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Implementation and Assessment of Proposed Bias-Correction Methods for Mark-Selective Fisheries into FRAM for Coho

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Abstract

The Fishery Regulation Assessment Model (FRAM), used in the Pacific Fishery Management Council's pre-season planning process to project mortalities during proposed coho and Chinook salmon fisheries underestimates the number of unmarked mortalities occurring in mark-selective fisheries and concurrent non-selective fisheries. The bias is caused by approximating the non-linear Baranov catch equation with a linear model. When MSF operate during a modeled time period, unmarked mortalities are underestimated because released fish that survive may encounter the fishing gear more than once during the time period.

The bias-correction methods proposed by Conrad et al. (2010, 2012) were incorporated into FRAM's computational structure and algorithms. The model was implemented with no CNR mortalities and drop-off mortalities to simplify the interpretation of results. FRAM outputs of mortality were compared to results from unbiased calculations.

FRAM produced unbiased estimates of mortalities by stock for fisheries modeled as scalars or quotas. FRAM also produced unbiased landed and non-landed mortalities.

FRAM's handling of drop-off mortality through the use of a bias correction ratio rectified most of the bias introduced by drop-off. FRAM does not address mortalities from non-retention fisheries (release of marked and unmarked) within the bias corrected equations. This resulted in a very slight underestimate of mortalities.

Introduction

Mark-selective fisheries for coho salmon (*Oncorhynchus kisutch*) were introduced as a management tool in 1998 off the Washington coast (PFMC 1999a). Regulations for mark-selective fisheries permit the retention of legal-size coho which have had their adipose fin removed (marked) and require the release of all coho salmon with an adipose fin (unmarked) that are brought to the boat. The objective of mark-selective fisheries is to provide for fisheries on abundant (marked) hatchery salmon while reducing the impact on wild salmon.

The Fishery Regulation Assessment Model (FRAM) is used by the Pacific Fishery Management Council (PFMC) during the pre-season planning process to project mortalities during proposed coho and Chinook salmon fisheries. FRAM is a single-pool, deterministic model that has discrete time steps that vary in length from one month to several months (PFMC 2008a). All fisheries during a time step are assumed to operate simultaneously on a single pool of fish. The pool of modeled fish consists of all stocks that have been caught historically in the fishery as estimated from coded-wire tag (CWT) recoveries (Nandor et al. 2010). Historical exploitation rates estimated from CWTs recovered during a base period when salmon abundances were relatively high and fisheries were widely distributed in both time and area are the basis for the FRAM predictions of fishery mortalities by stock (PSC 2005). Details for the methods and algorithms used in FRAM are presented in PFMC (2008b). PFMC (2007a and 2007b) provides a description of the base-period data used for the coho FRAM.

In FRAM, the exploitation rate on the unmarked stock is a linear function of the exploitation rate on the tagged indicator stock used to represent the unmarked stock and the release-mortality rate. Since all encountered marked fish die, the exploitation rate of the tagged indicator stock is synonymous with the exploitation rate of the marked stock. Therefore, the exploitation rate calculation for an unmarked stock in FRAM can also be described as the exploitation rate of the marked stock component (μ_M) multiplied by the release mortality rate (δ). These linear calculations produce accurate results for the marked component of the stock, as long as 100% of the marked encounters are removed. As has been demonstrated in multiple papers (Conrad and Yuen, 2009 and 2010; Lawson and Sampson, 1996), unmarked mortalities are underestimated, because unmarked fish surviving release decrease slower in abundance than marked fish and can subsequently be re-encountered (multiple encounter bias); a process that can be accurately described using exponential equations.

These equations have been tested and described in previous presentations to the council. Additionally, a method on how to evaluate and assess the bias in the existing FRAM was presented by Bob Conrad at the November 2011 council meeting (Conrad and Hagen-Breaux, 2011). At that meeting the Model Evaluation Workgroup (MEW) put forth a recommendation to investigate the feasibility of coding the bias-corrected equations into coho FRAM.

This document provides a description of the status of this project and an assessment of the accuracy of mortality reports delivered by FRAM relative to unbiased estimates generated external to the model. Table 2 summarizes the specific testing objectives associated with this evaluation.

Methods

Conrad and Yuen (2009 & 2010) described a simulation model that produced unbiased, unmarked exploitation rates for a range of fisheries with different release mortality rates. This simulation model was used to test equations computing unbiased, time step exploitation rates, unbiased fishery exploitation rates, as well as landed and non-landed mortalities for fisheries that were modeled as rates (scalars) or quotas. These calculations were presented previously to the SSC, STT and the Council.

Lawson and Sampson (1996) demonstrated that in a mark-selective fishery, the actual mortality rate of unmarked fish is an increasing function of the apparent harvest rate on the marked fish. This causes the total number of unmarked mortalities in mark-selective fisheries to be underestimated by models that compute fishery mortalities in discrete time steps using linear catch equations.

Conrad and Yuen (2010) described a bias correction method where the unbiased exploitation rate of the selectively exploited unmarked stock ($\hat{\mu}^U$) can be computed as an exponential function of the encounter rate of the corresponding marked stock component and the release mortality rate (δ) as long as all marked fish encountered die (no release of marked fish):

Basic Equations

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$$\hat{\mu}_I^U = 1 - (1 - \textstyle\sum_i \mu_i^M)^{\delta_w} \qquad (1a)$$

$$\mu_i^M = \mu_i^B = BPER_i * \propto_i \qquad (2)$$

In the absence of marked salmon releases, the marked exploitation rate (μ_i^M) is the same as the base period exploitation rate ($BPER_i$)times a fishery scalar ($\propto_i$).

Weighted Release Mortality Equations

FRAM's computational structure poses some challenges to applying the unbiased unmarked fishery mortality equations. In FRAM, all fisheries occurring in a time step operate simultaneously on a single pool of fish using different stock and fishery specific base-period exploitation rates. Therefore, $\hat{\mu}^M$ is computed as the sum of the marked exploitation rates[1] of all fisheries affecting a stock in a given time step. Additionally, these fisheries can be modeled with a range of different release mortality rates for the unmarked stock component. The bias-correction procedure used in this analysis, described in Conrad and Yuen (2010), addresses heterogeneity in encounter and release mortality rates. Specifically, the total exploitation rate in all fisheries (both non-selective and mark-selective) for the marked component of the stock is used in equation 7 of Conrad and Yuen (2010) and a weighted release-mortality rate (equations 8 and 9) is calculated using 1.00 as the release-mortality rate for non-selective fisheries (NSF).

The weighted release mortality (δ_w) is computed as:

$$\delta_w = \delta_1 * w_1 + \delta_2 * w_2 + \cdots \delta_i * w_i \qquad (3)$$

And,

[1] For a marked or unmarked stock component, a time-step specific exploitation rate uses all fishery-related mortalities occurring in the time step (harvest plus release mortalities from mark-selective fisheries) for the numerator and the cohort abundance "After Natural Mortality" for the time step as the denominator.

$$w_i = \frac{\mu_i^M}{\sum_i \mu_i^M} \quad (4)$$

Conrad, Hagen-Breaux, and Yuen (2012) determined that the weighted release mortality rate in absence of mark recognition error can simply be computed as the biased, unmarked, time step exploitation rate ($\tilde{\mu}_I^U$) divided by the marked, time step exploitation rate (μ_I^M):

$$\delta_w = \frac{\tilde{\mu}_I^U}{\mu_I^M} \quad (5)$$

where, *I = sum of all fisheries i on a stock in a time step*

Allocating Total Mortality to Fisheries

For management purposes, the unbiased, time step exploitation rate ($\hat{\mu}_I^U$)is reported on a fishery-specific basis ($\hat{\mu}_i^U$). This is accomplished by splitting the time step exploitation rate ($\hat{\mu}_I^U$) into a fishery exploitation rate using the ratio of the biased fishery rate divided by the time step sum of all the biased fishery exploitation rates ($\frac{\tilde{\mu}_i^U}{\sum_i \tilde{\mu}_i^U}$) (Conrad and Yuen, 2010).

$$\hat{\mu}_i^U = \hat{\mu}_I^U * \quad \pi_i \quad (6)$$

and

$$\pi_i = \frac{\tilde{\mu}_i^U}{\sum_i \tilde{\mu}_i^U} \quad (6a)$$

Mark Recognition Error and Allocating Fisheries Mortalities to Landed versus Released

Most mark-selective fisheries are modeled with parameters that account for mark recognition error. For marked fish, mark-recognition error occurs when a portion of the marked fish encountered are released; for unmarked fish, mark-recognition error occurs when a portion of the unmarked fish encountered are retained.

When marked fish are released they are subject to the same calculation bias as the unmarked cohort and can no longer be used to solve for $\hat{\mu}_I^U$ in equation 1.

Conrad, Hagen-Breaux, and Yuen (2012, under review) developed unbiased equations that address this estimation problem. Unbiased marked and unmarked mortalities can be computed as:

$$\hat{\mu}_I = 1 - (1 - \textstyle\sum_i \mu_i^B)^{\delta_w} \quad (1b)$$

where, *μ_i^B is calculated as in equation 2*

If it is still desired to express $\hat{\mu}_I^U$ in terms of $\hat{\mu}_I^M$ the following equation (Conrad, Hagen-Breaux, and Yuen, equation 16) applies:

$$\hat{\mu}_I^U = 1 - (1 - \hat{\mu}_I^M)^{\delta_{UI}^W / \delta_{MI}^W} \quad (1c)$$

In a single pool model δ_w can be considered the average release mortality of all fisheries affecting a stock in a time step. When marked fish are released the release mortality δ changes from 1 (100% of encounters die) to a value smaller than 1. Conversely, when unmarked fish are retained in a mark selective fishery the release mortality increases. These parameter changes can be addressed in the computation of the weighted release mortality(δ_w).

For any given fishery the weighted release mortality of the unmarked is:

$$\delta_{wi}^{U} = (1 - \zeta_i) + (\zeta_i \cdot \delta_i) \qquad (7a)$$

where ζ_i is the (correct) unmarked recognition rate

For any given fishery the weighted release mortality of the marked is:

$$\delta_{wi}^{M} = \gamma_i + [(1 - \gamma_i) \cdot \delta_i] \qquad (8a)$$

where γ_i is the (correct) marked recognition rate

In the absence of mark recognition error all marked mortalities stem from landings and all unmarked mortalities stem from releases. With mark recognition error both sources of mortality can occur for the marked and unmarked cohort. To compute mortalities by source (landed versus released) the following equations apply:

For an unmarked cohort, landed catch for fishery i ($\widehat{D}_{Li}^{U}$) is calculated as:

$$\widehat{D}_{Li}^{U} = \widehat{D}_{i}^{U} * \frac{1 - \zeta_i}{(1 - \zeta_i) + (\zeta_i \cdot \delta_i)} \qquad (7b)$$

and non-landed mortality ($\widehat{D}_{Ni}^{U}$) is calculated as:

$$\widehat{D}_{N\,i}^{U} = \widehat{D}_{i}^{U} \cdot \frac{(\zeta_i \cdot \delta_i)}{(1 - \zeta_i) + (\zeta_i \cdot \delta_i)} \qquad (7c)$$

Similarly for a marked cohort:

$$\widehat{D}_{L\,i}^{M} = \widehat{D}_{i}^{M} \cdot \frac{\gamma_i}{\gamma_i + [(1 - \gamma_i) \cdot \delta_i]} \qquad (8b)$$

and non-landed mortality ($\widehat{D}_{Ni}^{M}$) is calculated as:

$$\widehat{D}_{N\,i}^{M} = \widehat{D}_{i}^{M} \cdot \frac{(1 - \gamma_i) \cdot \delta_i}{\gamma_i + [(1 - \gamma_i) \cdot \delta_i]} \qquad (8c)$$

Compare FRAM Bias-corrected Mortalities to Mortalities from Unbiased Calculations

In 2010, for testing purposes, James Packer added unbiased exploitation rate calculations for unmarked coho to FRAM program code in Visual Studio.Net. In 2011 and 2012, as new calculations were developed to deal with a range of fisheries scenarios and FRAM’s computational structure, James Packer and Peter McHugh adjusted and added to existing algorithms into the testing version of FRAM.

Conrad and Hagen-Breaux (2011) described the step-wise procedures to calculate the bias in the FRAM estimates of exploitation rates, external to the model (i.e., in a spreadsheet). Once the size of the bias and the unbiased exploitation rates were known, comparisons to biased and unbiased FRAM output of mortality were made using a "Popstat" (Population Statistics, e.g., Table 1) report, which summarizes abundance, pre- and post-fishery mortality, for all FRAM stocks for each time step. To simplify the evaluation of results, FRAM was run with drop-off mortalities and non-retention fisheries set to zero. Comparisons were made using the final 2009 pre-season model run.

Table 1. Example of a PopStat Report and Comparison of FRAM and Calculated Results

Popstat Output				Calculations		
Tstep	Starting Cohort	After Nat Mort	After Fishing	Catch	Exploitation Rate (ER)	Calculated Unbiased ER
1	1615.97	1426	1425	1	0.052%	0.052%
2		1396	1363	33	2.361%	2.411%
3		1335	1279	56	4.172%	4.352%

(note: this is an example from a FRAM run that has not been bias adjusted)

Table 2. Testing phases and criteria used to evaluate the implementation of bias-corrected calculations of fishery impacts in FRAM.

Testing objectives
Phase 1. Bias correction in the absence of mark recognition error
Testing criteria: Scalar fisheries, unmarked exploitation rates
Testing criteria: Quota fisheries, unmarked exploitation rates
Testing criteria: Time step- and stock-specific fishery impacts, by number (landed, total) and rate for a stock by fishery
Phase 2. Bias correction accounting with mark recognition error
Testing criteria: Scalar fisheries, unmarked and marked exploitation rates
Testing criteria: Quota fisheries, unmarked and marked exploitation rates
Testing criteria: Time step- and stock-specific fishery impacts, by number (landed, non-landed, total) and rate for a stock by fishery

Results

Assessment of Basic Bias Correction

In FRAM, fisheries are modeled as either rates (scalars) or as quotas. For fisheries modeled as scalars, FRAM's bias-corrected exploitation rates match exploitation rates from unbiased calculations (Figure 1, Table 3).

Figure 1. Biased FRAM, Bias-Corrected FRAM, and Unbiased Estimates of Exploitation Rates for Model Stocks when Fisheries are Modeled as Scalars

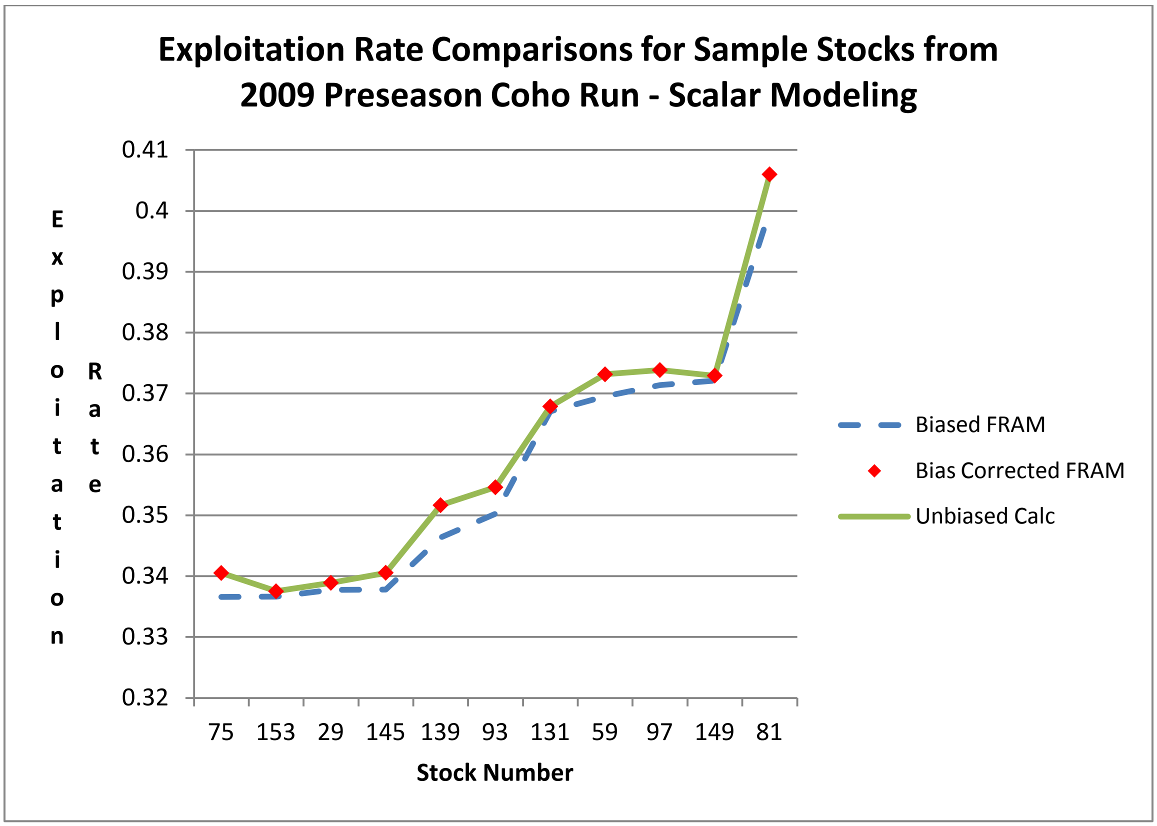

Table 3. Biased FRAM, Bias Corrected FRAM, and Unbiased Estimates of Exploitation Rates for Model Stocks when Fisheries are Modeled as Scalars

Stock #	Name	Biased FRAM ER	Bias Corrected FRAM ER	Unbiased Calculation	Initial Relative Bias
75	Area 13 Misc Wild	0.33660	0.34051	0.34051	-1.15%
153	Humptulips Wild	0.33666	0.33751	0.33751	-0.25%
29	Stillaguamish Wild	0.33776	0.33890	0.33890	-0.33%
145	Quinault Fall Nat	0.33779	0.34055	0.34055	-0.81%
139	Queets Fall Nat	0.34634	0.35165	0.35165	-1.51%
93	Area 10E Misc Wild	0.35027	0.35459	0.35459	-1.22%
131	Quillayute Fall Nat	0.36708	0.36787	0.36787	-0.21%
59	Skokomish Wild	0.36956	0.37315	0.37315	-0.96%
97	Green Wild	0.37138	0.37385	0.37385	-0.66%
149	Chehalis Wild	0.37213	0.37293	0.37293	-0.22%
81	Area 13A Misc Wild	0.39999	0.40599	0.40599	-1.48%

For fisheries modeled as quotas, FRAM's bias corrected exploitation rates match exploitation rates from unbiased calculations (Figure 2, Table 4).

Figure 2. Biased FRAM, Bias Corrected FRAM, and Unbiased Estimates of Exploitation Rates for Model Stocks when Fisheries are Modeled as Quotas

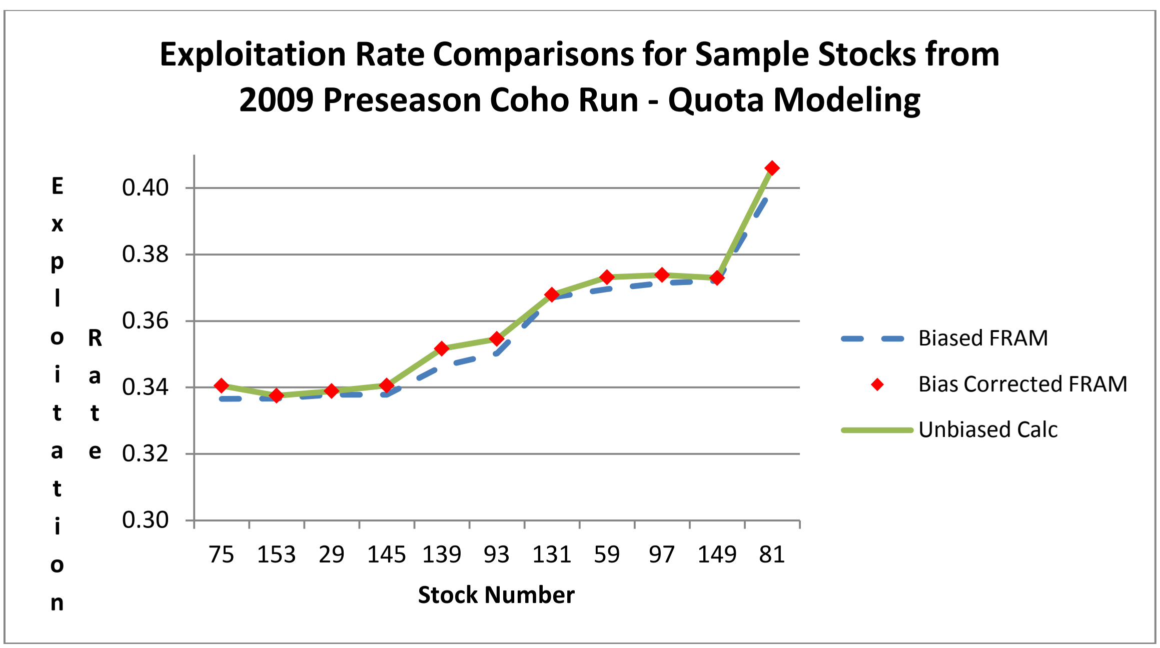

Table 4. Biased FRAM, Bias Corrected FRAM, and Unbiased Estimates of Exploitation Rates for Model Stocks when Fisheries are Modeled as Quotas

Stock #	Name	Biased FRAM ER	Bias Corrected FRAM ER	Unbiased Calculation	Initial Relative Bias
75	Area 13 Misc Wild	0.33660	0.34051	0.34051	-1.15%
153	Humptulips Wild	0.33666	0.33751	0.33751	-0.25%
29	Stillaguamish Wild	0.33776	0.33890	0.33890	-0.33%
145	Quinault Fall Nat	0.33779	0.34055	0.34055	-0.81%
139	Queets Fall Nat	0.34634	0.35165	0.35165	-1.51%
93	Area 10E Misc Wild	0.35027	0.35459	0.35459	-1.22%
131	Quillayute Fall Nat	0.36708	0.36787	0.36787	-0.21%
59	Skokomish Wild	0.36956	0.37315	0.37315	-0.96%
97	Green Wild	0.37138	0.37385	0.37385	-0.66%
149	Chehalis Wild	0.37213	0.37293	0.37293	-0.22%
81	Area 13A Misc Wild	0.39999	0.40599	0.40599	-1.48%

Allocating Total Mortality to Fisheries

In order to produce bias-corrected results that match unbiased calculations, accurate weighted release mortality rate equations have to be implemented in FRAM. Once it was established that FRAM could compute unbiased, time step exploitation rates, FRAM's output of bias-corrected mortalities by fishery were evaluated.

To apportion the time-step, bias corrected, unmarked exploitation rate of a stock to the individual fisheries, the simple (biased) unmarked exploitation rate was used as described in equation 6.

The bias-corrected fishery-specific mortalities and exploitation rates returned by FRAM match values calculated external to the model using the unbiased calculations.

Mark Recognition Error

In a mark selective fishery, mark recognition error is defined as the release of marked fish or the retention of unmarked fish. Estimates of these parameters are supplied to FRAM for each mark selective fishery, and their role in unbiased calculations is manifested within the weighted release mortality calculation of the unbiased equation (equations 7a, 8a).

In order to address the bias introduced by mark recognition error, three major changes were made to already existing bias corrected FRAM equations:

1. Discontinue use of marked exploitation rates to compute unbiased, unmarked mortalities. When marked fish are released, they also are subject to the "multiple encounter bias" and can no longer be used as a surrogate for non-selective exploitation rates. Instead, μ^B from equation 2 was used to compute unbiased unmarked exploitation rates.
2. Use unbiased equations to calculate mortalities of marked stock components.

3. To model quotas, find fisheries scalars iteratively. A quota is an unbiased estimate of marked and unmarked landed catch of all stocks in a fishery. The scalar that produces a quota is found using unbiased equations. Since these equations are exponential, the previous linear approach of computing the correct scalar, as quota catch divided by the catch that results from a scalar of 1, is no longer accurate. Instead, the correct scalar is found by iteratively repeating this calculation until a user specified precision is achieved (Conrad et al. 2012).

A comparison of FRAM output with unbiased calculations with non-zero mark recognition error (external to the model) reveals that the bias-correction algorithms correctly address mark recognition error.

For fisheries modeled as scalars or quotas, FRAM bias corrected unmarked exploitation rates match unbiased calculations.

Allocating Total Mortality to Landed and Release Mortality

FRAM bias corrected landed and non-landed mortalities match mortalities from unbiased calculations (equations 7b, 7c, 8b, 8c).

Correcting Bias Introduced by Drop-Off (DO) and Fisheries that Require Coho Non-Retention (NR)

Drop-off (the loss of a fish before it is brought on-board or on-shore) is modeled as 5% of the landed catch for the marked cohort and 5% of encounters (fish that would have been landed during a retention fishery) for the unmarked cohort. Bias corrected equations are incorporating the effects of drop-off through the use of a "Bias Corrected Ratio". This ratio is computed as unbiased exploitation rate divided by biased exploitation rate $\frac{\hat{\mu}}{\tilde{\mu}}$.

$$DO_{bias\ corrected} = DO * Bias\ Corrected\ Ratio$$

This approach produces exploitation rates that are slightly lower than "true unbiased rates". These unbiased rates can be computed by incorporating drop-off mortality in equation 1b.

Table 5. Influence of Drop-Off Mortality (DO) on Exploitation Rates

			Biased			Unbiased Calculations			Bias Corrected FRAM		
μ^B	δ	δ^w	Total	DO	MSF	Total	DO	MSF	Total	DO	MSF
0.05	0.14	0.181	0.0095	0.0025	0.0070	0.0097	0.0026	0.0072	0.0097	0.0026	0.0072
0.10	0.14	0.181	0.0190	0.0050	0.0140	0.0199	0.0052	0.0146	0.0199	0.0052	0.0146
0.15	0.14	0.181	0.0285	0.0075	0.0210	0.0305	0.0080	0.0225	0.0305	0.0080	0.0225
0.20	0.14	0.181	0.0380	0.0100	0.0280	0.0418	0.0110	0.0308	0.0417	0.0110	0.0308
0.25	0.14	0.181	0.0475	0.0125	0.0350	0.0536	0.0141	0.0395	0.0536	0.0141	0.0395
0.30	0.14	0.181	0.0570	0.0150	0.0420	0.0662	0.0174	0.0488	0.0661	0.0174	0.0487
0.35	0.14	0.181	0.0665	0.0175	0.0490	0.0795	0.0209	0.0586	0.0794	0.0209	0.0585
0.40	0.14	0.181	0.0760	0.0200	0.0560	0.0939	0.0247	0.0692	0.0937	0.0246	0.0690
0.45	0.14	0.181	0.0855	0.0225	0.0630	0.1093	0.0288	0.0805	0.1090	0.0287	0.0803
0.50	0.14	0.181	0.0950	0.0250	0.0700	0.1260	0.0332	0.0929	0.1255	0.0330	0.0925
0.55	0.14	0.181	0.1045	0.0275	0.0770	0.1444	0.0380	0.1064	0.1435	0.0378	0.1058

A non-retention fishery requires the release of every marked and unmarked coho encountered. Bias corrected equations are currently not incorporating the effects of non-retention fisheries[2], resulting in a slight underestimate of actual mortalities.

Table 6. Influence of Coho Non-Retention (NR) on Exploitation Rates

				Biased			Unbiased Calculations			Bias Corrected FRAM		
μ^B	μ^{NR}	δ	δ^w	Total	MSF	NR	Total	MSF	NR	Total	MSF	NR
0.050	0.039	0.14	0.5175	0.0470	0.0070	0.040	0.0472	0.0072	0.040	0.0472	0.0072	0.040
0.100	0.038	0.14	0.3778	0.0540	0.0140	0.040	0.0547	0.0147	0.040	0.0546	0.0146	0.040
0.150	0.037	0.14	0.3113	0.0610	0.0210	0.040	0.0625	0.0225	0.040	0.0625	0.0225	0.040
0.200	0.036	0.14	0.2723	0.0680	0.0280	0.040	0.0708	0.0308	0.040	0.0708	0.0308	0.040
0.250	0.035	0.14	0.2467	0.0750	0.0350	0.040	0.0795	0.0395	0.040	0.0795	0.0395	0.040
0.300	0.034	0.14	0.2285	0.0820	0.0420	0.040	0.0888	0.0488	0.040	0.0887	0.0487	0.040
0.350	0.033	0.14	0.2149	0.0890	0.0490	0.040	0.0987	0.0587	0.040	0.0985	0.0585	0.040
0.400	0.032	0.14	0.2043	0.0960	0.0560	0.040	0.1093	0.0693	0.040	0.1090	0.0690	0.040
0.450	0.031	0.14	0.1959	0.1030	0.0630	0.040	0.1206	0.0806	0.040	0.1203	0.0803	0.040
0.500	0.030	0.14	0.1889	0.1100	0.0700	0.040	0.1329	0.0929	0.040	0.1325	0.0925	0.040
0.550	0.029	0.14	0.1830	0.1170	0.0770	0.040	0.1464	0.1064	0.040	0.1458	0.1058	0.040

Summary of Results

Table 7. Summary of testing phases and criteria used to evaluate the implementation of bias-corrected calculations of fishery impacts in FRAM

Testing objectives	Status
Phase 1. Bias correction in the absence of mark recognition error	
Testing criteria: Scalar fisheries, unmarked exploitation rates	X
Testing criteria: Quota fisheries, unmarked exploitation rates	X
Testing criteria: Time step- and stock-specific fishery impacts, by number (landed, total) and rate for a stock by fishery	X
Phase 2. Bias correction with mark recognition error	
Testing criteria: Scalar fisheries, unmarked and marked exploitation rates	X
Testing criteria: Quota fisheries, unmarked and marked exploitation rates	X
Testing criteria: Time step- and stock-specific fishery impacts, by number (landed, non-landed, total) and rate for a stock by fishery	X

[2] For coho, non-retention fisheries are provided to FRAM as 'total dead coho'; FRAM distributes this mortality in a manner similar to a non-MSF quota fishery.

Conclusions

New FRAM code has been added to address the mark selective fishing bias in coho FRAM. This code has eliminated the mark selective fishing bias on marked and unmarked stock components with the exception of a very slight bias still remaining due to the handling of drop-off and non-retention mortalities.

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