the threshold if a jurisdiction's ISBM fisheries had an impact equivalent to the ISBM general obligation. Paragraph 13(e) is evaluated for ISBM fisheries in both jurisdictions, whereas Paragraph 13(d) is evaluated only for the jurisdiction in which the stock originates. Paragraph 13(e) prevents a stock from being incorrectly identified as having not achieved its escapement-based management objective because a jurisdiction's ISBM fisheries exceeded the general obligation.

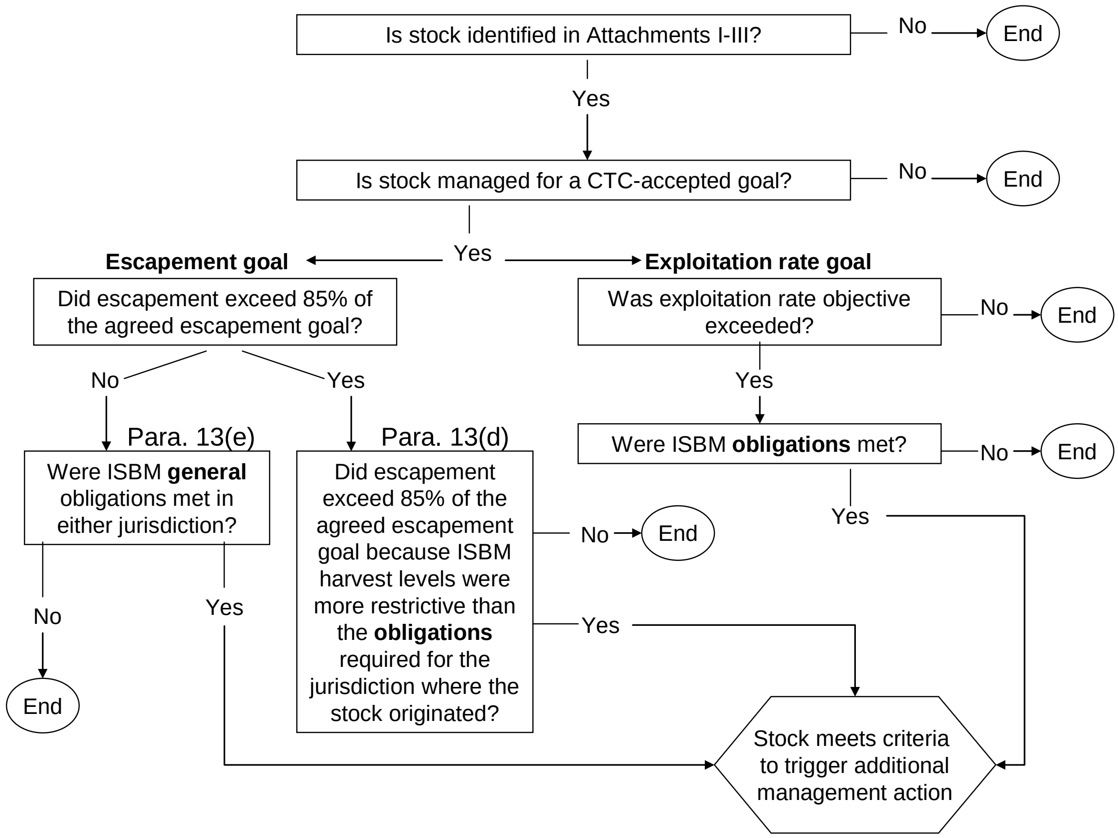

Figure 4.3 A diagram outlining the steps to perform the evaluation in Paragraph 13(d) and 13(e) of the 2008 Agreement pertaining to performance of ISBM fisheries.

4.2.1. Methods for Paragraph 13(d) and 13(e) evaluation

Paragraph 13(d) and 13(e) can be evaluated using a common method since both require estimation of the spawning escapement that would have occurred if a jurisdiction's ISBM fishery impact was the same as the obligation level. The annual ISBM exploitation rate ($E\hat{R}I_{a,j,y}$) for year *y*, jurisdiction *j*, and age *a* is given by:

$$E\hat{R}I_{a,j,y} = \frac{\sum_{f=ISBM_j} AEQ\_TM_{f,j,y,a}}{A_{a,y}}; \tag{4.1}$$

where $AEQ\_TM_{f,j,y,a}$ represents the total mortality in adult equivalency units for fishery *f*, jurisdiction *j*, year *y*, and age *a*, and *A* represents the cohort abundance after natural mortality. Both *AEQ_TM* and *A* can be obtained from the CTC 'hrj database[11]' for CWT exploitation rate indicator stocks. All other exploitation in other fisheries ($E\hat{R}O_{a,y}$) is given by:

$$E\hat{R}O_{a,y} = \frac{\sum_{f \neq ISBM_j} AEQ\_TM_{f,j,y,a}}{A_{a,y}}; \tag{4.2}$$

The ISBM exploitation rate ($E\hat{R}P_{a,j}$) can be either the average that occurred during base period years 1979-1982 multiplied by the general obligation reduction (GO_j = 60% for U.S. and 63.5% for Canada) or the average of 1991-1996, only for the jurisdiction in which the stock originates, depending on whichever is the most restrictive.

$$E\hat{R}P_{a,j} = GO_j \frac{\sum_{y=1}^{y=n} \frac{\sum_{ISBM_j} AEQ\_TM_{f,j,y,a}}{A_{a,y}}}{n} \tag{4.3}$$

The escapement ($E_{a,y}$) is the component of the mature cohorts that survived AABM and ISBM fisheries and reached the spawning grounds. Escapement can be estimated from the abundance ($A_{a,y}$), maturation rate (M_a), and the exploitation rates in the ISBM ($E\hat{R}I_{a,j,y}$) and all other fisheries ($E\hat{R}O_{a,y}$):

$$\hat{E}_{a,y} = A_{a,y} M_a \left(1 - E\hat{R}I_{a,j,y} - E\hat{R}O_{a,y}\right)) \tag{4.4}$$

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[11] The .hrj file is an output file in the CTC exploitation rate analysis and reporting process that includes information on CWT based AEQ and nominal mortalities by stock, age and brood year across fisheries as well as cohort sizes and terminal run size for terminal fisheries.

$$\hat{P}_{a,y} = A_{a,y} M_a \left(1 - E\hat{R}P_{a,j} - E\hat{R}O_{a,y}\right) \qquad (4.5)$$

where the projected escapement ($\hat{P}_{a,y}$) is estimated by rearranging equation 4 to calculate $A_{a,y} M_a$ and then substituting it for $A_{a,y} M_a$ in equation 5:

$$\hat{P}_{a,y} = \hat{E}_{a,y} \frac{\left(1 - E\hat{R}P_{a,j} - E\hat{R}O_{a,y}\right)}{\left(1 - E\hat{R}I_{a,j,y} - E\hat{R}O_{a,y}\right)} \qquad (4.6)$$

The projected escapements are summed over all ages that comprise the escapement objective:

$$\hat{P}_y = \sum_a \hat{P}_{a,y} \qquad (4.7)$$

Note, if the projected escapement ($\hat{P}_y$) is below the threshold, and if the ISBM fishery in the jurisdiction of origin had not been constrained to less than the obligations in Paragraph 8, then the stock is flagged as meeting the criteria to trigger additional management action in the AABM fisheries (Table 4.3). If the projected escapement would have exceeded the threshold if the ISBM fisheries had met the general obligation, then the stock is not flagged as meeting the criteria to trigger additional management action in the AABM fisheries (Table 4.4).

Table 4.3 Case 1 when the ISBM fisheries are below the Paragraph 8 obligation and the flag applies.

Case 1: Restricted below obligation			Projected E Under ISBM Obligation			Ratio Estimator	
ERI	0.2		ERP (ISBM rate)	0.5			
1-ERI	0.8		1-ERP	0.5		1-ERI	0.8
						1-ERP	0.5
A	1000		A	1000		E	640
M	0.8		M	0.8			
$E_{Observed}$	640		Predicted (P)	400		P	400
$E_{Threshold}$	480		$E_{Threshold}$	480		$E_{Threshold}$	480

Table 4.4 Case 2 when the ISBM fisheries exceed the general obligation and the flag does not apply.

Case 2: Exceed obligation			Projected E Under ISBM Obligation			Ratio Estimator	
ERI	0.65		ERP	0.5			
1-ERI	0.35		1-ERP	0.5		1-ERI	0.35
						1-ERP	0.5
A	1250		A	1250		E	350
M	0.8		M	0.8			
$E_{Observed}$	350		Predicted (P)	500		P	500
$E_{Threshold}$	480		$E_{Threshold}$	480			

4.2.2. Paragraph 13(d) and (e) evaluation examples

The Harrison and Nehalem river stocks were chosen to demonstrate how the Paragraph 13(d) and 13(e) evaluation can be used to improve the CTC's evaluation of indicator stock performance and to be consistent with the evaluation conditions described in the 2008 Agreement.

4.2.2.1. Harrison River Paragraph 13(d) evaluation for 2009

The 2009 escapement to the Harrison River (72,162) exceeded 63,835 which is 85% of the lower value of the escapement goal range (escapement goal range: 75,100-98,500), however it is unclear if the stock should be flagged for triggering additional management actions because the Canadian ISBM fisheries were restricted more than required pursuant to Paragraph 8.

The Harrison River escapement indicator stock is represented by the Chilliwack River exploitation rate indicator stock. As the first CWT'd brood year that the CTC uses for Chilliwack River is 1981, the CTC out-of-base cohort analysis procedure (Starr and Scott 1991) was used to estimate exploitation rates during 1979-1982 (Table 4.5). Base period exploitation rates were multiplied by the Canadian fishery general obligation (0.635) to calculate $E\hat{R}P_{a,j}$. Paragraph 8 identifies that the ISBM fishery obligation can be the average exploitation rate during 1991-1996 if it is less than the general obligation for the British Columbia fisheries where the stock originates. Average Canadian ISBM fishery exploitation rates during 1991-1996 were derived from the Chilliwack CWT data (CHI hrj file) with exclusion of terminal sport fishery exploitation rates: the Chilliwack River sport fishery does not represent the effects of terminal sport fisheries on the Harrison stock.

The Harrison escapement projected under the additional 1991-1996 obligation exceeds the threshold, whereas the escapement projected under the general obligation is below the threshold (Table 4.5). The additional obligation would be used for the ISBM evaluation because it is more restrictive than the general obligation. Therefore, the Harrison stock would not be flagged as meeting the criteria to trigger additional management action under Paragraph 13(d) for 2009.

Table 4.5 Exploitation rates and escapement data used to project escapements for the Harrison River escapement indicator stock in 2009 under two obligation levels pursuant to Paragraph 8 of the 2008 Agreement.

Variable	Symbol	Age-3	Age-4	Age-5	Total
Base Period Exploitation Rates					
Canadian ISBM[1]		0.604	0.412	0.025	NA
Canadian ISBM @ 0.635 Obligation[1]	$E\hat{R}P_a$	0.383	0.261	0.016	NA
1991-1996 Average Exploitation Rates					
Canadian ISBM[1]	$E\hat{R}P_a$	0.123	0.080	0.042	NA
2009 Exploitation Rates					
Canadian ISBM[1]		0.042	0.083	0.000	NA
All Other Fisheries	$E\hat{R}O_{a,y}$	0.082	0.120	0.000	NA
Escapements					
2009 Observed	$\hat{E}_{a,y}$	3,279	66,865	2,018	72,162
2009 Projected at General Obligation ER	$\hat{P}_{a,y}$	2,000	51,874	1,986	55,860
2009 Projected at 1991-1996 Obligation ER	$\hat{P}_{a,y}$	2,975	67,096	1,934	72,005
Escapement Objective Threshold		NA	NA	NA	63,835

[1]excludes terminal sport in Chilliwack River.

4.2.2.2. Nehalem River Paragraph 13(e) evaluation for 2008

The 2008 escapement to the Nehalem River (3,809) was below 5,941 which is 85% of the lower value of the escapement goal range (escapement goal: 6,989), however under Paragraph 13(e) it is necessary to determine if the escapement objective was not attained because the U.S. ISBM fisheries exceeded the General Obligation pursuant to Paragraph 8. The Nehalem River is only identified in Attachment V for the U.S. ISBM fisheries, thus there is not an ISBM obligation for Canadian fisheries.

The Nehalem River escapement indicator stock is represented by the Salmon River exploitation rate indicator stock. The first CWT'd brood year that the CTC uses for Salmon River is 1977, so CWT data were used to estimate base period and average 1991-1996 exploitation rates. Salmon River Chinook salmon mature at ages 2 to 6. However, age-5 and age-6 CWT data were combined due to limits with the number of ages used by the CTC cohort analysis program. Base period exploitation rates were multiplied by the U.S. fishery general obligation (0.60) to calculate $E\hat{R}P_{a,j}$. For the U.S. ISBM general obligation, the Salmon River terminal exploitation rates were used to represent those in the Nehalem River for example purposes, as more specific information from the base period was not available to characterize the terminal sport fishery. However, more specific information was available for the 2008 Nehalem River terminal sport fishery, accordingly those exploitation rates were used instead of those for the Salmon River terminal sport fishery.

The Nehalem 2008 escapement projected at the General Obligation was less than the threshold, (Table 4.6), therefore, the Nehalem stock would be flagged as meeting the criteria in 2008 for triggering additional management actions under Paragraph 13.

Table 4.6 Exploitation rates and escapement data used to project escapements for the Nehalem River escapement indicator stock in 2008 under two obligation levels pursuant to Paragraph 8 of the 2008 Agreement.

Variable	Symbol	Age-3	Age-4	Age-5&6	Total
Base Period Exploitation Rates					
U.S. ISBM		0.044	0.090	0.236	NA
U.S. ISBM @ 0.60 Obligation	$E\hat{R}P_a$	0.026	0.054	0.141	NA
2008 Exploitation Rates					
U.S. ISBM[1]		0.029	0.004	0.170	NA
All Other Fisheries	$E\hat{R}O_{a,y}$	0.033	0.787	0.435	NA
Escapements					
2008 Observed	$\hat{E}_{a,y}$	234	1,055	2,520	3,809
2008 Projected at U.S. General Obligation	$\hat{P}_{a,y}$	235	804	2,706	3,745
Escapement Objective Threshold		NA	NA	NA	5,941

[1]Nehalem River terminal harvest rate used to calculate terminal sport mortalities instead of SRH terminal sport recoveries.

5 GENERAL CONCLUSIONS

5.1 ALTERNATIVE ISBM INDICES

The alternative ISBM metrics provide several analytical approaches ranging from standard evaluations of exploitation rates, and whether escapement goals are met or exceeded for conservation purposes, to complex approaches involving GLMs and statistical catch-at-age models. No single alternative metric corrected all the limitations of the current indices nor exhibited all the desirable attributes. However, methods that allow for the computation of pre-season and post-season indices under a common analytical framework are highly desirable. Currently, pre-season indices are produced by the PSC Chinook Model while post-season indices are based on the analysis of CWT data, thus producing indices that track each other poorly in most cases. Methods based on GLM-based CWT projections (Method 1), effort-based catch-at-age models (Method 2), and FRAM-based indices (Method 5) have a common analytical framework but only methods 1 can be currently applied coastwide.

In terms of parsimony and simple usage, the mortality distribution ISBM index (Method 3) may do an adequate job of evaluating whether some ISBM obligations were met and has the ability to fill base period data gaps. However, this method only applies to post-season assessments and is currently affected by the delay in CWT data from U.S. ISBM fisheries for several ISBM stocks. Methods 1b (a variant of Method 1 based on a Poisson model), 2 and 3 have the advantage of being relatively insensitive to the effect of incomplete broods on post-season estimates. Under data-rich situations (e.g., URB stock), a more comprehensive assessment could be conducted using Method 2. However, effort data are scarce for many ISBM fisheries, therefore limiting the coastwide application of this method.

The composite index (Method 4) could remove information gaps in ISBM evaluations given our existing data and coverage but it requires a restructuring of the Attachment tables and the 2008 Agreement to have regional based composites for different areas with highly correlated ISBM fishery impacts. A restructuring of the Attachment tables in the Agreement including regional composites for different areas could remove information gaps in ISBM evaluations given our existing data and coverage. This can be deemed as an appropriate alternative to pursue in the presence of incomplete or missing data for stocks. Using a composite may provide some inference on the regional aggregate of stocks and/or fisheries. Alternatively, in much the same manner the overage/underage provision in the Treaty has moved to an evaluation of whether AABM fisheries are meeting their expectations or not, the ISBM could be tracked on a case by case basis. Patterns of exceeded ISBM obligations can be identified to the Commission and consequential conservation fishing plans developed to address these issues, in much the same way the Pacific Fisheries Management Council develops over-fishing reports when a stock does not meet a goal for three consecutive years.

The CTC recommends Methods 1a (a variant of Method 1 based on the current ISBM equation) and 1b as approaches deserving further investigation towards their usage in ISBM performance evaluations. Although Method 1a has the advantage of using the current algorithm, thus facilitating a transition to a new metric, it still suffers from instability of post-season computations under incomplete broods. In contrast, Method 1b does not suffer from this limitation but it uses an alternative algorithm for post-season computations. From the point of view of simplicity, Method 3 could facilitate the computation of post-season estimates for stocks currently not evaluated due to lack of base period data with further refinement to better represent the ocean distribution and terminal fisheries of ISBM stocks. Nonetheless, new analytical effort would have to be invested by CTC members in order to fully implement the use of a new approach for the computation of pre- and post-season ISBM indices.

5.2 THE CURRENT ISBM INDICES

A variety of alternative approaches were examined to calculate the ISBM indices. The existing methodology for calculating the pre-season and post-season versions of the ISBM indices has also been given some fresh scrutiny, which has identified several ways to improve the current indices. Some improvements have already been achieved, and some are expected to occur in the future as the CTC proceeds with planned improvements to the CAS database system and the PSC Chinook Model. The improvements that have already occurred should increase stability of the index in the most recent 3 - 4 calendar years, depending on the stock. This will result from improved treatment of incomplete broods through adoption of different algorithms to calculate the pre-fishery cohort size at each age present in the incomplete broods. The effect of all agencies attempting to provide current CWT estimates based on the best catch estimates available at the time would also be considerable.

Future improvements will take place with current ISBM index calculations when the annual exploitation rate analysis and Model calibration are based on a set of fisheries that accurately represent the true ISBM impacts of fisheries prosecuted by each country. Currently, aggregation of certain fisheries (e.g., the AABM QCI sport and ISBM North Sport) result in the exclusion of those impacts from the ISBM calculations for practical reasons. The aggregation of certain fisheries currently results in ISBM values that are either higher or lower than they should be because they are incorrectly attributed (or not) to a country. For example, terminal net and sport impacts to date have been assigned to the country of origin of the stock rather than the terminal area of the country in which the impacts happened. This decision was made when computer memory was severely limited but modern computing and programming technology have removed such limitations. The CTC will be testing and will begin using a new version of the CAS database based on the enhanced fishery strata for the exploitation rate analysis in 2012. Corresponding changes to the fishery structure in the PSC Chinook Model will follow in the future. Other future improvements will occur as the new and updated data are incorporated to create the stock- and age-specific data representing the 1979-1982 base period and the PSC Chinook Model is recalibrated.

The sum effect of all these improvements is unknown at this time and not all problems with the existing indices will be resolved. Changes in the index values will continue until all fish from a given brood have died of natural causes have been caught in fisheries or have spawned. All ISBM index approaches will suffer from some of the same problems (though not all from the incomplete brood issue) or even from some additional ones. No one alternative has been proposed that appears likely to possess all the desired qualities, overcome all the known problems or to provide a more reliable tool for post-season assessment or pre-season planning. One definite step forward, regardless of the approach eventually chosen, will be the adoption of one common framework (algorithm and data) for calculating both the pre-season and post-season versions of the index.

5.3 ASSESSMENT OF ISBM FISHERIES UNDER PASS-THROUGH PROVISIONS

The main finding from the quantitative assessment of pass-through provisions was that a 10% reduction in AABM fisheries does not translate into an equivalent increase in escapement. Based on the modeled scenarios, the savings of mature fish accruing to terminal run varied among stocks. Proportional increases in escapement were less than 4% in all stocks, except for Upper Georgia Strait and North/Central. The magnitude of the savings for a specific stock is influenced by its cohort size and exploitation in the AABM fisheries. If the stock is caught in small numbers in the AABM fisheries, then there will be few fish saved for that stock. All savings from catch reductions in AABM fisheries do not accrue into terminal runs and escapements the same year because not all saved fish mature that same year. Immature fish saved in a given year experience natural and fishing mortality for at least one additional year prior to maturing. The differences in terminal runs and escapements in 2007 are identical for both scenarios and only include mature fish saved in 2007. The differences in terminal runs and escapements for 2008 and 2009 are different for each scenario because scenario 1 had additional AABM reductions in 2008 and 2009. The differences for 2008 and 2009 in scenario 1 include savings from both prior year reductions and current year reductions while the differences for 2008 and 2009 in scenario 2 only include savings resulting from the reduction in 2007.

The absolute reductions required to ISBM harvest rates were less than or equal to 1%, with the exception of Columbia River Summers in 2007 with 1.7% (2.4% relative reduction). In terms of relative changes, Oregon Coast in 2007 required the largest relative reductions to ISBM harvest rates (3.7%), followed by WCVI Naturals in 2008 (3.5%). This means that all the savings could be passed into escapement with little reduction in ISBM harvest. ISBM harvest rate reductions would have to occur in several consecutive years (e.g., 3 years) to pass all savings that result from a 10% reduction in AABM catch. Scenario 1 shows that the harvest rate does not have to be reduced as much as it does for scenario 2 to ensure that all savings are passed to escapement. This is due to the fact that scenario 2 incorporates additional reductions to AABM fisheries in 2008 and 2009 that result in larger savings that must be passed to escapement. The modeled scenarios held the FP scalars constant for all stocks caught in ISBM fisheries from 2007-2009. This is equivalent to assuming the same annual harvest rate for 2007-2009 in the ISBM fisheries. In reality, the annual harvest rates will vary for each stock caught in an ISBM fishery and the harvest rate of a specific stock in a specific fishery will control the amount of savings for a stock that is passed into escapement. In many instances, observed harvest rates are substantially lower than levels allowable under ISBM general obligations.

The scenarios presented are suitable to evaluate impacts on the stock complexes included in the PSC Chinook Model. In most instances these complexes include mixtures of hatchery and wild stocks; consequently, the statistics presented do not necessarily represent savings for individual natural stocks of conservation concern. The modeled scenarios also assume all stocks did not meet escapement goals. In reality, when spawning escapement meets the escapement goal, ISBM fisheries are not required to pass additional savings into escapement. The scenarios presented were a retrospective analysis using years with observed data. Projecting the impacts of a 10% catch reduction pre-season would not provide an accurate estimate of savings due to the unknowns of some input data (i.e. FP's, catch, incidental mortalities, etc.). The capacity to evaluate impacts as a result of reductions to AABM and ISBM catch is affected by limitations of the existing model (e.g. one time step, inadequate representation of natural stocks), uncertainties regarding where and when these reductions would occur, and the short timeframe available for timely assessments that could influence management decisions.

5.4 1991-1996 AVERAGE ISBM AS AN ADDITIONAL OBLIGATION

While the average 1991-1996 ISBM indices (i.e., additional obligation) for Canadian fisheries suggest that a lower harvest impact could become a threshold if stocks were not meeting their escapement goals and needed further reductions in exploitation rate targets, this argument does not hold for the U.S. ISBM fisheries. Given that the more restrictive of the two obligations, general obligation or additional obligation, would be recommended to meet escapement goals, the additional obligation would apply to all the Canadian ISBM stocks that were evaluated, except for Upper Georgia Strait, and it would apply the Deschutes and Lewis River Wild. The results of this evaluation indicate that the general obligation would serve as the primary threshold for most U.S. ISBM fisheries whereas the 1991-1996 average criterion would serve as a lower threshold for most Canadian ISBM fisheries. This lower threshold limit would only be applicable if stocks fail to meet the escapement goals even after the general obligation has been implemented in these fisheries (see also Appendix 1).

Since this evaluation shows that the general obligation would serve as the primary threshold for most U.S. ISBM fisheries whereas the 1991-1996 average criterion would serve as a lower threshold for most Canadian ISBM fisheries, the CTC concludes the additional obligation, using the 1991-1996 average exploitation rate, is more restrictive for Canadian ISBM fisheries than for U.S. ISBM fisheries.

5.5 ASSESSMENT OF PARAGRAPHS 13(D) AND 13(E)

The conditions described in Paragraphs 13(d) and (e) are seen as new components of the 2008 Agreement that improve on the precautionary features that were already part of the 1999 Agreement. These components evaluate the effect of ISBM fisheries on observed spawning escapements and determine if the stock exceeded the escapement threshold of 85% of the escapement goal. Paragraph 13(d) describes a situation when a stock can be identified as meeting the criteria to trigger additional management action under Paragraph 13, even if escapement exceeded the threshold, whereas Paragraph 13(e) describes a situation when a stock can be excluded from triggering additional management action under Paragraph 13, even if escapement is less than the threshold. The CTC demonstrated that Paragraphs 13(d) and 13(e) can be quantitatively evaluated using a common method since both require estimation of the spawning escapement that would have occurred if a jurisdiction's ISBM fishery impact was the same as the obligation level.

5.6 RECOMMENDATIONS FOR FUTURE WORK

- In order to further assess the applicability and performance of methods 1a and 1b, these methods should be applied to other stocks listed in attachments IV and V beyond the example provided with the URB stock.

- This report compares pre-season versus post-season indices within a method and across methods. However, the accuracies of these ISBM methods (i.e., current and alternative indices) are unknown. To compare the accuracy of the methods, a simulated data set is required. The simulated data set would provide a known total adult equivalent mortality rate for the base period and for the current period being evaluated. Extensive analytical work would be required to test the accuracy of each ISBM method using the simulated dataset. The CTC recommends contracting a third party to undertake this task.

- Although ISBM method 3 shows merits in terms of parsimony and simple usage, as well as its ability to fill base period data gaps, index computations will improve once AABM and ISBM contributions are clearly separated in mortality distribution tables and after further stratification of pre-terminal ISBM fisheries allows to uniquely represent terminal ISBM fisheries. Currently, the CTC is refining fishery strata to more accurately represent pre-terminal and terminal fisheries.

- It is recommended that CDFO communicate a proposal with options to correctly identify the AABM and ISBM CWT recoveries for the WCVI sport fishery to the Data Sharing and Chinook technical committees.

- The CTC should review the scope of the consequences of the absence of CNR impacts in base period exploitation rate for ISBM indices computed with the current approach.

- If late CWT data reporting issues continue to be irresolvable for some U.S. ISBM fisheries, then estimation models should be developed and reviewed to enable the CTC to report the ISBM indices on time to use in the pre-season management process for the next season.

- It took considerable time to evaluate the paragraph 13 ISBM provisions for the two stocks in Section 4.2.2. It is unlikely that the evaluation can occur within the timeframe of the annual CTC model calibration process for all stocks in order to provide timely advice to the Commission about the conditions for additional fishery management actions. Accordingly, the CTC recommends that a computer program be developed to use the CWT exploitation rate data (currently in the CTC hrj database) and escapement data to evaluate whether the paragraph 13 ISBM provisions were met. A computer program should enable the CTC to provide timely advice to the Commission about the Paragraph 13 ISBM provisions.

- Mark selective fisheries (MSF) present a significant challenge for making inferences on ISBM fishery impacts to wild stocks. MSF and mixed-bag MSF regulations create special conditions for the identification and analysis of CWT data to represent ISBM fishery impacts on natural stocks. Accordingly, the development of data sets and analytical methods for Chinook salmon should be developed collaboratively by PSC CTC, SFEC, and Data Sharing Committee.

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7 APPENDICES

Appendix 1. Extract from memorandum sent to the PSC Chinook Interface Group on June 16th, 2011.

TO: PSC Chinook Interface Group
FROM: John Carlile. Chuck Parken and Rishi Sharma (CTC co-chairs)
DATE: June 16th, 2011.
SUBJECT: Potential policy and other issues identified by the CTC in the June 2011 meeting.

While working on the CTC ISBM assignment, the CTC identified some potential issues that need clarification in order to conduct the necessary quantitative analysis to properly report on each Party's success and compliance with meeting the ISBM provisions in paragraphs 13 and 8. The issues generally involve interpretation of the different wording in the provisions as they apply to the types of management objectives and obligations as stated in the two paragraphs.

The 1999 and 2008 Agreements appear to have different applications of the "general obligation" for stocks that do not yet have agreed escapement objectives. The 1999 Agreement states:

> *4. The Parties agree that in respect of ISBM fisheries:*
> *(d) for the purposes of this paragraph, **until agreed escapement objectives** for the stock groups listed in Attachments I to V to this Chapter have been achieved, Canada and the United States shall reduce by 36.5 percent and 40 percent respectively, the total adult equivalent mortality rate, relative to the 1979-82 base period, in their respective ISBM fisheries that affect those stock groups. The reduction identified in this sub-paragraph shall be referred to as the "general obligation";*

In other words, if a stock group does not have escapement goals (or has failed to meet their agreed-to goals), the Parties are obligated to reduce their ISBM fisheries by the stated percentages.

The 2008 Agreement specifies similar, but not identical obligations in paragraph 8, and states:

> *8. With respect to ISBM fisheries, the Parties agree that:*
> *(c) for the purposes of this Chapter, and based on stock-specific information exchanged pre-season, Canada and the United States shall limit the total adult equivalent mortality rate in the aggregate of their respective ISBM fisheries to no greater than 63.5 percent and 60 percent, respectively, of that which occurred during the 1979 to 1982 base period on the indicator stocks identified in Attachments IV and V12 **for stocks not achieving their management objectives**. This limit shall be referred to as the general obligation. For those stocks for which the general obligation is insufficient to meet **the agreed MSY or other biologically-based escapement objectives**, the Party in whose waters the stock originates shall further constrain its fisheries to the extent necessary to achieve the agreed MSY or other biologically-based escapement objectives, provided that a Party is*

not required to constrain its fisheries to an extent greater than the average of that which occurred in the years 1991to 1996. Notwithstanding the foregoing, a Party need not constrain its ISBM impacts on a stock originating in its waters to an extent greater than necessary to achieve the agreed MSY or other biologically-based escapement objectives;

The 2008 Agreement appears to have omitted provisions calling for the general obligation to apply to stock groups listed in Attachments I-V without agreed management objectives (either escapement- or exploitation rate-based). Is this the correct interpretation or does the general obligation still apply to stocks without CTC-agreed management objectives?

Appendix 2. Chinook Stocks in FRAM and CWT brood years used for base period data sets.

Stock Name	Abbreviated Name	CWT Broods Included*
Nooksack-Samish summer/fall	NkSm FlFi	77, 79
North Fork Nooksack early (spring)	NFNK Sp–g	OOB - 84, 88 (N. Fk.)
South Fork Nooksack early (spring)	SFNK S–rg	OOB - 84, 88 (N. Fk.)
Skagit summer/fall fingerling	Skag FlFi	76, 77
Skagit summer/fall yearling	Skag FlYr	76
Skagit spring yearling	Skag S–Yr	OOB - 85, 86, 87, 90
Snohomish summer/fall fingerling	Snoh F–Fi	OOB - 86, 87, 88
Snohomish summer/fall yearling	Snoh FlYr	76
Stillaguamish summer/fall fingerling	Stil F–Fi	OOB - 86, 87, 88-90
Tulalip summer/fall fingerling	Tula F–Fi	OOB - 86, 87, 88
Mid S. Puget Sound fall fingerling	USPS FlFi	78,79
UW Accelerated fall fingerling	UW-A FlFi	77-79
Deep S. Puget Sound fall fingerling	DSPS FlFi	78,79
South Puget Sound fall yearling	SPSo FlYr	78,79
White River spring fingerling	Whte SpFi	OOB – 91-93
Hood Canal fall fingerling	HdCl FlFi	78,79
Hood Canal fall yearling	HdCl FlYr	78,79
Juan de Fuca Tribs. fall fingerling	SJDF FlFi	78,79
Oregon Lower Columbia River Hatchery	Oregn LRH	78,79
Wash. Lower Columbia River Hatchery	Washn LRH	77,79
Lower Columbia River Wild	Low CR Wi	77-78
Bonneville Pool Hatchery tule	BP H Tule	76-79
Columbia Upriver summer	Upp CR Su	76,77
Columbia Upriver bright	Col R Brt	75-77
Washington Lower River spring	WaLR Sprg	77
Willamette spring	Will Sprg	76-78
Snake River fall	SnakeR–Fl	OOB - 84, 85, 86
Oregon North Migrating fall	Ore No Fl	76-78
West Coast Vancouver Island Total	WCVI Totl	74-77
Fraser Late	Fraser–Lt	OOB - 81, 82, 83
Fraser Early	Fraser Er	78,79, OOB -, 86
Lower Georgia Strait fall	Lwr Geo St	77, 78
White River spring yearling	Whte SpYr	OOB – 91-93
Lower Columbia Natural Tule	LwrColN	77-79
Central Valley-Sacramento River	Ctr–al	OOB - 98-99
Washington North Coast	WA N Cst	77-78
Willapa Bay	Wilpa	OOB – 83-85
Hoko	Hoko	OOB – 85-87

*OOB = Out-of-base stock.

Appendix 3. Chinook fisheries in FRAM

Fishery Name	Fishery Name
Southeast Alaska Troll	NT Juan de Fuca Net (Area 4B,5,6,6C)
Southeast Alaska Net	T Juan de Fuca Net (Area 4B,5,6,6C)
Southeast Alaska Sport	Area 8 Sport a
North/Central British Columbia Net	NT Skagit Net (Area 8)
West Coast Vancouver Island Net	T Skagit Net (Area 8)
Strait of Georgia Net	Area 8D Sport
Canada Juan de Fuca Net (Area 20)	NT Stilly-Snohomish Net (Area 8A)
North/Central British Columbia Sport	T Stilly-Snohomish Net (Area 8A)
North/Central British Columbia Troll	NT Tulalip Bay Net (Area 8D)
West Coast Vancouver Island Troll	T Tulalip Bay Net (Area 8D)
West Coast Vancouver Island Sport	Area 9 Sport
Strait of Georgia Troll	NT Area 6B/9 Net
North Strait of Georgia Sport	T Area 6B/9 Net
South Strait of Georgia Sport	Area 10 Sport
BC Juan de Fuca Sport	Area 11 Sport
NT Cape Flattery-Quillayute Troll (Area 3-4)	NT Area 10/11 Net
T Cape Flattery-Quillayute Troll (Area 3-4)	T Area 10/11 Net
Cape Flattery-Quillayute Sport (Area 3-4)	NT Area 10A Net
Cape Flattery-Quillayute Net (Area 3-4)	T Area 10A Net
NT Grays Harbor Troll (Area 2)	NT Area 10E Net
T Grays Harbor Troll (Area 2)	T Area 10E Net
Grays Harbor Sport (Area 2)	Area 12 Sport
NT Grays Harbor Net	NT Hood Canal Net (Area 12,12B,12C)
T Grays Harbor Net	T Hood Canal Net (Area 12,12B,12C)
Willapa Net	Area 13 Sport
NT Columbia River Troll (Area 1)	NT Deep S. Puget Sound Net (13,13D-K)
Columbia River Sport (Area 1)	T Deep S. Puget Sound Net (13,13D-K)
Columbia River Net	NT Area 13A Net
Buoy 10 Sport	T Area 13A Net
Orford Reef-Cape Falcon Troll (Central OR)	Freshwater Sport
Orford Reef-Cape Falcon Sport (Central OR)	Freshwater Net
Horse Mountain-Orford Reef Troll (KMZ)	
Horse Mountain-Orford Reef Sport (KMZ)	
Southern California Troll	
Southern California Sport	
Area 7 Sport	
NT San Juan Net (Area 6A,7,7A)	
T San Juan Net (Area 6A,7,7A)	
NT Nooksack-Samish Net	
T Nooksack-Samish Net	
T Juan de Fuca Troll (Area 5,6,7)	
Area 5/6 Sport	

NT=Non-treaty; T= Treaty Indian

Appendix 4. Number of observed CWT recoveries that were either mapped to the wrong jurisdiction's ISBM fishery or omitted entirely during the 2011 Exploitation Rate Analysis.

				CWT Indicator Stock								
Location	**ATN**	**CHE**	**CHI**	**COW**	**NAN**	**NIC**	**NKS**	**NSF**	**RBT**	**SAM**	**SHU**	**SUM**
US Terminal Net												
Area 10F Ship Canal				1								
Columbia R Net			1			1			2			
Duwamish R		1	1	1	1							
Lummi Bay				1								
Nisqually R				3					1			
Nooksack R				4							1	
Quillayute R									2			
Quinalt R					2							
Satsop R			1									
SkagitT R			1	1	1							
Sub Total	***0***	***1***	***4***	***11***	***4***	***1***	***0***	***0***	***5***	***0***	***1***	***0***
Canadian Terminal Net												
Fraser R							2					1
Sub Total	***0***	***0***	***0***	***0***	***0***	***0***	***2***	***0***	***0***	***0***	***0***	***1***
US Terminal Sport												
CR BUOY 10		1	2									
OR Ocean Area 3	1		1			1						
OR Ocean Area 4			1									
OR Ocean Area 5			1									
Term. (OUTSIDE CR)			1									
Sub Total	***1***	***1***	***6***	***0***	***0***	***1***	***0***	***0***	***0***	***0***	***0***	***0***
Canadian Terminal Sport												
Campbell R										1		
Gold R								1		1		
Sub Total	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***1***	***0***	***2***	***0***	***0***
Grand Total (n=42)	**1**	**2**	**10**	**11**	**4**	**2**	**2**	**1**	**5**	**2**	**1**	**1**

Appendix 5. Current post-season ISBM Index values for 1991-1996 for U.S. and Canadian fisheries.

Year	COW US	COW Canada	Deschutes US	Deschutes Canada	Gray US	Gray Canada	GRN US	GRN Canada	GSQ US	GSQ Canada	Harrison-CHI US	Harrison-CHI Canada
91	2.304203	0.59798	0.6741428	na	1.234758	na	0.954442	0.207264	na	0.802931	0.732464	0.3266303
92	1.501038	0.673807	0.3972099	na	0.89837	na	1.089841	0.552693	na	0.692208	0.8461868	0.3277148
93	1.687469	0.924423	0.5703037	na	1.354143	na	0.829258	0.427749	na	1.13527	0.7372997	0.3284614
94	2.18878	0.475328	0.2101622	na	1.041005	na	0.450892	0.522962	na	0.638263	0.3126053	0.1955891
95	2.405341	0.478229	0.3881193	na	1.29412	na	0.35158	0.254988	na	0.607491	0.2322804	0.1274216
96	3.714933	0.577529	0.3442532	na	0.701564	na	0.479349	0.394266	na	0.542308	0.2352571	0.1933276
Average	2.300294	0.621216	0.430698517	na	1.087327	na	0.69256	0.39332	na	0.736412	0.51601555	0.249857467

Year	HOH US	HOH Canada	LRW US	LRW Canada	Nehalem US	Nehalem Canada	NKS US	NKS Canada	Queets US	Queets Canada	Quilayute US	Quilayute Canada
91	1.958524	na	0.9006345	na	1.732129	na	na	0.194165	0.6023209	na	0.8053026	na
92	0.797412	na	0.9668977	na	1.442119	na	na	0.157357	0.6934796	na	0.6702904	na
93	1.600369	na	0.4755361	na	2.746385	na	na	0.194939	0.7941731	na	1.046298	na
94	0.3566	na	0.0586249	na	2.404514	na	na	1.096019	0.8235379	na	0.511354	na
95	1.136138	na	0.8578258	na	2.588197	na	na	0.180019	1.058986	na	0.8197039	na
96	0.900504	na	0.2681554	na	2.795729	na	na	0.159402	0.4715535	na	0.7362047	na
Average	1.124925	na	0.587945733	na	2.284846	na	na	0.330317	0.740675167	na	0.764858933	na

Year	RBT US	RBT Canada	Siletz US	Siletz Canada	Siuslaw US	Siuslaw Canada	STL US	STL Canada	SUM US	SUM Canada	URB US	URB Canada
91	na	0.713203	0.5890342	na	0.916698	na	0.401994	0.207937	2.083865	na	2.41658	na
92	na	0.275649	0.7985403	na	0.935779	na	0.672625	0.24832	2.622274	na	1.550524	na
93	na	0.599684	1.336488	na	2.174949	na	1.08559	0.336958	5.924662	na	1.706971	na
94	na	0.773139	0.7430945	na	1.264324	na	0.199564	0.421942	na	na	1.397432	na
95	na	0.441612	1.220728	na	1.148371	na	0.222706	0.336877	0.7800857	na	1.626076	na
96	na	0.076057	1.189272	na	2.077357	na	0.26165	0.268076	0.3774334	na	1.561947	na
Average	na	0.479891	0.979526167	na	1.41958	na	0.474022	0.303352	2.35766402	na	1.709921667	na