A Method for Utilizing Recent Coded Wire Tag Recovery Data to Adjust FRAM Base Period Exploitation Rates

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Introduction:

In the Chinook Fishery Regulation Assessment Model (FRAM), fisheries are either pre-terminal (fish on all fish alive during the time step) or terminal (fish on only mature fish in the time step). Even non-local fish caught in a terminal fishery are considered to be part of the mature run of the non-local stock, no matter the distance from the natal stream or the condition of the fish. FRAM does not differentiate between an immature, non-local fish caught in a terminal net fishery and a mature, non-local fish that has strayed to that terminal area and is caught in the net fishery; both are counted as a part of the non-local stock's terminal run (as a mature fish). This can cause numerous problems in accounting for fish mortality for management purposes and for forecasting; the problems tend to be fairly negligible when fisheries and/or mature run sizes are small, but when fisheries and/or mature run sizes are large the problems can impact effective management of the stock.

FRAM-estimated catch of non-local stocks in terminal net fisheries in Hood Canal has grown over the past few years from 661 non-local fish in 2009 to 1761 non-local fish in 2013 pre-season runs. Deep South Puget Sound Fall Fingerlings (SPS FF) make up the majority of the non-local catch in these fisheries in FRAM, and the large catch of mature SPS FF in a distant terminal fishery seemed suspect to managers of the stock. This prompted a comparison with coded wire tag (CWT) recoveries of non-local fish in Hood Canal; the disparity was quite large. Figure 1a shows the pre-season FRAM-estimated proportion of non-local catch for recent years compared to the proportion of non-local CWT recoveries for Hood Canal marine terminal net fisheries. Figure 1b shows the increase in total catch in Hood Canal terminal net fisheries estimated by pre-season runs of FRAM over recent years; although the FRAM-estimated proportion of non-local stock caught in these fisheries is declining, the increase in total fish means that the number of non-local fish caught is increasing.

At the same time, overall catch in Deep South Puget Sound net fisheries has decreased and the pre-season FRAM-estimated proportion of Hood Canal Fall Fingerlings (HC FF) in those fisheries has been changing in a pattern out of sync with the proportion of HC CWTs recovered in Deep South Puget Sound fisheries (Figures 2a and b). Because there are some ESA-listed stocks in the FRAM stock units for both SPS FF and HC FF, the disparity between FRAM-derived estimates of non-local catch in terminal fisheries and CWT-derived estimates is particularly problematic for fisheries managers. Some management goals are based on FRAM metrics, but changes in fisheries impacts might not be properly captured by these metrics when large terminal fisheries impacts are inaccurate. Also, fisheries managers interested in the conservation and rebuilding of the stocks would like to get the best possible information about how their stocks will be affected by fishing regulations, and FRAM is not providing that in these cases. Co-managers in Puget Sound have repeatedly expressed a desire to have FRAM estimate those impacts more accurately.

In FRAM, catch in each fishery (f) during each time step (t) is determined for each age (a = 2-5) of each stock (s) individually using the equation:

$$Catch_{s,a,f,t} = FishScalar_{f,t} * BPER_{s,a,f,t} * Cohort_{s,a,t} * PV_{s,a,f,t} \quad (1)$$

where

$FishScalar_{f,t}$ = the Fishery Scalar, the strength of this year's catch or effort in fishery f during time step t relative to the catch or effort in the base period,

$BPER_{s,a,f,t}$ = the base period exploitation rate, the number of fish of stock s age a caught in fishery f during time step t divided by the number of fish alive and of legal size in fishery f from age a, stock s during time step t,

$Cohort_{s,a,t}$ = the number of fish alive of age a, stock s in time step t, or the number of mature fish alive of age a, stock s, in time step t for terminal fisheries, and

$PV_{s,a,f,t}$ = is the proportion vulnerable, which is the proportion of fish of age *a*, stock *s* of legal size to be landed in fishery *f* during time step *t* (see Model Evaluation Workgroup, 2008a and b, for FRAM details.)

It appears that the large catch of SPS FF in Hood Canal and the large catch of HC FF in Deep South Puget Sound result from large base period exploitation rates (BPERs) in FRAM. If the Fishery Scalars (either input directly by the user or calculated from input fishery quotas) were causing the problem, the total catch in the terminal net fisheries would be too large, not just the catch of one portion of the catch. If the cohort sizes were causing the problem, there should also be large disparities between FRAM-estimated catch and reported catch in other terminal fisheries or between modeled and observed escapement. If the PV were causing the problem, there would also be problems in other pre-terminal and terminal fisheries for that stock. An error in the BPERs, however, could account for the problem being limited to just certain stocks in certain fisheries. In many cases for stocks that were present but rare in fisheries in the FRAM base period, there is low statistical confidence in the BPERs but managers were willing to accept the overall model because many of the big impacts for stocks were in fisheries with much greater tag recoveries. It was also believed that non-local impacts would balance out with non-local stocks caught in local terminal fisheries being roughly equivalent to local stocks caught in other terminal fisheries, but this assumption was never thoroughly tested. As stock abundances and fishery strengths have changed over time, the problems with FRAM estimates of non-local impacts have become larger for some stocks. For example, the fisheries managers of the Nisqually Indian Tribe are interested in fixing this error in FRAM-estimated impacts because the over-estimate of terminal fishery impacts in a distant net fishery lessens fishing opportunities for their Tribal fishers. Furthermore, FRAM does not include non-local terminal fishery impacts when expanding pre-season terminal run forecasts out to ocean cohort sizes, which means that terminal run size forecast methods for stocks with large non-local terminal impacts may be incompatible with FRAM.

It is possible to estimate more accurate impacts to the Hood Canal and Nisqually stocks external to FRAM, but that may create problems with evaluating ESA compliance and it means that impacts on other stocks in FRAM would still be in error (in quota fisheries, relative abundances of stocks matter in determining impacts). Thus, it seems preferable to find a method to estimate a more appropriate BPER for Deep South Puget Sound stocks in Hood Canal terminal net fisheries and vice versa, and to replace the current BPERs with the new ones.

Chinook FRAM BPERs are estimated in the base period calibration procedures using cohort analysis, which requires CWT recoveries in escapement and catch for complete brood years. Here, an alternative method is proposed for estimating a BPER for use in FRAM that uses more recent data. It is intended for use solely when large disparities are found between FRAM estimates and CWT-derived estimates of impacts. The method is stock-, age-, fishery- and time step-specific, and can be used for pre-terminal or terminal fisheries. Like the recent fixes that utilized more recent data on the ratio of legal:sub-legal encounters and patched a known problem with modeling size limit changes, using more recent CWT data to better estimate terminal fishery impacts can provide a short-term solution to known issues with FRAM modeling.

The Proposed Method:

The Base Period Exploitation Rate (BPER) is a stock-, age-, fishery- and time step-specific rate describing the proportion of fish alive during that time step in the base period that were landed by a fishery during the base period. In mathematical terms,

$$BPER_{s,a,f,t} = \frac{Catch_{s,a,f,t}}{Cohort_{s,a,t} * PV_{s,a,f,t,}} \qquad (2)$$

To improve a FRAM BPER that has been identified as problematic, stock-, age- and time step-specific estimates are needed of landed catch by fishery and of cohort size. Coded wire tag recoveries are currently the standard for deriving stock- and age-specific information about fishery impacts, with tagged fish used as an indicator for untagged fish. The sampling program in place for CWTs provides estimates of landed catch of tagged fish, but complete brood years are required to use CWT recoveries to estimate cohort sizes. There is not any other sampling program in place to provide estimates of cohort size, either. Here, the CWT landed catch estimate is used to estimate the numerator of the BPER, and the denominator is borrowed from FRAM. The denominator is less likely to be the problematic part of the BPER estimate anyway, since an error in cohort size would create problems in all terminal fisheries, not just one or two.

Since we want to use data from years other than the base period, the actual quantity that will be determined by the CWT recovery data is:

$$FishScalar_{f,t} * BPER_{s,a,f,t} = \frac{Catch_{s,a,f,t}}{Cohort_{s,a,t} * PV_{s,a,f,t,}} \qquad (3)$$

While catch is straightforward to estimate from CWT recoveries, CWT recoveries represent *tagged* fish and the FRAM stock of interest is *marked* (adipose fin-clipped) fish. The main novelty of this method is to use CWT-derived estimates of catch and release information for all tagged fish and all marked fish to come up with a FRAM-compatible substitute for the numerator in equation (3).

The following description of the method is for a single marked FRAM stock, Stock S, caught in a single FRAM fishery, Fishery F, during a single time step, Time Step T. The method can easily be adapted to more fisheries or time steps. In this description, "marked" is used in the sense it is used in FRAM and refers only to adipose fin-clipped fish.

(1) First, all CWT recoveries for components of Stock S in the region of Fishery F should be downloaded from the Regional Mark Information System (RMIS, database access provided at www.rmpc.org). The time span must be specified for the CWT recoveries, and will need to balance the desire for recent data with the scarcity of CWT recoveries of non-local stocks. These recoveries should then be sorted by fishery type and by time step, and the recoveries from Fishery F in Time Step T selected for further analysis. If data from certain years is going to be discarded due to insufficient sampling or tag recoveries within the fishery, that should be done at this point.

The release information for the tag codes for all CWT recoveries selected for further analysis should then be downloaded from RMIS, and the information used to separate recoveries by separated by mark status, age, and release stage (fingerling, yearling, etc.) Only fish from the release stage of Stock S should be retained (fingerlings and yearlings are separate stocks in FRAM). Only tag codes for marked and coded wire tagged fish should be used for further analysis. If BPERs for only certain ages of fish are being evaluated, unneeded ages can be discarded.

(2) The estimated number of CWT recoveries of Stock S fish in Fishery F during Time Step T should then be summed by age and year of recovery. For each year of analysis, there will be a sum of estimated recoveries of tagged fish by age.

(3) Next, the records of all marked releases for Stock S for the brood years represented in the coded wire tags in step 2 should be downloaded from RMIS. For each brood year, the number of coded wire tagged and marked fish should be summed, and the number of marked fish (tagged or untagged) should be summed. The former result (CWT & Mark) should be divided by the latter result (Mark) to get a proportion of the marked fish that had CWTs.

(4) Each estimate of the total tagged catch by year and age from step 2 should be divided by the final result for the appropriate brood year from step 3 (the proportion of tagged and marked releases to marked releases) to give an estimate of the marked fish of Stock S by age caught in Fishery F during Time Step T. This expands the estimate of CWT catch to an estimate of marked catch, which is what is used in FRAM.

(5) To estimate a new BPER using this estimate of marked catch, the estimate of marked catch is used as the numerator and the appropriate cohort size can be taken from the FRAM PopStat report for the appropriate stock, age, time step and maturation status. Cohort sizes can be taken from either pre- or post-season runs, depending on the goals of the analysis and availability (post-season runs may not be available for recent years).

(6) The result of step 5 is the equivalent of the Fishery Scalar * BPER from FRAM as shown in equation 3, so it must be divided by either a FisheryScalar or by an average of recent FisheryScalars to give a BPER replacement value. Again, the goals of the analysis must be considered in choosing whether to use one FisheryScalar or an average of FisheryScalars, the time period over which to average values, and whether to use pre- or -post-season FisheryScalars. The BPER derived from this method for the marked stock should then be inserted into the base period file for both the marked and unmarked portions of Stock S.

Testing the method:

An example was carried out using the catch of marked South Puget Sound Fall Fingerlings (FRAM stock 22) in Hood Canal terminal net fisheries (FRAM fisheries 65 and 66) in Time Step 3, July-September, when fish mature and terminal fisheries are executed (see Appendix 1). The methods given above were followed, using recoveries from 2003-2012. Using the last 10 years for which sampling was complete was an attempt to limit the analysis to recent recoveries while still capturing relatively rare events. The denominator of the estimated exploitation rate for each year was determined using the post-season cohort number for available years at the time of analysis (2003-2010) and the pre-season cohort number from the other years (2011, 2012). The CWT-derived exploitation rate was split between Treaty and non-Treaty fisheries based on the averages of the past 3 years, then converted to a BPER by dividing by the fishery scalars for the most recent three years of final PFMC pre-season models (2012 to 2014).

A similar analysis was carried out for marked Hood Canal Fall Fingerlings (FRAM stock 32) in South Puget Sound terminal net fisheries (FRAM fisheries 68-71) (Appendix 2).

The results for both stocks and the terminal net fisheries were then used to create a new base periods for the runs from 2012-2014, and the pre-season runs for 2012-2014 were performed using the unaltered and altered base periods. The impacts of the BPER changes on the metrics used for ESA decision-making are summarized in Table 1 (exploitation rates) and Table 2 (escapements). Because the impacts are only in terminal fisheries, only stocks that co-occur in those terminal net fisheries showed changes in exploitation rates (ERs) are output of FRAM, unlike the BPERs, and reflect the AEQ (adult equivalence) total fishing mortality for a stock over that total fishing mortality plus escapement. The biggest changes in ER were seen for Hood Canal and South Puget Sound stocks, with small (<0.04%) changes in ER for all other stocks. Catch of the two stocks was much smaller in the non-local marine terminal net fisheries (Figures 3 and 4), as expected, but with only small changes seen in the escapements (Table 2) those fish were caught mostly in local terminal fisheries. In the terminal net fisheries in both locations, the "lost" non-local catch is primarily made up by the local mature run, with tiny increases in the contribution of other non-local stocks. This resembles the catch composition seen in CWT recoveries.

Conclusion:

This methodology seeks to use the best available data of landed catch by stock and age to improve estimates of catch in Chinook FRAM. It is not the goal of this methodological description to provide guidelines on what FRAM estimates should be considered problematic and thus candidates for the method, but to provide a tool that can be used when managers deem it necessary to do so.

This method is meant to be a temporary fix between model calibrations. It does not account for the interactions between stocks or for coded wire tag recoveries not representing all stocks in a fishery at a given time, as a full calibration does. The method assumes that the error in the BPER comes only from the numerator (the catch), even though the methods for deriving cohort estimates from cohort analysis result in large confidence intervals. However, there is no sampling program that provides good cohort size estimates at this time, especially on the time-scale most managers will want to use. It is also difficult to capture very recent trends with this method when CWT recoveries are rare, since often 10 or more years might be needed to even detect presence of a stock in a fishery. Despite these potential drawbacks, this method provides a transparent means of temporarily fixing biases or inaccuracies that hopefully results in better FRAM metrics for management.

Works Cited.

Model Evaluation Workgroup (MEW). 2008a. Chinook Fisheries Regulation Assessment Model (FRAM) Base Data Development v. 3.0 (Auxiliary Report to FRAM Technical Documentation for Coho and Chinook). (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Model Evaluation Workgroup (MEW). 2008b. Fisheries Regulation Assessment Model (FRAM) Technical Documentation for Coho and Chinook v. 2.0. (Document Prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Table 1. Change in exploitation rates (ER) for ESA-listed stocks (New BPER FRAM Run - Original BPER FRAM Run), from the TAMM ER_ESC_Overview Spreadsheets, for the pre-season FRAM runs of 2012-2014. Total ER reflects all FRAM and TAMM fishing during the management year. SUS ER, or Southern U.S. ER, reflects all FRAM and TAMM fishing by the U.S., excluding Alaska. SUS PTER is the Southern U.S. ER for only pre-terminal fisheries. Results for stocks with changes to BPERs are shown in bold.

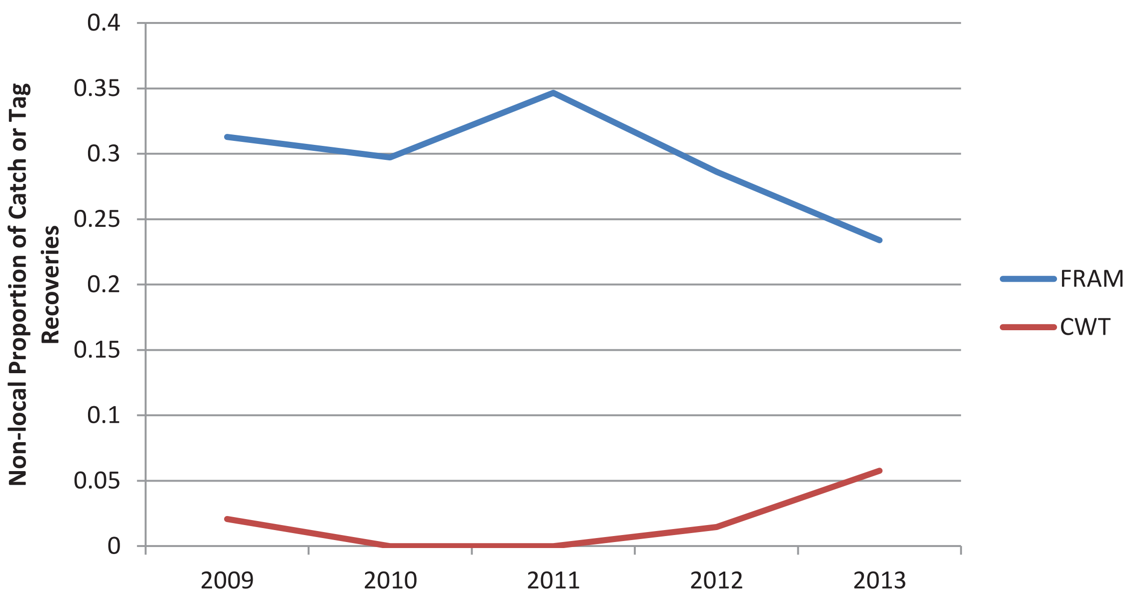
Stock	Total ER			SUS ER			SUS PTER		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
Spring/Early:									
Nooksack (n) - Total	0.0%	-0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Skagit (n) - Total	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
White	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dungeness	0.0%	-0.5%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%
Summer/Fall:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Skagit - Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Stillaguamish (n) - Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Snohomish (n) - Total	0.0%	0.3%	0.0%	0.0%	0.4%	0.0%	0.0%	0.4%	0.0%
Lake Wa. (Cedar R.)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Green	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Puyallup	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Nisqually	**-0.7%**	**-1.2%**	**-1.1%**	**-0.7%**	**-1.1%**	**-1.1%**	**-1.0%**	**-1.6%**	**-1.5%**
Western Strait-Hoko	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Elwha	0.0%	-0.5%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%
Mid-Hood Canal tribs. (n)	**-0.2%**	**-0.2%**	**-0.2%**	**-0.2%**	**-0.1%**	**-0.2%**	**-0.2%**	**-0.2%**	**-0.2%**
Skokomish	**1.0%**	**0.9%**	**0.6%**	**1.0%**	**1.0%**	**0.6%**	**-0.2%**	**-0.2%**	**-0.2%**

Table 2. Change in escapement for ESA-listed stocks (New BPER FRAM Run - Original BPER FRAM Run), from the TAMM ER_ESC_Overview Spreadsheets, for the pre-season FRAM runs of 2012-2014. Results for stocks with changes to BPERs are shown in bold.

Stock	2012	2013	2014
Spring/Early:			
Nooksack (n) - Total	0	0	0
North Fork	0	0	0
South Fork	0	0	0
Skagit (n) - Total	0	0	0
Upper Sauk	0	0	0
Upper Cascade	0	0	0
Suiattle	0	0	0
White	0	0	0
Dungeness	-1	0	0
Summer/Fall:	0	0	0
Skagit - Total	0	0	0
Upper Skagit	0	0	0
Sauk	0	0	0
Lower Skagit	0	0	0
Stillaguamish (n) - Total	0	0	0
North Fork Summer	0	0	0
South Fork Fall	0	0	0
Snohomish (n) - Total	0	0	0
Skykomish	0	0	0
Snoqualmie	0	0	0
Lake Wa. (Cedar R.)	0	0	0
Green	0	0	0
Puyallup	0	0	0
Nisqually	**16**	**23**	**86**
Western Strait-Hoko	0	0	0
Elwha	-2	-1	-2
Mid-Hood Canal tribs. (n)	**1**	**1**	**2**
Skokomish	**-34**	**-28**	**-15**

Figure 1: (a) The proportion of total FRAM catch that is non-local and the proportion of CWTs recovered that are non-local in Hood Canal marine terminal net fisheries from 2009 to 2013. FRAM predicts that >90% of non-local catch is from South Puget Sound. (b) Total number of fish in the landed catch of Hood Canal Terminal Net Fisheries from the FRAM Fishery Mortality Report.

a.



b.

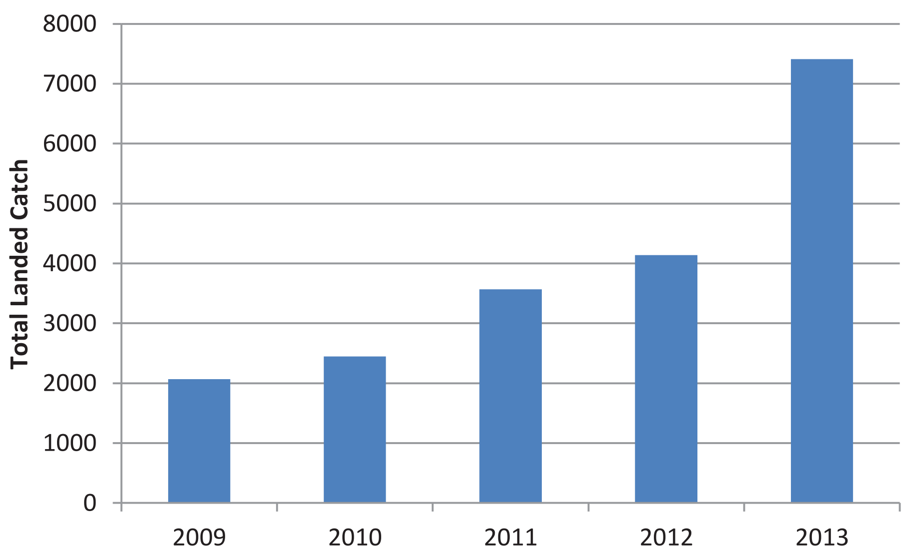
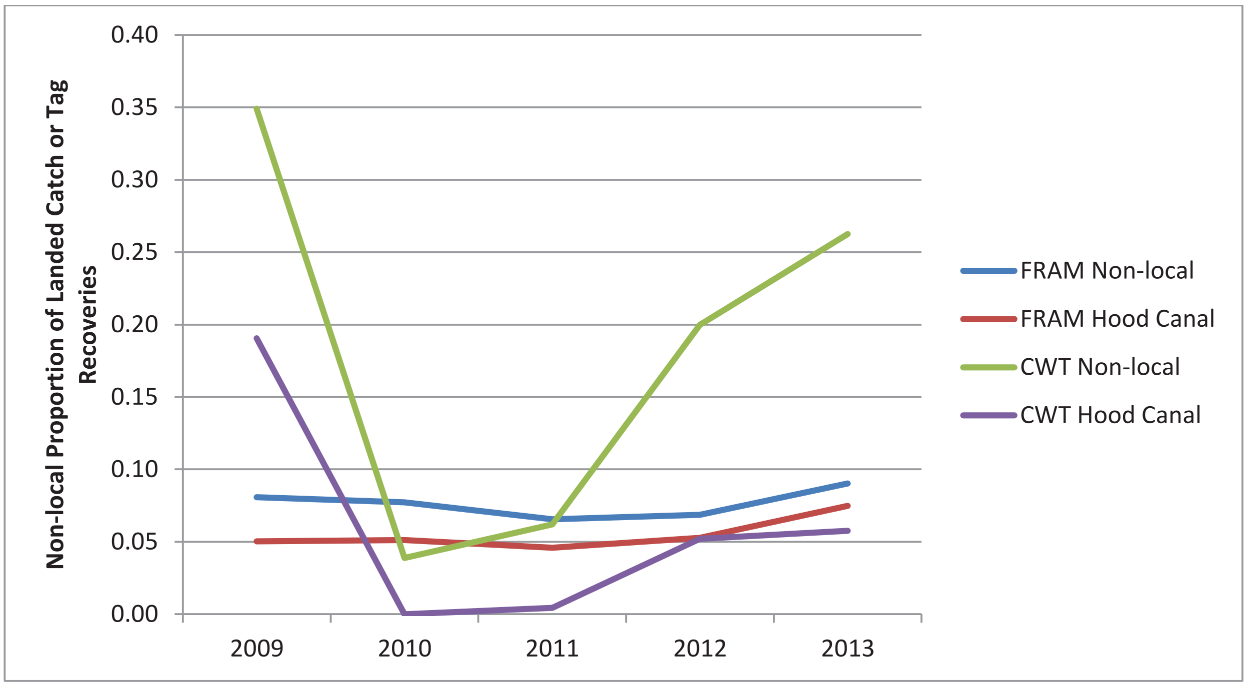


Figure 2: (a) The proportion of total FRAM catch that is non-local and from Hood Canal and the proportion of CWTs recovered that are non-local and from Hood Canal in South Puget Sound marine terminal net fisheries from 2009 to 2013. (b) Total number of fish in the landed catch of Hood Canal Terminal Net Fisheries from the FRAM Fishery Mortality Report.

a.



b.

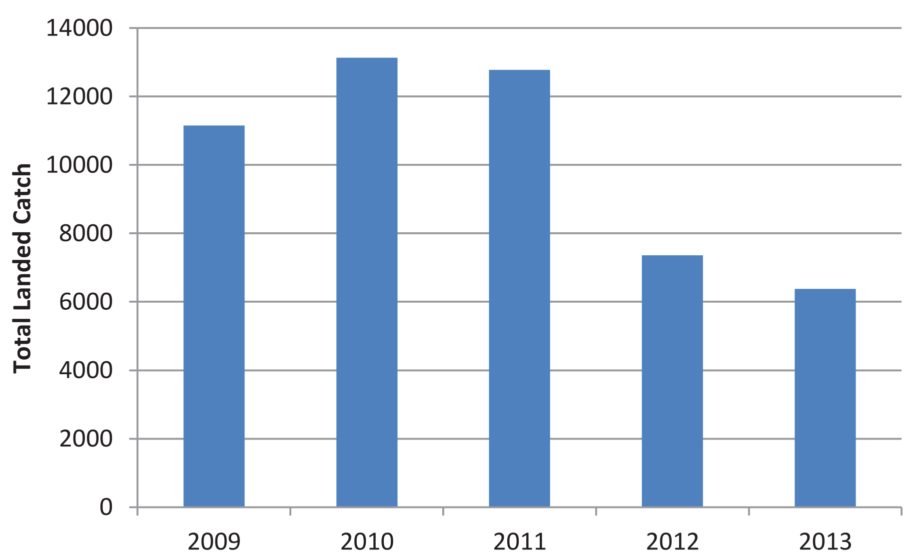


Figure 3: A comparison of AEQ Total Fishery Mortality for South Puget Sound Fall Fingerlings (SPS FF) in Hood Canal terminal marine net fisheries in the original FRAM pre-season runs and in the runs with new BPERs.

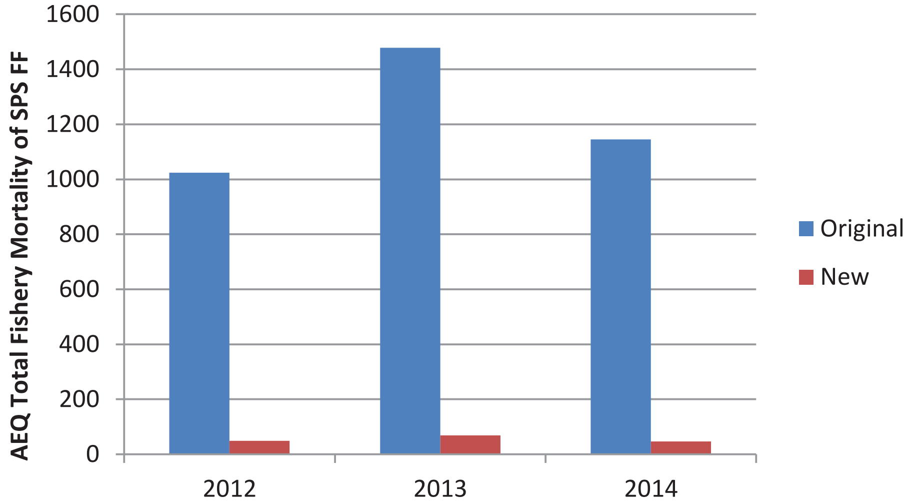


Figure 4: A comparison of AEQ Total Fishery Mortality for Hood Canal Fall Fingerlings (HC FF) in the South Puget Sound terminal marine net fisheries in the original FRAM pre-season runs and in the runs with new BPERs.