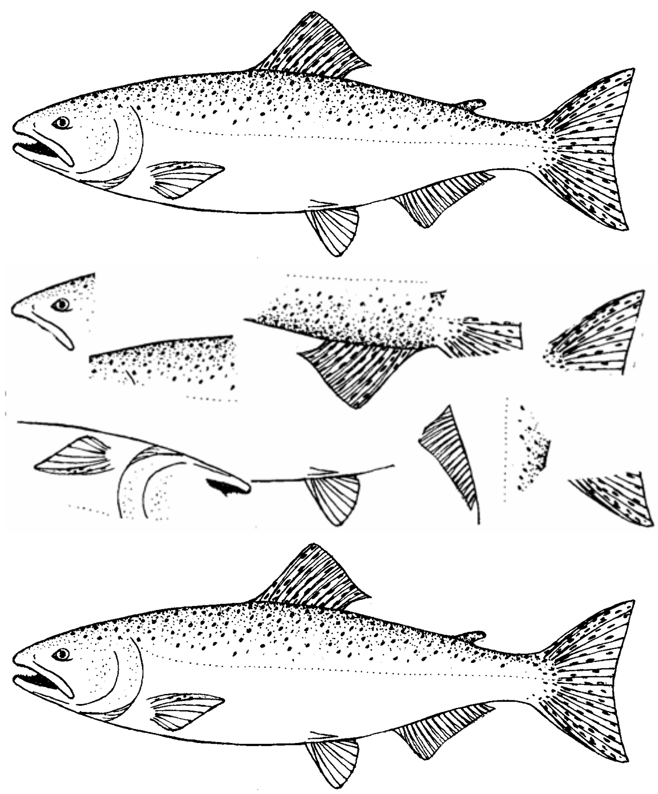
FISHERY REGULATION ASSESSMENT MODEL (FRAM)

Technical Documentation for Coho and Chinook – v. 3.0



MODEL EVALUATION WORKGROUP

Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220-1384
(503) 820-2280
www.pcouncil.org

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MODEL EVALUATION WORKGROUP

MR. ANDY RANKIS, CHAIR
Northwest Indian Fisheries Commission, Olympia, Washington

MR. LARRIE LAVOY, VICE CHAIR
Washington Department of Fish and Wildlife, Olympia, Washington

MR. ETHAN CLEMMONS
Oregon Department of Fish and Wildlife, Newport, Oregon

MR. ROBERT CONRAD
Northwest Indian Fisheries Commission, Olympia, Washington

MR. ALLEN GROVER
California Department of Fish and Game, Santa Rosa, California

MR. JIM PACKER
Washington Department of Fish and Wildlife, Olympia, Washington

MR. RISHI SHARMA
Columbia River Intertribal Fish Commission, Portland, Oregon

MR. DELL SIMMONS
National Marine Fisheries Service, Lacey, Washington

MR. HENRY YUEN
U.S. Fish and Wildlife Service, Vancouver, Washington

PACIFIC FISHERY MANAGEMENT COUNCIL STAFF

MR. CHUCK TRACY
MS. RENEE DORVAL
MS. CARRIE MONTGOMERY
MS. KIM MERYDITH

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1. INTRODUCTION

The Fishery Regulation Assessment Model (FRAM) is currently used by the Pacific Fishery Management Council (PFMC) to annually estimate impacts of proposed ocean and terminal fisheries on Chinook and coho salmon stocks. FRAM is a single-season modeling tool with separate processing code for Chinook and coho salmon. The Chinook version evaluates impacts on most stock groups originating from the California Central Valley (Sacramento River), north-central Oregon coast, Columbia River, Willapa Bay, north Washington coast, Puget Sound, and Southern British Columbia. The coho version evaluates impacts on a comprehensive set of stocks originating from Central California to Southeast Alaska and is considered to represent total West Coast production. The FRAM produces a variety of output reports that are used to examine the impacts of proposed fisheries for compliance with management objectives, allocation arrangements, Endangered Species Act (ESA) compliance, and domestic and international legal obligations. Until recently, FRAM was not used for assessing compliance with Chinook or coho agreements in international fisheries management forums. However, the U.S. and Canada have developed a common coho base period data set of fisheries and stocks allowing FRAM to be used as the first version of a bilateral regional planning tool for coho salmon management. The intent is to have a single common tool that can support both domestic and international fishery planning processes using a common set of data and assumptions.

1.1 Background

The need for a tool to project the impact of proposed salmon fisheries at the stock-specific level became apparent in the mid-1970s with treaty Indian fishery rights litigation and the associated legal obligation for the states of Washington and Oregon to provide treaty tribes with the opportunity to harvest specific shares of individual runs. Other legal issues such as the Magnuson-Stevens Fishery Conservation and Management Act and the Law of the Seas convention contributed to the need for developing better assessment tools. These legal issues in conjunction with the information available from the coast wide coded-wire tag (CWT) program provided the impetus for developing the early salmon fishery assessment models.

In the late 1970s, the Washington Department of Fisheries (WDF) and U.S. National Bureau of Standards (NBS) developed a model for evaluating alternative fishery regulatory packages. The WDF/NBS Model could be configured for either Chinook or coho by using different input data files. This model was coded in FORTRAN and ran on a mainframe computer at the University of Washington. Model runs were usually processed over night and results were painstakingly extracted from large volumes of printed output reports. The WDF/NBS model was not extensively used by the PFMC because it proved costly to operate and its results were difficult to obtain in a timely manner. Morishima and Henry (2000) provide a more in-depth history of Pacific Northwest salmon management and fishery modeling.

In the early 1980s, the development of personal computers permitted the WDF/NBS model to be converted into simple spreadsheet models. This transformation improved accessibility to the model during the PFMC pre-season planning processes. The first spreadsheet model for Chinook used by the PFMC was developed in the mid-1980s to model Columbia River "tule" fall Chinook. The Coho Assessment Model (CAM) was the corresponding spreadsheet model for coho and covered stocks from the Columbia River, Puget Sound, and Washington and Oregon coastal areas. The CAM was revised over time, principally to improve report generation capabilities and provide more detailed information on management of terminal area fisheries in Puget Sound through the use of Terminal Area Management Modules (TAMMs). The CAM was used as the primary model for evaluating coho impacts for proposed PFMC fisheries until the mid-1990s.

The increased complexity of proposed fishery regulation regimes and the need for increased time and area resolution for the impact projections soon surpassed the capability of the spreadsheet models. In the mid-1990s, CAM was programmed in QUICK BASIC and was renamed FRAM. The recognition that common algorithms underlie both the coho and Chinook spreadsheet models led to the effort to develop the QUICK BASIC version of FRAM for both species. The FRAM code could be used to evaluate proposed fishery regulation regimes for either Chinook or coho by using different input file configurations. In 1998, FRAM was converted to VISUAL BASIC to take advantage of the improved user interface available through the MS-WINDOWS operating system. A multi-agency Model Evaluation Workgroup periodically reviewed model performance and parameter estimation methods and coordinated revisions to the model during this period (1998-2000).

2. MODEL OVERVIEW

The FRAM is a discrete, time-step, age-structured, deterministic computer model used to predict the impacts from a variety of proposed fishery regulation mechanisms for a single management year. It produces point estimates of fishery impacts by stock for specific time periods and age classes. The FRAM performs bookkeeping functions to track the progress of individual stock groups as the fisheries in each time step exploit them. Individual stock-age groups are exploited as a single pool, that is, in each time step all pre-terminal fisheries operate on the entire cohort simultaneously and all terminal fisheries operate on the mature run.

2.1 Stocks

Currently, 123 stock groups are represented in Coho FRAM and 38 stock groups are represented in Chinook FRAM (see Appendices 1 and 2 for lists of the stocks). Each of these groups have both marked and unmarked components to permit assessment of mark-selective fishery regulations. For most wild stocks and hatchery stocks without marking or tagging programs, the cohort size of the marked component is zero; therefore, the current version of FRAM has a virtual total of 76 stock groups for Chinook and 246 for coho. Stocks or stock-aggregates represented in the FRAM were chosen based on the level of management interest, their contribution rate to PFMC fisheries, and the availability of representative CWT recoveries in the historical CWT database.

2.2 Fisheries

The FRAM includes pre-terminal and terminal fisheries in southeast Alaska, Canada, Puget Sound, and off the coasts of Washington, Oregon, and California. There are 198 fisheries in Coho FRAM and 73 fisheries in Chinook FRAM. The intent is to encompass all fishery impacts to modeled coho and Chinook stocks in order to account for all fishing-related impacts and thereby improve model accuracy. Terminal fisheries in Coho FRAM are modeled with finer resolution than Chinook FRAM, most notably by including individual freshwater fisheries. Terminal fisheries in Chinook FRAM are aggregations of gears and management areas. Fishery number and fishery name for each of the FRAM fisheries are listed in Appendix 3 for coho and Appendix 4 for Chinook.

2.3 Time Steps

The time step structure used in FRAM represents a compromise level of resolution that corresponds to management planning fishery seasons and species-specific migration and maturation schedules.
The FRAM consists of five time periods for coho and four periods for Chinook (Table 2-1). At each time step a cohort is subjected to natural mortality, pre-terminal fisheries, and also potentially to maturation (Chinook only), and terminal fisheries.

Table 2-1. FRAM time steps for coho and Chinook.

Coho		Chinook	
Period	Months	Period	Months
Time 1	January-June	Time 1	Preceding October-April
Time 2	July	Time 2	May-June
Time 3	August	Time 3	July-September
Time 4	September	Time 4	October-April
Time 5	October - December		

The recovery data available in the CWT database limit the time-step resolution of the model. Increasing the time-step resolution of the model usually decreases the number of CWT recoveries for a stock within a time period. Since estimation of fishery impacts, e.g. exploitation rates, is dependent on CWT recovery information, decreasing the number of CWT recoveries in time/area strata increases the variance of the estimated exploitation rates in those strata. In recognition of these data limitations, efforts were made to restrict the level of time-step resolution to that necessary for fishery management purposes.

2.4 Assumptions and Limitations

Major assumptions and limitations of the model are described briefly below.

1. CWT fish accurately represent the modeled stock. Many "model" stocks are aggregates of stocks that are represented by CWTs from only one production type, usually hatchery origin. For example, in nearly all cases wild stocks are aggregated with hatchery stocks and both are represented by the hatchery stock's CWT data. Therefore, for each modeled stock aggregate, it is assumed that the CWT recovery data from non-mark selective fisheries accurately represent the exploitation and distribution patterns of all the untagged fish in the modeled stock.

2. Length at age of Chinook is stock specific and is constant from year to year. Von Bertalanffy growth functions (Section 6.4.2) are used for Chinook in determining the proportion of the age class that is legal size in size-limit fisheries. Parameters for the growth curves were estimated from data collected over a number of years. It is assumed that growth in the year to be modeled is similar to that in the years used to estimate the parameters of the Von Bertalanffy growth model.

3. Natural mortality is constant from year to year. Natural mortality is assumed to be constant across months--but not necessarily time steps--for all stocks (Appendix 5). Rates for Chinook are age specific and yield the same annual rate as used in PSC Chinook model.

4. Stock distribution and migration is constant from year to year and is represented by the average distribution of CWT recoveries during the base period. We currently lack data on the annual variability in distribution and migration patterns of coho and Chinook salmon stocks. In the absence of such estimates, fishery-specific exploitation rates are computed relative to the entire cohort. Changes in the distribution and migration patterns of stocks from the base period will result in poor estimates of stock composition and stock-specific exploitation rates.

5. Fish do not encounter gear multiple times in a specific time-area fishery stratum. Within each time/area/fishery stratum, fish are assumed to be vulnerable to the gear only once. The catch equations used in the model are discrete and not instantaneous. Potential bias in the estimates may increase with large selective fisheries or longer time intervals, both of which increase the likelihood that fish will encounter the gear more than once.

While it is difficult to directly test the validity of these assumptions, results of validation exercises could provide one assessment of how well these assumptions are met and the sensitivity of the model to the assumptions. Currently, there is little effort directed at model validation.

3. BASE PERIOD DATA

Coho and Chinook CWT recovery data for abundances and stocks during a "base period" are used to estimate average base period stock abundances, age-specific time/area/fishery exploitation rates, and maturation rates (Chinook only) for modeled stocks. These estimates are derived through species-specific cohort analysis procedures. Cohort analysis is a series of procedures that use CWT recoveries and base period catch and escapement data to "back-calculate" or reconstruct a pre-fishing cohort size for each stock and age group using assumed natural mortality and incidental mortality rates. See MEW (2007a, 2007b) for a more detailed description of the cohort analysis procedures for coho and Chinook.

Model base period data for the Coho FRAM is derived from fishery and escapement recoveries of CWTs and terminal area run size estimates for the return years 1986-1992. The model base period data for Coho FRAM is an average of the annual values from each of the separate run reconstructions and cohort analysis for the 1986-92 return years. See MEW (2007a) for a more detailed description of the development of the coho base period data.

The Chinook FRAM is calibrated using escapement, catch, and CWT recovery data from 1974-1979 brood year CWT releases. The model base period data for Chinook FRAM is derived from a single run reconstruction and cohort analysis by aggregating CWT data from several consecutive brood years. During the late 1970s and early 1980s fisheries were conducted across an extensive geographic area and were typically of longer duration than current fisheries. The CWT recovery data from this period provides a very good representation of the distribution and migration timing of many stocks. Not all stocks represented in the Chinook FRAM have CWT recovery data available from the 1974-1979 brood years in the base period (e.g., Snake River fall Chinook); these stocks are categorized as "Out-of-Base" stocks. Available CWT data for the "Out-of-Base" stocks are translated to equivalent base period recovery and escapement data using known fishing effort and harvest relationships between recovery years. See MEW (2007b) for a more detailed description of the development of the Chinook base period data. Appendix 2 lists the brood years of CWT releases used to develop each stock's base period data.

4 GENERAL INPUT TYPES

There are five general types of input that are used by FRAM. The first three types are defined annually to reflect projected stock abundances and proposed fishery regulations for the current model year. The last two types of input are specifications for different sources of fishery-related mortalities. While these values can change as more information becomes available from additional data collection and new studies, they typically do not change on an annual basis.

1. **Cohort Abundance:** For each stock or stock aggregate, an annual forecast of abundance at age is obtained from a source that is independent of the model. For preseason modeling, these forecasts of stock abundance are used to estimate initial cohort sizes in the current year. For coho, only one age class (age 3) is assumed vulnerable to fisheries; coho abundances are input to the model as January age-3 abundance. For Chinook, initial stock abundance estimates are needed by age class, from age-2 to age-5 fish. Coho and Chinook abundance estimates are further segregated by mark status ("marked" or "unmarked").

2. **Size Limits:** For coho, age-3 fish are assumed fully vulnerable and age-2 fish are assumed not to be vulnerable to modeled fisheries. For Chinook, minimum size limits are specified by fishery where appropriate.

3. **Fishery Catch Mortality:** The model provides four options for estimating mortality in a fishery: a quota, an exploitation rate scalar, a ceiling, and a harvest rate (for Puget Sound terminal fisheries only).
   a) <u>Quota:</u> Total catch in the fishery is set equal to a value input by the user.
   b) <u>Exploitation rate scalar</u>: The exploitation rate in the fishery is scaled, relative to the base period average, using a scalar input by the user. The most common scaling mechanism used is fishing effort (e.g., vessel-days, angler-trips) relative to the average level during the base period.
   c) <u>Ceiling:</u> A ceiling catch for the fishery is input by the user. Fishery catch is first calculated based on an exploitation rate scalar and then compared to a ceiling; if the estimated catch exceeds the ceiling, then the catch is truncated at the ceiling value.
   d) <u>Harvest rate:</u> Using the Puget Sound TAMMs, a terminal area harvest rate is applied to either all fish present in the terminal area (coho or Chinook) or to the number of local-origin stock only (coho only).

4. **Release Mortality:** This is the mortality associated with the release of landed fish from hook-and-line and other gears. Release mortality rates assumed for coho are shown in Table 4-1a and for Chinook in Table 4-1b. Hook-and-release mortality is assessed when coho or Chinook are not allowed to be retained (so-called "Coho/Chinook non-retention", or CNR fisheries), when size limits apply, or in mark-selective fisheries. Release mortality has been estimated by a number of studies of hook-and-line fisheries, and release mortality rates for troll and recreational fisheries in the ocean have been formally adopted by the PFMC following analysis by Salmon Technical Team (2000). Release mortality in net fisheries with coho or Chinook non-retention is estimated externally to FRAM and input into the model as either additional "landed catch" or as CNR mortality.

   Mark-selective fisheries have two additional variations of "release" mortality that are described as either the inappropriate retention of an unmarked fish or the release of a marked fish which consequently may be subject to release mortality. The failure to release an unmarked fish by an angler is a user input to the model called "<u>Unmarked Retention Error</u>" (or Retention Error Rate) and is the proportion of the unmarked fish encountered that are retained. The release of marked fish by anglers is a user input to the model called "Marked Recognition Error" and is the proportion of the marked fish encountered that are released. These released fish are subject to release mortality. These rates are identified in Table 4-2.

5. **Other Non-landed Mortality:** This includes fishing-induced mortality not associated with direct handling (or landing) of the fish (see Table 4-1a for coho and Table 4-1b for Chinook). Included in this category are sport and commercial troll "drop-off" (fish that drop off from the hook before they are brought to vessel but die from hook injuries), and net gear "drop-out" (fish which are not brought on board but die from injury as a result of being netted). In general, a 5% mortality rate is applied to the landed catch to account for "other non-landed mortality" in hook-and-line fisheries. Net drop-out mortality rates vary depending on species, net type, and terminal versus pre-terminal nature of the fishery.

Table 4-1a. FRAM/TAMM fishery-related mortality rates for coho salmon used for Southern U.S. fisheries in 2008.

Fishery: (designated by area, user group, and/or gear type)	**Fishery Type**	**Comments**	**Release Mortality**	**"Other" Mortality**[a]
PFMC Ocean Recreational[d]	MSF Non-Retention Non-Retention	barbless N. Pt. Arena S. Pt. Arena	14.0% 14.0% [b] 23.0% [b]	5.0% 5.0% [b] 5.0% [b]
PFMC Ocean T-Troll PFMC Ocean NT-Troll	Retention Non-Retention MSF	 barbless	n.a.[c] 26.0% [b] 26.0%	5.0% 5.0% [b] 5.0%
Area 5, 6C Troll	Retention		n.a.	5.0%
Puget Sound Recreational[e]	Retention MSF	 barbless	n.a. 7.0%	5.0% 5.0%
WA Coastal Recreational	Retention		n.a.	5.0%
Buoy 10 Recreational	MSF	barbed	16.0%	5.0%
Gillnet and Setnet			n.a.	2.0%
PS Purse Seine			26.0% [b]	2.0%
PS Reef Net, Beach Seine, Round Haul			n.a.	2.0%
Freshwater Net			n.a.	2.0%
Freshwater Recreational	Retention Non-Retention		n.a. 10.0% [b]	5.0% 5.0% [b]

[a] The "other" mortality rates (which include drop-out and drop-off) are applied to landed fish (retention fisheries), thus FRAM does not assess "drop-off" in non-retention fisheries. Drop-off (and release mortality) associated with CNR fisheries are estimated outside the model and used as inputs to the model. For mark-selective fisheries (MSF), "other" mortality rates are applied to estimated encounters of marked and unmarked fish.
[b] Rate assessed externally to FRAM.
[c] None assessed.
[d] Source: Salmon Technical Team (2000).
[e] Source: WDF et al. (1993).

Table 4-1b. FRAM/TAMM fishery-related mortality rates for Chinook salmon used for Southern U.S. fisheries in 2008.

Fishery: (designated by area, user group, and/or gear type)	**Fishery Type**	**Comments**	**"Shaker" Release Mortality**	**"Adult" Release Mortality**	**"Other" Mortality**[a]
PFMC Ocean Recreational[e]	Retention	N Point Arena	14.0%	n.a.[c]	5.0%
	Retention	S Point Arena	23.0%	n.a.	5.0%
PFMC Ocean Troll	Retention	barbless	25.5%	n.a.	5.0%
Area 5,6,7 T-Troll	Retention	barbless	25.5%	n.a.	5.0%
Puget Sound (PS) Recreational[f]	Retention	barbless	20.0%	n.a.	5.0%
	MSF	barbless	20.0%	10.0%	5.0%
	Non-Retention	barbless	20.0%	10.0% [b]	5.0% [b]
Buoy 10 Recreational	not modeled within FRAM		n.a.	n.a.	n.a.
Commercial Net					
PS Areas 4B,5,6,6C	PT[d] GN, SN		n.a.	n.a.	3.0%
WA Coastal & Col R. Net	PT[d] GN, SN		n.a.	n.a.	3.0%
PS Areas 6A,7,7A	PT[d] GN, SN, Purse S		n.a.	n.a.	1.0%
NT PS Areas: 6B,9,12,12B,12C	PT[d] GN, SN, Purse S		n.a.	n.a.	1.0%
T PS Areas:7B,7C,7D	PT[d] GN, SN, Purse S		n.a.	n.a.	1.0%
All other PS marine net	Terminal GN, SN		n.a.	n.a.	2.0%
PS Purse Seine	Non-Retention	immature	n.a.	45.0% [b]	0.0%
	Non-Retention	mature	n.a.	33.0% [b]	0.0%
PS Reef Net, Beach Seine	Non-Retention		n.a.	n.a.	n.a.
Freshwater Net			n.a.	n.a.	n.a.
Freshwater Recreational	Retention		n.a.	n.a.	n.a.
	MSF	TAMM	n.a.	10.0% [b]	n.a.
	Non-Retention	TAMM	n.a.	10.0% [b]	n.a.

[a] The "other" mortality rates (which include drop-out and drop-off) are applied to landed fish (retention fisheries), thus FRAM does not assess "drop-off" in non-retention fisheries. Drop-off (and release mortality) associated with CNR fisheries are estimated outside the model and used as inputs to the model. For mark-selective fisheries (MSF), "other" mortality rates are applied to estimated encounters of legal sized marked and unmarked fish.
[b] Rate assessed externally to FRAM.
[c] None assessed.
[d] PT = Pre-terminal.
[e] Source: Salmon Technical Team (2000).
[f] Source: WDF et al. (1993).

Table 4-2. Mark-selective fishery input values for Southern U.S. fisheries.

Fishery and Years Used	Unmarked Retention Error Rate (% of unmarked fish retained)	Mark Recognition Error Rate (% of marked fish released)
NOF troll, sport SOF sport	2% 2%	6% 6%
Area 5,6 sport—2001 coho Area 5,6 sport—2002-07 coho Area 5,6 sport—2003-07 Chinook Area 5,6 sport—2008	2% 2% 8% 6%	34% 38% 6% 6%
Area 7 sport—2001 coho Area 7 sport—2002-07 coho Area 7 sport—2007-08 Chinook	5% 8% 8%	6% 9% 6%
Area 8-1,2 sport—2005-07 Chinook Area 8-1,2—2008 Chinook	8% 7%	6% 10%
Area 9 sport—2007 Chinook Area 9 sport—2008 Chinook	8% 6%	6% 6%
Area 10 sport—2007 Chinook Area 10 sport—2008 Chinook	8% 6%	6% 6%
Area 13 sport—2007-08 Chinook	8%	6%

5. OUTPUT REPORTS AND MODEL USE

Model results are available as either standard FRAM printed output reports or in Excel spreadsheets that have a summary of FRAM results/reports. The Terminal Area Management Module (TAMM) spreadsheets provide comprehensive summaries of fishery mortalities, exploitation rates, run sizes, and escapements for key stocks in the PFMC and North of Falcon annual salmon season setting processes. The coho TAMM spreadsheet reports fishery impacts for all coho stocks of management interest while Chinook TAMM spreadsheet reports are limited to Puget Sound stocks. Other model results not shown in the spreadsheets can be generated directly from FRAM. These reports include summaries of projected catch by fishery, catch by stock, and catch by age, and escapement/run size reports. A new report has been created for FRAM to provide more detailed information relative to mark-selective fisheries for coho and Chinook. For a full scope of FRAM report generating functions, refer to "User Manual for the Fishery Regulation Assessment Model (FRAM) for Chinook and Coho" (MEW 2007c). Summaries of important FRAM and TAMM output reports used during PFMC and NOF management processes are shown in Appendix 7-1, 7-2.

6. COMPUTATIONAL STRUCTURE

For each time step and fishery, FRAM simulates fishery regulations following the sequence of computations depicted for coho (Figure 1) and Chinook (Figure 2). The first step for both coho and Chinook is to scale the predicted cohort size for the current year to the base period average cohort size. This is done by stock for the January age-3 cohort for coho and for the age-2 through age-5 cohorts for Chinook. Each stock's cohort is then processed through a time step loop defined for the species (five time steps for coho and four for Chinook). Within the time step loop: (1) natural mortality is applied to the beginning cohort size at age; (2) the procedures to calculate projected catches for all fisheries operating in the time step are executed; and (3) all fishery mortalities for the cohort (stock) are totaled and the remaining abundance of the stock at age is calculated.

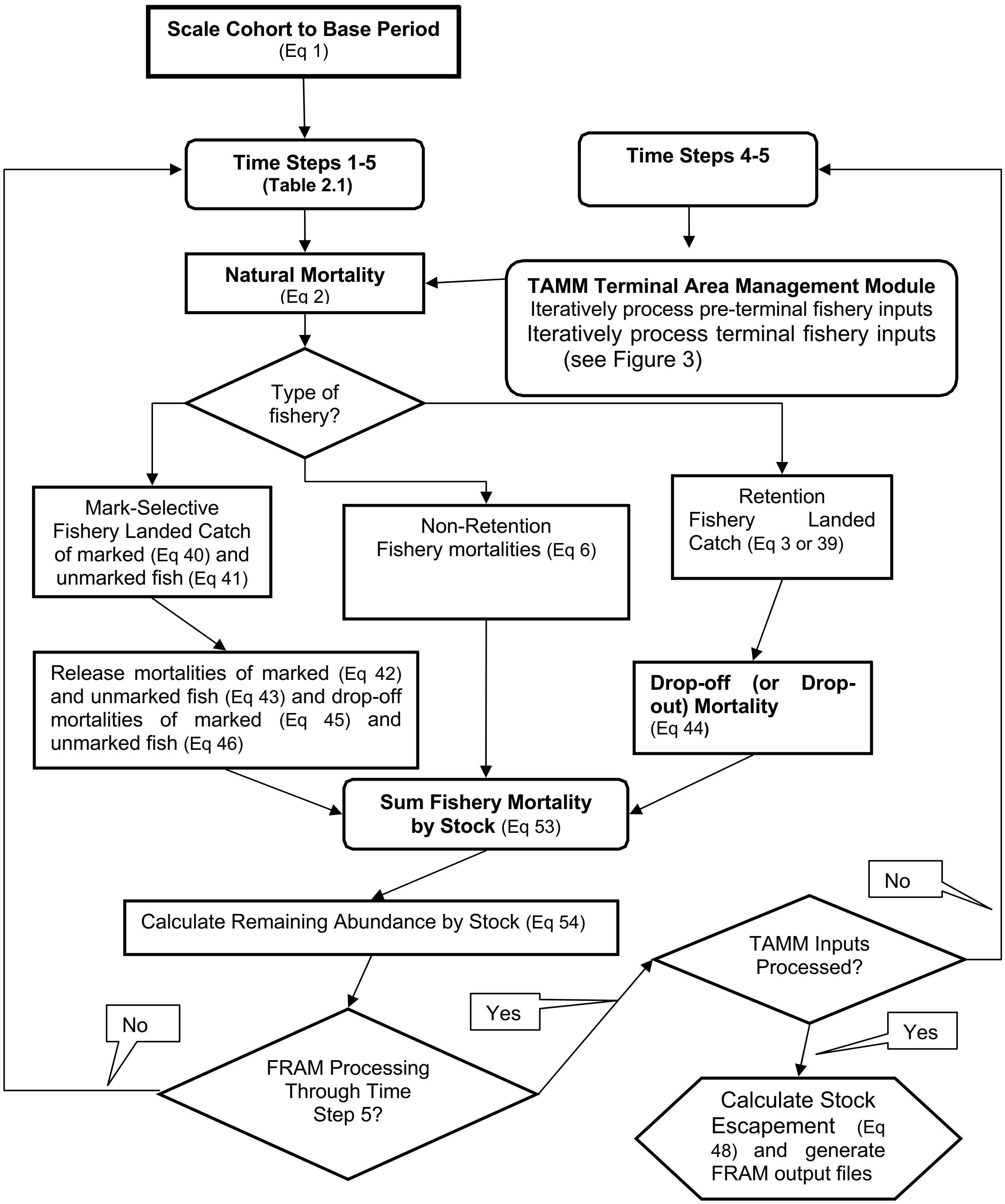

Figure 1. Flow chart for Coho FRAM.

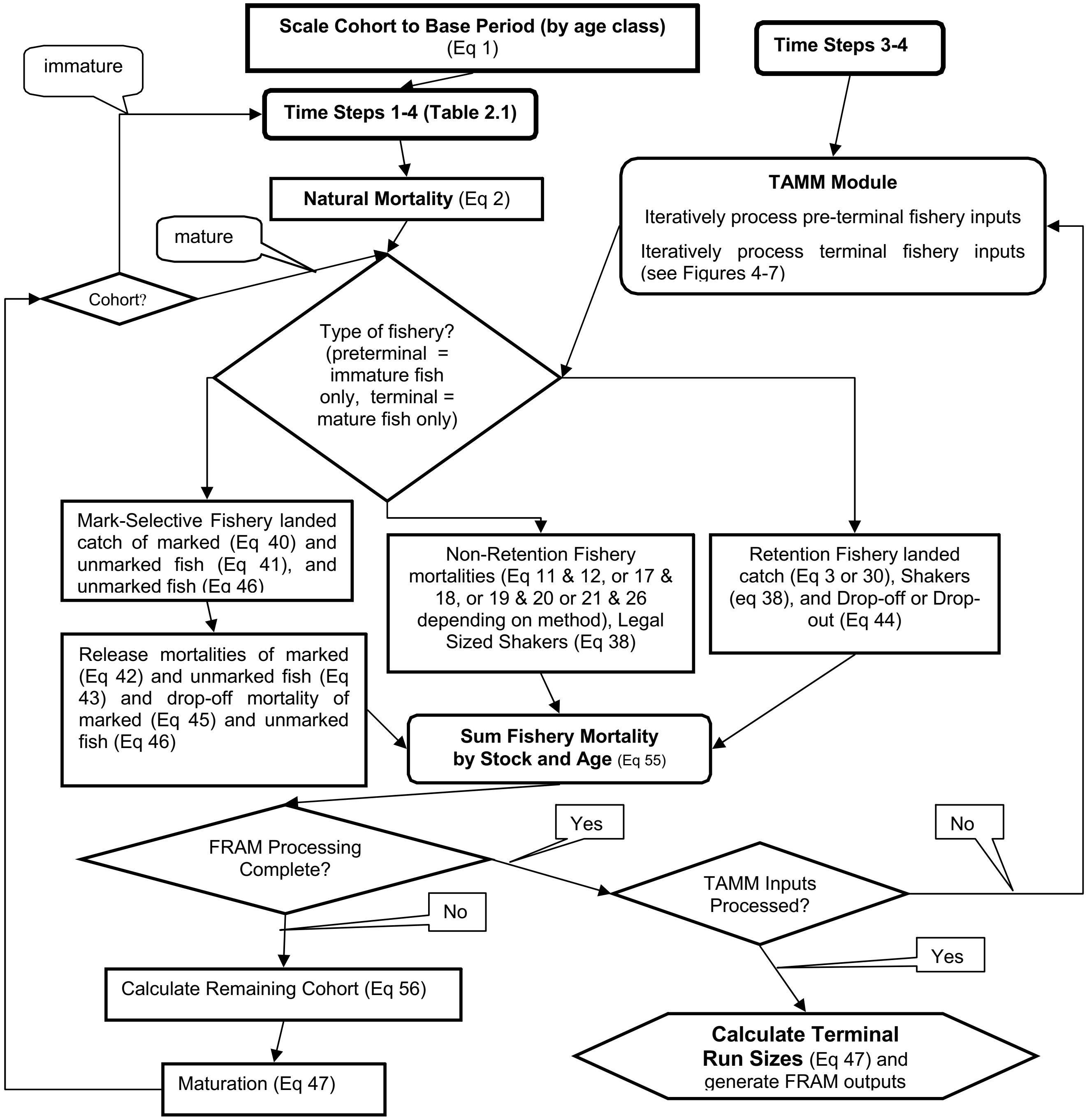

Figure 2.   Flow chart for Chinook FRAM.

After FRAM has processed all steps in the time step loop the program checks for the presence of an optional TAMM. If the model user has not specified a TAMM input file for additional modeling, FRAM processing is complete and final terminal run sizes (Chinook) or escapements (coho) are calculated. If a TAMM has been specified, then FRAM will repeat processing through the specified fisheries and time step loops. Although TAMMs are focused upon terminal area fisheries, some of the TAMM fisheries are in mixed-stock areas and may impact both mature and immature Chinook. Thus, an iterative FRAM/TAMM process is used to obtain the final tabulations of fishery mortalities and stock escapements (see Section 7 for further TAMM explanation).

6.1 Scale Cohort to Base Period

The equation below establishes the starting cohort size for all stocks as a product of two parameters: the average cohort size during the base period for stock *s* at age *a* in the first time period ($BPCohort_{s,a}$) and a stock and age-specific scalar ($StockScalar_{s,a}$). $StockScalar_{s,a}$ is estimated externally to the model and is an annual input to the model (see Section 8.1 for more *StockScalar* detail).

(1) $$Cohort_{s,a,1} = \overbrace{BPCohort_{s,a}} \times \underbrace{StockScalar_{s,a}}$$ [1]

For coho, the starting cohort size is the projected number of age-3 fish in January of the fishing year for each stock. For Chinook, separate cohort sizes for the first time step (October to April) preceding the beginning of the fishery year are required for age-2, age-3, age-4, and age-5 fish in each stock.

FRAM was developed using this approach of applying an abundance scalar from the yearly command file to the base period abundance in the base period data file to yield an initial stock size for the run year. FRAM code was written to follow this general structure. Associated cohort analysis and calibration programs were likewise written to produce values that correspond to this approach. Converting the FRAM and associated input files to use direct abundance numbers rather than scalars has been considered but so far has not been pursued further. Depending on perspective, the scalar approach or the direct number approach might be considered more informative. The scalar approach is more informative with respect to the stock abundance status relative to the base years, but does not provide the population size. The direct numbers approach does not provide an historical context for stock abundance.

6.2 Natural Mortality

At the beginning of each time step *t(i)*, each cohort is decreased to account for projected natural mortality prior to application of fishing mortality and maturation rates using the following equation:

(2) $$Cohort_{s,a,t} = Cohort_{s,a,t(i)} \times (1 - \overbrace{M_{a,t}})$$

where $M_{a,t}$ is the natural mortality rate for age *a* fish during time step *t* (see Appendix 5 for specific rates used for coho and Chinook).

6.3 Catch

The FRAM simulates fisheries through the use of linear equations. Different types of computations are used depending upon whether or not a fishery operates under mark-retention restrictions. If all fish can be retained regardless of mark status, the following general formula is used (mark-selective fisheries are described in Section 6.5):

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[1] Parameters with a bracket over them indicate they are from base period data file (STKXXXX.out) either as an average estimated from cohort analysis (e.g., $\overbrace{BPCohort}$) or as an assigned fixed value from independent studies (e.g., $\overbrace{M}$). Parameters with a bracket under them (e.g., $\underbrace{StockScalar_{s,a}}$) are externally calculated and inputted by the user in the run command file (XXXX.cmd).

(3) $$Catch_{s,a,f,t} = Cohort_{s,a,t} \times \overbrace{BPER_{s,a,f,t}} \times \underbrace{FishScalar_{f,t}} \times PV_{s,a,t} \times \underbrace{SHRS_{s,f,t}}$$

and

(3a) $$TotCatch_{f,t} = \sum_{s} \sum_{a} Catch_{s,a,f,t} \times (1/\overbrace{PropModelStock_{f}})$$

where:

$Catch_{s,a,f,t}$	=	Catch of stock *s*, age *a*, in fishery *f*, at time step *t;*
$BPER_{s,a,f,t}$	=	Average Base Period Exploitation Rate (average harvest rate for terminal fisheries) for stock *s*, age *a*, in fishery *f*, at time step *t* (*BPER* is derived from cohort analysis using CWT release and recovery data);
$Cohort_{s,a,t}$	=	Estimated number of fish in cohort (Chinook are expressed as both immature and mature cohorts) for stock *s* at age *a* in time step *t*;
$FishScalar_{f,t}$	=	Impact scalar for fishery *f* at time step *t* relative to the base period; externally calculated by user as effort scalar or calculated internally in model for fixed catch (quota) type fisheries.
$PV_{s,a,f,t}$	=	Proportion of cohort for stock *s*, age *a*, vulnerable to the fishery at time step *t* (for coho *PV* is always = 1.0; for Chinook *PV* is a function of a von Bertalanffy growth curve); and
$SHRS_{s,f,t}$	=	Stock-specific exploitation rate scalar for stock *s*, in fishery *f*, at time step *t* (the default value of 1.0 is rarely changed)
$PropModelStock_{f}$,	=	Average proportion of model Chinook stocks in the catch relative to total catch in fishery *f* for the base period. It is set to 1.0 for coho (see Section 6.8).

The parameter $FishScalar_{f,t}$ is the foundation for the model's fishery simulation algorithms. FRAM can evaluate two general types of fisheries: (1) effort-based or (2) catch-based. For effort-based fisheries, the parameter $FishScalar_{f,t}$ is specified by the modeler to reflect expected effort relative to the average effort observed during the model's base period. For catch-based fisheries, $FishScalar_{f,t}$ is computed automatically so as to attain a specified catch level. In addition, FRAM can model input catches as either quotas or ceilings. In a quota fishery, the input catch is always achieved. In a ceiling fishery, input value is a catch cap, which may or may not be reached by the fishery. If the catch level is to be modeled as a quota, then $FishScalar_{f,t}$ is computed as:

(4) $$FishScalar_{f,t} = \frac{\underbrace{QuotaLevel_{f,t}}}{\sum_{s} \sum_{a} Catch_{s,a,f,t} \times (1/\overbrace{PropModelStock_{f}})}$$

where $\sum_{s} \sum_{a} Catch_{s,a,f,t}$ is computed with $FishScalar_{f,t}$ = 1.0 in Equation 3 in the first of a two step process. This first step simulates catch at base period effort levels for the given stock abundances. The result from dividing the quota by this simulated base period total catch produces the value for $FishScalar_{f,t}$ that equals $QuotaLevel_{f,t}$.

If the catch level is to be modeled as a ceiling, both an effort scalar and quota are specified. A catch estimate is made during a first iteration of FRAM using the effort scalar. If the effort scalar computes a catch level that is less than the catch ceiling, then the final catch estimate is this effort-based catch. If the initial effort scalar results in a catch level that exceeds the ceiling, then the final catch estimate is the ceiling. In the case of a ceiling-type fishery, the final $FishScalar_{f,t}$ will be calculated based on the lower of the two types of catch estimates (effort scalar or quota).

6.4 Incidental Mortality

Several types of incidental mortality can be accounted for in FRAM either through external calculations of mortality or through internal FRAM processing. Incidental mortality associated with hook-and-line drop-off and net drop-out is expressed as a fraction of retained catch or as a fraction of encounters in the case of mark-selective fisheries. Incidental mortality in mark-selective fisheries is discussed in the next section.

6.4.1 Mortality Calculations for Salmon Non-Retention Fisheries

Mortalities in coho non-retention fisheries (CNR) are derived using estimates calculated outside of the FRAM using historical landing information (Method 1). Chinook non-retention mortalities are modeled using inputs of legal and sub-legal encounters (Method 2), from total encounters (Method 3), or from the level of open versus non-retention effort within each time step (Methods 4 and 5). The methods were developed to fit observations available from various fisheries. Methods 4 and 5, which have not been used in recent years, were developed for Canadian and Alaskan fisheries which had both open and non-retention regulation periods in the same season and had changes in the gear or fishing patterns to avoid Chinook encounters.

METHOD 1 (Coho) – Computed from external estimates of non-retention mortalities

(5) $$\mathrm{PropCatch}_{\mathrm{s,f,t}} = \frac{Cohort_{s,t} \times \overbrace{BPER_{s,f,t}} \times \underbrace{SHRS_{s,f,t}}}{\sum_{s} Cohort_{s,t} \times \overbrace{BPER_{s,f,t}} \times \underbrace{SHRS_{s,f,t}}}$$

(6) $$CNR_{s,f,t} = \underbrace{EstCNRMorts_{f,t}} \times PropCatch_{s,f,t}$$

where the previous definitions of parameters are still applicable and:

$PropCatch_{s,f,t}$	=	Proportion of the total catch in fishery *f* of stock *s* at time step *t;*
$EstCNRMorts_{f,t}$	=	Estimate of total CNR mortalities in fishery *f* at time step *t*; and
$CNR_{s,f,t}$	=	Coho non-retention mortality for stock *s* in fishery *f*, at time step *t.*

METHOD 2 (Chinook) – Computed from external estimates of legal and sub-legal sized encounters

(7) $$LegalPropTempCatch_{s,a,f,t} = TempCatch_{s,a,f,t} \Big/ \sum_{s} \sum_{a} TempCatch_{s,a,f,t}$$

(8) $$SubLegPop_{s,a,t} = Cohort_{s,a,t} \times (1 - PV_{s,a,t})$$

(9) $$SubLegNR_{s,a,f,t} = SubLegPop_{s,a,t} \times \overbrace{SubER_{s,a,f,t}} \times \overbrace{RelRate_{f,t}}$$

(10) $$SubLegPropEnc_{s,a,f,t} = SubLegNR_{s,a,f,t} \Big/ \sum_{s} \sum_{a} SubLegNR_{s,a,f,t}$$

(11) $$CNRLegal_{s,a,f,t} = LegalPropCatch_{s,a,f,t} \times \underbrace{LegalEnc_{f,t}} \times \overbrace{RelRate_{f,t}} \times \overbrace{PropModelStock_{f}}$$

(12) $$CNRSub_{s,a,f,t} = SubLegPropEnc_{s,a,f,t} \times \underbrace{SubLegEnc_{f,t}} \times \overbrace{RelRate_{f,t}} \times \overbrace{PropModelStock}_{f}$$

where the previous definitions of parameters are still applicable and:

$LegalTempPropCatch_{s,a,f,t}$	=	Proportion of legal-sized catch of stock *s,* age *a*, in fishery *f*, at time step *t* using *FishScalar* = 1.0 (ie base period);
$TempCatch_{s,a,f,t}$	=	For temporary calculation, the expected landed catch of stock *s,* age *a,* in fishery *f,* at time step using *FishScalar* = 1.0
$SubLegPop_{s,a,t}$	=	Sub-legal sized population for stock *s*, age *a*, at time step *t*;
$SubLegNR_{s,a,f,t}$	=	Sub-legal sized non-retention mortalities for stock *s*, age *a*, in fishery *f*, at time step *t*;
$SubER_{s,a,f,t}$	=	Sub-legal sized encounter rate for stock *s*, age *a*, in fishery *f*, at time step *t* calculated from base period data;
$RelRate_{f,t}$	=	Release mortality rate for fish in fishery *f* at time step *t*;
$SubLegPropEnc_{s,a,f,t}$	=	Sub-legal sized proportion of encounters for stock *s*, age *a*, in fishery *f*, at time step *t*;
$LegalEnc_{f,t}$	=	Total number of legal-sized encounters in fishery *f* at time step *t* (model input for Method 2);
$SubLegEnc_{f,t}$	=	Total number of sub-legal sized encounters in fishery *f* at time step *t* (model input for Method 2);
$LegalEnc_{s,a,f,t}$	=	Legal-sized encounters for stock *s*, age *a*, in fishery *f*, at time step *t*;
$SubLegEnc_{s,a,f,t}$	=	Sub-legal sized encounters for stock *s*, age *a*, in fishery *f*, at time step *t*;
$CNRLegal_{s,a,f,t}$	=	Legal-sized adult non-retention mortality for stock *s*, age *a*, in fishery *f*, at time step *t*; and
$CNRSub_{s,a,f,t}$	=	Sub-legal sized non-retention mortality for stock *s*, age *a*, in fishery *f*, at time step *t*.

METHOD 3 (Chinook) – Computed from external estimate of total encounters

(13) $$LegalPropTempCatch_{s,a,f,t} = TempCatch_{s,a,f,t} \Big/ \sum_{s} \sum_{a} TempCatch_{s,a,f,t}$$

(14) $$LegalEnc_{s,a,f,t} = Cohort_{s,a,t} \times \overbrace{BPER_{s,a,f,t}} \times LegalPropCatch_{s,a,f,t} \times PV_{s,a,t} \times SHRS_{s,f,t}$$

(15) $$SubLegEnc_{s,a,f,t} = SubLegPop_{s,a,t} \times \overbrace{SubER_{s,a,f,t}}$$

(16)
$$CNRScaler_{f,t} = \frac{\underbrace{TotalEstCNR_{f,t}}}{\sum_s \sum_a LegalEnc_{s,a,f,t} + \sum_s \sum_a SubLegEnc_{s,a,f,t}}$$

(17)
$$CNRLegal_{s,a,f,t} = LegalEnc_{s,a,f,t} \times CNRScaler_{f,t} \times \overbrace{RelRate_{f,t}}$$

(18)
$$CNRSub_{s,a,f,t} = SubLegEnc_{s,a,f,t} \times CNRScaler_{f,t} \times \overbrace{RelRate_{f,t}}$$

where the previous definitions of parameters are still applicable and:

$TotalEstCNR_{f,t}$	=	Total estimated non-retention (legal and sub-legal) in fishery *f* at time step *t* (model input for Method 3); and
$CNRScalar_{f,t}$	=	Non-retention scalar in fishery *f* at time step *t*.

METHOD 4 (Chinook) – Computed from ratio of non-retention to retention days

(19)
$$CNRLegal_{s,a,f,t} = Catch_{s,a,f,t} \times (\underbrace{CNRDays_{f,t}} / \underbrace{RetentDays_{f,t}}) \times \overbrace{RelRate_{f,t}} \times \underbrace{LegalSelRate_{f,t}}$$

(20)
$$CNRSub_{s,a,f,t} = Shakers_{s,a,f,t} \times (\underbrace{CNRDays_{f,t}} / \underbrace{RetentDays_{f,t}}) \times \underbrace{SubSelRate_{f,t}}$$

where the previous definitions of parameters are still applicable and:

$CNRDays_{f,t}$	=	Number of non-retention days in fishery *f*, at time step *t* (model input for Method 4);
$RetentDays_{f,t}$	=	Number of retention days in fishery *f* at time step *t* (model input for Method 4);
$LegalSelRate_{f,t}$	=	Legal-sized adult selectivity rate for fishery *f* in time step *t*, in response to changes in gear or fishing pattern (model input for Methods 4 and 5);
$SubSelRate_{f,t}$	=	Sub-legal sized selectivity rate for fishery *f* in time step *t*, in response to changes in gear or fishing pattern (model input for Methods 4 and 5); and
$Shakers_{s,a,f,t}$	=	Sub-legal shaker mortality for stock *s*, age *a*, in fishery *f*, at time step *t* (see following sub-section for method of calculation).

METHOD 5 (Chinook) – Computed from relative effort of non-retention to retention period mortality

(21)
$$CNRLegal_{s,a,f,t} = Catch_{s,a,f,t} \times \frac{1 - FishScalar_{f,t}}{FishScalar_{f,t}} \times \overbrace{RelRate_{f,t}} \times \underbrace{LegalSelRate_{f,t}}$$

(22)
$$TotalLegPop_{f,t} = \sum_s \sum_a (Cohort_{s,a,t} \times PV_{s,a,t}) \quad \text{for stocks with catch in fishery } f$$

(23)
$$TotalSubLegPop_{f,t} = \sum_s \sum_a (Cohort_{s,a,t} \times (1 - PV_{s,a,t})) \quad \text{for stocks with catch in fishery } f$$

(24) $$EncRate_{f,t} = TotalSubLegPop_{f,t} \Big/ TotalLegPop_{f,t}$$

(25) $$TotCatch_{f,t} = \sum_{s}\sum_{a} Catch_{s,a,f,t} \times (1/\overbrace{PropModelStock_f})$$

(26) $$CNRSub_{s,a,f,t} = TotCatch_{f,t} \times EncRate_{f,t} \times \frac{1 - FishScalar_{f,t}}{FishScalar_{f,t}} \Big/ \overbrace{RelRate_{f,t}} \times \underbrace{SubSelRate_{f,t}} \times PropSubPop_{s,a,f,t}$$

where the previous definitions of parameters are still applicable and:

$TotalLegPop_{f,t}$	=	Total number of legal-sized fish from modeled stocks available to fishery *f* at time step *t*;
$TotalSubLegPop_{f,t}$	=	Total number of sub-legal sized fish from modeled stocks available to fishery *f* at time step *t*;
$EncRate_{f,t}$	=	For modeled stocks, the ratio of sub-legal sized Chinook encountered for every legal-sized Chinook in fishery *f* at time step *t*;
$TotCatch_{f,t}$	=	Total landed catch in fishery *f* at time step *t*; and
$PropSubPop_{s,a,f,t}$	=	Proportion of sub-legal sized population for stock *s*, age *a*, in fishery *f*, at time step *t*.

6.4.2 Sub-Legal Shaker Mortality

Sub-legal shaker mortality is not estimated for coho since most minimum size limits - if they exist - apply to age-2 fish that are not represented in the model. FRAM models sub-legal sized Chinook shaker mortalities through the use of the von Bertalanffy growth equation for stocks that contribute to each fishery. The mean size of each stock at the midpoint of the time step is evaluated against the stock-specific growth equation to estimate the proportion vulnerable by stock.

(27) $$KTime_{s,a,t} = (Age_s - 1) \times 12 + \overbrace{MidTimeStep(Months)}$$

(28) $$MeanSize_{s,a,t} = \overbrace{L_s} \times (1 - (\exp(-\overbrace{K}_s) \times (\overbrace{KTime_{s,a}} - \overbrace{T0_s})))$$

(29) $$StdDev_{s,a,t} = \overbrace{CV_{s,a}} \times \overbrace{MeanSize_{s,a,t}}$$

(30) $$PV_{s,a,t} = 1 - NormalDistr(\underbrace{Minsize_{f,t}}, \overbrace{Meansize_{s,a,t}}, StdDev_{s,a})$$

where:

$KTime_{s,a}$	=	Time for estimate of growth equation for stock ***s***, age ***a***,
$PV_{s,a,t}$	=	Percent Vulnerable for stock *s,* age *a*, at time step *t*,
L_s	=	Von Bertalanffy growth parameter for stock *s (Max Size)*,
K_s	=	Von Bertalanffy growth parameter for stock *s (Slope)* ,
$T0_s$	=	Von Bertalanffy growth parameter for stock *s (Time Zero)*,
$CV_{s,a}$	=	Coefficient of Variation of size distribution at $KTime_{s,a}$ for stock *s*, age *a*,
$MinSize_{f,t}$	=	Minimum Size Limit for fishery *f*, time step *t*, and
$MeanSize_{s,a,t}$	=	Mean total length of a fish of stock *s* at age *a* at time step *t*.

The distribution of Chinook sizes by age at a particular time is assumed to be normal with a variance that was calculated using lengths from CWT recovery data. Evaluation of the normal distribution is done using a calculation method developed for the original WDF/NBS Chinook model.

(31) $$Z = (\underbrace{MinSize_{f,t}} - \overbrace{Meansize_{s,a,t}}) \Big/ StdDev_{s,a}$$

(32) $$A1 = Z \times (0.000005383 \times Z + 0.0000488906) + 0.0000380036$$

(33) $$A2 = Z \times (A1 + 0.0032776263) + 0.0211410061$$

(34) $$A3 = 1/(1 + Z \times (Z \times A2 + 0.049867347))$$

(35) $$A4 = 1 - (0.5 \times A3^{16}) = PV_{s,a,t}$$

For Chinook, the sub-legal and legal size encounters are stock- and age- specific and are calculated using the von Bertalanffy growth curves described above. The calculations for sub-legal sized Chinook (shakers) are shown below:

(36) $$SubLegProp_{s,a,t} = 1 - PV_{s,a,t}$$

(37) $$SubLegPop_{s,a,t} = Cohort_{s,a,t} \times SubLegProp_{s,a,t}$$

(38) $$Shakers_{s,a,f,t} = \overbrace{SubER_{s,a,f,t}} \times SubLegPop_{s,a,t} \times \underbrace{FishScalar_{f,t}} \times \overbrace{RelRate_{f,t}}$$

where all components are defined previously and (1-$PV_{s,a,t}$) is the proportion of the cohort for stock *s*, age *a*, not vulnerable to the gear at time step *t* (for Chinook *PV* is function of von Bertalanffy growth curve; for coho *PV* is always = 1).

6.5 Mark-Selective Fisheries

The implementation of mark-selective fishery regulations requires the use of more complex computations, which incorporate release and retention mortality parameters that are not part of normal non-selective fishery accounting. Both coho and Chinook FRAM allow the user to input the values for: (1) release mortality rate; (2) unmarked fish retention error, i.e., the proportion of unmarked fish brought to the boat that are improperly retained; (3) marked recognition error, i.e., the proportion of marked fish brought to the boat that are released; and (4) drop-off mortality (a commonality with non-selective fisheries). Except for the inclusion of the mark-selective fishery parameters (1-3 above), FRAM cycles through algorithms the same as in non mark-selective fisheries by keeping separate accounting of cohort sizes and mortalities of unmarked and marked components. The time-period specific forms of the general equations utilized in coho FRAM under non-selective and mark-selective fisheries s follows:

	Non-Selective Fisheries Discrete Equations	Mark-Selective Fisheries Marked Fish	 Unmarked Fish
Landed mortalities	(39) $C_{s,f} = N_{s,t} \times ER_{s,f}$	(40) $C_{s,f} = N_{s,t} \times ER_{s,f} \times (1 - \underbrace{mre_f})$	(41) $C_{s,f} = N_{s,t} \times ER_{s,f} \times \underbrace{ure_f}$
Release mortalities		(42) $R_{s,f} = N_{s,t} \times ER_{s,f} \times \underbrace{mre_f} \times \underbrace{rm_f}$	(43) $R_{s,f} = N_{s,t} \times ER_{s,f} \times (1 - \underbrace{ure_f}) \times \underbrace{rm_f}$
Drop-off mortalities	(44) $D_{s,f} = C_{s,f} \times \overbrace{dmr_f}$	(45) $D_{s,f} = N_{s,t} \times ER_{s,f} \times \underbrace{dmr_f}$	(46) $D_{s,f} = N_{s,t} \times ER_{s,f} \times \underbrace{dmr_f}$

where:

$C_{s,f}$ = number of landed mortalities of stock *s* in fishery *f*, (same as $Catch_{s,f}$);

$N_{s,t}$ = cohort size for stock *s* at the beginning of time period *t*, (same as $Cohort_{s,t}$);

$D_{s,f}$ = drop-off (or drop-out) mortalities for stock *s* in fishery *f*, (same as $Dropoff_{s,f}$);

dmr_f = drop-off (or drop-out) mortality rate in fishery *f*;

$ER_{s,f}$ = exploitation rate for stock *s* in fishery *f* (this parameter is equivalent to *BPER* x *PV* x *SHRS* in the previously described formulation);

mre_f = marked recognition error (releasing marked fish in a selective fishery) in fishery *f*;

$R_{s,f}$ = number of release mortalities for stock *s* in fishery *f*;

rm_f = release mortality rate in fishery *f*, (same as $RelRate_{f,t}$) and

ure_f = unmarked retention error (retaining and landing unmarked fish in a selective fishery) in fishery *f*.

Computations for Chinook mark-selective fisheries must account for sub-legal mortality, which does not differ between marked and unmarked components. The counterpart equations for Chinook would contain the elements associated with sub-legal mortality, but due to the increased complexity this introduces the analogous equations for Chinook are not presented here.

Base period estimates for the marked and unmarked stocks are generated by splitting each original stock cohort into two equal components and using the original stock exploitation rate for each component. This process was chosen because mass marking was not done during the base period years but is consistent with the assumption that the marked and unmarked components have the same geographical distribution and exploitation rate pattern. Annual age-specific abundance scalars then fix the starting abundance of marked and unmarked stock components. When the model is run with mark-selective fisheries the differences in the exploitation rate pattern are accounted for by the different rate of change in the cohort sizes between the marked and unmarked components. The differences are accounted for in subsequent time steps because discrete catch equations are used for each time step on each single-pool stock. The $StockScalar_{s,a}$ variables for each model run must be calculated using the split cohort sizes for the marked and unmarked component stocks.

6.6 Maturation (Chinook only)

For Chinook, the maturation process occurs after the pre-terminal catch has been calculated and results in a mature cohort for each stock, age, and time step. The number of fish from the age *a* cohort for stock *s* that matures at time step *t* ($TermCohort_{s,a,t}$) is calculated as:

(47) $$TermCohort_{s,a,t} = Cohort_{s,a,t} \times \overbrace{MatRate_{s,a,t}}$$

where $MatRate_{s,a,t}$ is a stock, age, and time step specific maturation rate that is calculated from base period data. The mature portion of the cohort is available to those fisheries, during the same time period, that have been designated as harvesting only mature fish. The immature portion of the cohort ($Cohort_{s,a,t,}$ - $TermCohort_{s,a,t}$) is then used to initiate the next time step.

6.7 Escapement

Escapement is defined as any fish from the mature cohort that do not die from fishery-related mortality and is assumed to equal spawning escapement if mortality during "prespawning" holding time is negligible or ignored. In the current versions of the coho and Chinook base periods, all maturation and escapement of a stock occurs within a single time step. The only exceptions are Skagit stocks of spring and summer/fall Chinook and Columbia River summer Chinook. For coho, fisheries during time steps 1 through 4 are on immature fish and by default all coho fisheries in time step five are on mature fish. All Chinook fisheries in FRAM are designated as pre-terminal or terminal in the base period data. The terminal fisheries only harvest fish from the mature cohort thus simulating a migration pattern from the pre-terminal mixed stock areas to the terminal areas. The equations for coho and Chinook are given below:

Coho:

(48) $$Escape_{s,a} = Cohort_{s,a,5} - (\sum_{f}(Catch_{s,f,5} + LegalShakers_{s,f,5} + Dropoff_{s,f,5} + CNR_{s,f,5}))$$

Chinook:

(49) $$TotTermMort_{s,a,t} = \sum_{f-term}(Catch_{s,a,f,t} + Shakers_{s,a,f,t} + Dropoff_{s,a,f,t} + LegalShakers_{s,a,f,t} + CNR_{s,a,f,t})$$

(50) $$Escape_{s,a,t} = TermCohort_{s,a,t} - TotTermMort_{s,a,t}$$

where age = 3 and time step = 5 for coho, and:

$Escape_{s,a,t}$	=	Escapement for stock *s*, age *a*, at time step *t*;
$TotTermMort_{s,a,t}$	=	Total terminal fishery mortality for stock *s*, age *a*, at time step *t*;
$Catch_{s,a,f,t}$	=	Catch for stock *s*, age *a*, in terminal fishery *f*, at time step *t*;
$LegalShakers_{s,a,f,t}$	=	Legal-sized mortality of fish released during mark-selective fisheries for stock *s*, age *a*, in terminal fishery *f*, at time step *t*;
$Dropoff_{s,a,f,t}$	=	Non-landed mortality for stock *s*, age *a*, in terminal fishery *f*, at time step *t*;
$Shakers_{s,a,f,t}$	=	Sub-legal mortality for stock *s*, age *a*, in terminal fishery *f*, at time step *t*; and
$CNR_{s,a,f,t}$	=	Non-retention mortality (legal and sub-legal sized) for stock *s*, age *a*, in terminal fishery *f*, at time step *t*.

6.8 Other Algorithms and Equations Used in the Model

Adult Equivalency (Chinook only). Fishery-related mortality for Chinook is expressed as a nominal value or adjusted for "Adult Equivalents" (AEQ) to account for the multiple ages that the fish mature and become vulnerable to fisheries. Fishery-related mortalities are expressed as adult equivalent mortalities so that all fishery mortalities can be expressed in a common unit of measure, which is the number of fish that would have matured (escaped to spawn) in the absence of fishing. The AEQ factors adjust for the natural mortality that would have occurred between the time/age the fish were caught and the time/age that they would have matured or escaped to spawn. The factors used in FRAM are calculated during the CWT base period calibration process and take into account fixed age-specific natural mortality rates and age- and stock- specific maturation rates, which are calculated from CWT recoveries during cohort analysis. Stock- and age- specific AEQ values are expressed relative to the expected contribution to the age-5, time step 3 fish, which is the oldest age-class at the final time step for mature fish. The AEQ value at the maximum age and final time-step is by definition 1.0 and all other age/time-step values are a proportion of this value. Note that all age classes have an AEQ value of 1.0 in designated "terminal fisheries" (exploitation rates for Chinook are usually expressed in terms of adult equivalent mortality). In other words, all mature fish have an AEQ equal to 1.0, regardless of age. The AEQ factor is calculated as:

$$(51)\quad \overbrace{AEQ_{s,a,t}} = [MatRate_{s,a,t} + (1 - MatRate_{s,a,t}) \times (1 - M_{a,t+1})] \times AEQ_{s,a,t+1}$$

where $AEQ_{s,a,t}=1$ for $a = 5$ and $t = 3$ (maximum age and final time step for most Chinook stocks).

Proportion Modeled Stocks (for Chinook only and calculated using base period data). The "model stock proportion" is a value unique to Chinook and is the proportion of the total catch in a fishery that is accounted for by the modeled stocks. These proportion modeled stocks values (presented in Appendix 3) are calculated during the Chinook FRAM calibration process. They represent modeled stock proportions during the base period and are used "as-is" for preseason Chinook FRAM modeling even though the relative abundance of the non-modeled stocks may differ significantly from the base period. Model stock proportions are fishery specific and remain constant through all time periods. The coho cohort analysis used to create the model base period exploitation rates include estimates for all stock production regions, thus the proportion modeled stock is 1.0.

$$(52)\quad \overbrace{PropModelStock_f} = \frac{\sum_s \sum_a \sum_t Catch_{s,a,f,t}}{TotalCatch_f}$$

where $TotalCatch_f$ = the average total Base Period catch in fishery f.

Total Mortality. Total mortality is used to calculate simple exploitation rates by stock, age (Chinook), and time period. The equations used for coho and Chinook, respectively, are:

Coho:

$$(53)\quad TotMort_{s,t} = \sum_f (Catch_{s,f,t} + Dropoff_{s,f,t} + LegalShakers_{s,f,t} + CNR_{s,f,t})$$

The cohort surviving to the next time step is:

$$(54)\quad Cohort_{s,t+1} = Cohort_{s,t} - TotalMort_{s,t}.$$

Chinook:

(55) $$TotMort_{s,a,t} = \sum_{f} (Catch_{s,a,f,t} + Shakers_{s,a,f,t} + Dropoff_{s,a,f,t} + LegalShakers_{s,a,f,t} + CNR_{s,a,f,t})$$

or

$$AEQTotMort_{s,a,t} = \sum_{f} [(Catch_{s,a,f,t} + Shakers_{s,a,f,t} + Dropoff_{s,a,f,t} + LegalShakers_{s,a,f,t} + CNR_{s,a,f,t}) \times (AEQ_{s,a,t})]$$

The cohort surviving to the next time step is:

(56) $$Cohort_{s,a,t+1} = Cohort_{s,a,t} - \Sigma TotMort_{s,a,t} - Escape_{s,a,t}.$$

Total Exploitation Rate. The general equation for exploitation rate differs only by the use of adult equivalent mortalities (AEQ) for Chinook.

Coho:

(57) $$ER_s = \frac{\sum_a \sum_t TotMort_{s,a,t}}{\sum_a \sum_t TotMort_{s,a,t} + \sum_a \sum_t Escape_{s,a,t}}$$

or

Chinook:

$$ER_s = \frac{\sum_a \sum_t AEQTotMort_{s,a,t}}{\sum_a \sum_t AEQTotMort_{s,a,t} + \sum_a \sum_t Escape_{s,a,t}}$$

where all components are defined previously.

7. TERMINAL AREA MANAGEMENT MODULE (TAMM)

The FRAM program interacts with two species-specific (coho and Chinook) EXCEL spreadsheets that contain detailed information on terminal fisheries in regional Terminal Area Management Modules (TAMM). These spreadsheets allow modelers to specify terminal fishery impacts on a finer level of resolution than possible with FRAM's temporally and spatially larger fishery units and larger aggregated stock units. The TAMM spreadsheets were first developed for the six Puget Sound terminal areas (Table 7-1) that are defined in the Puget Sound Salmon Management Plan (1985) for the State of Washington and the Treaty Tribes of Puget Sound. This structure has supported development of unique regional management goals and allows managers the flexibility to analyze and report FRAM model output according to regional needs. The scope of the modeling results and information presented in the coho and Chinook TAMM spreadsheets has expanded dramatically from their initial focus on Puget Sound terminal fisheries. The Chinook TAMM still contains the original Puget Sound regional sections, while the coho TAMM has been expanded to allow FRAM output report generation for several non-Puget Sound stock groups. Both TAMM spreadsheets provide abundance, escapement, and fishery impact assessments for many of the key hatchery and natural stocks needed for PFMC and other fishery management processes.

Table 7-1. Puget Sound terminal management regions.

Nooksack-Samish	Skagit
Stillaguamish-Snohomish	South Sound
Hood Canal	Strait of Juan de Fuca

The expansion of stocks and fisheries in the present coho FRAM base period has contributed to diverging processes between the coho and Chinook TAMM spreadsheets. Coho FRAM output now includes stock-specific impacts from marine and freshwater fisheries (complete coverage for Puget Sound stocks and fisheries); thus, escapement values are calculated within FRAM in terms of "escapement from freshwater fisheries". The coho TAMM generates reports of escapements and exploitation rates for all coho stocks. In contrast, Chinook FRAM output is available only for pre-terminal fisheries and escapement values are in terms of "escapement from ocean fisheries", or "terminal run size". The Chinook TAMM is used to both calculate and report Puget Sound stock escapements and exploitation rates. While the functions of the coho and Chinook TAMMs have diverged in recent years, as terminal area management modules they retain common features:

- Receive input for TAMM fisheries
- Receive input for TAMM stock abundances (now Chinook only)
- Receive input for TAMM stock management criteria
- Provide fishery input to FRAM for iterations with FRAM fisheries
- Receive FRAM output of FRAM fishery impacts upon FRAM stock units
- Use FRAM output to complete TAMM fishery impact modeling upon TAMM stocks
- Generate TAMM reports of combined FRAM and TAMM fishery impacts upon TAMM stock units (Chinook)
- Generate TAMM reports of FRAM fishery impacts upon FRAM stocks (coho only).

7.1 Coho TAMM

The current version of coho TAMM provides the following key functions:

1. Terminal fishery inputs to FRAM for Puget Sound stocks.

2. Catch/mortality calculations in Columbia River and coastal Washington terminal fisheries.

3. Reports (tables) of fishery impacts, catch distributions, exploitation rates, and escapements, which are needed management criteria for all key U.S. and Canadian hatchery and natural coho stocks.

After the upgrade of the coho base period database (MEW 2007a), FRAM was able to model all stock/fishery interactions entirely within the FRAM program. With the stock and fishery coverage provided by this new base period, the coho TAMM could have been abandoned as obsolete. However, the decision was made to continue using the coho TAMM for the following reasons:

- generate the commonly used output reports,
- maintain continuity of established methods for providing Puget Sound fishery inputs,
- facilitate input and error checking among a larger pool of knowledgeable participants, and
- maintain a spreadsheet tool for functions outside of the FRAM program.

Terminal area fisheries (i.e., TAMM-type) for coho occur during model time steps 4 (Sept.) and 5 (Oct.-Dec.). Table 2-1 shows the differences between coho and Chinook time steps. The marine fisheries can be modeled within both these time steps while the freshwater fisheries are modeled only for time step 5. Marine area fisheries, in both time steps, may be "mixed stock" fisheries impacting both local and non-local stocks; while freshwater and a few marine "extreme terminal area" fisheries are modeled to impact only local stocks. There may be occasions when individual fisheries open prior to the first calendar date of the appropriate model time step; however, the catch is modeled as occurring within the upcoming step. This is justified, for example, when the run timing of maturing individual stocks do not strictly conform to monthly time steps but the fisheries are occurring on a stock composition consistent with the modeled base period.

The 1986-1991 coho base period expansion allows FRAM to estimate the impacts of 87 Puget Sound fisheries (see Appendix 3, fishery numbers 80-166) upon marked and unmarked components for 61 Puget Sound stocks (see Appendix 1, stock numbers 1-122). All coho stock abundance forecasts are now entered directly into FRAM. At the option of regional managers, Puget Sound extreme terminal and freshwater fishery inputs are still entered into the TAMM, as is the case for most marine area "mixed stock" net fisheries. However, Puget Sound marine sport inputs are entered directly into FRAM. Those terminal area and freshwater net and sport fisheries entered via the TAMM are often divided into smaller units for TAMM purposes. For example, whereas FRAM defines and models the treaty Indian Skagit River freshwater net fishery as a single unit, the TAMM input can be by temporal components (pink, coho, chum, or steelhead management periods) and/or by gear type (test fishery). The TAMM will sum the fishery components as needed to fit FRAM fishery definitions when providing input to FRAM.

Fishery impacts on Puget Sound coho stocks are completely modeled by FRAM, but that is not the case for Washington coastal coho stocks. The present version of coho TAMM performs terminal fishery modeling tasks for Washington coastal coho stocks in their terminal fishery areas to resolve discrepancies between the terminal area harvest management models for coastal coho stocks developed by regional staff and FRAM modeling of those same terminal fisheries. The regional terminal models utilize a harvest rate approach for the terminal fisheries while FRAM uses an exploitation rate approach over a more widely distributed set of fisheries.

Time step intervals are another difference between the FRAM and several coastal terminal fishery models. FRAM time step 4 is one month and time step 5 is three months long, while the coastal regional models generally use weekly time steps. In several regions wild and hatchery coho have different return timing and the weekly arrangement of fishing schedules can be structured to take advantage of those differences and, when needed, minimize annual impacts on wild stocks. Thus a regional terminal area model may produce total fishery harvest rates for individual local stocks (derived from weekly scheduled fisheries) that vary significantly from FRAM estimates based upon the average base period exploitation rates used for the FRAM time steps. In this scenario, FRAM with a given total catch input for a coastal terminal fishery, will calculate a different local stock composition for that catch than the weekly harvest rate driven stock composition used by local managers. For the Washington coastal stocks, TAMM reconciles these differences and generates stock-specific reports that use FRAM's stock impact estimates for the pre-terminal fisheries and TAMM's local stock impact estimates for the terminal fisheries.

Consistent with the harvest rate versus exploitation rate issue mentioned previously, FRAM operates on an abundance pool of all stocks while the regional models operate on the terminal abundance of local stocks. Some stocks may temporarily enter estuaries to terminal areas other than their own ("dip-in") at significant levels before returning to their own terminal area. The FRAM base period fishery data includes "dip-in" catch, while several coastal regional models are based upon data which has "dip-in" catch removed. For the same fishery, while a regional model is structured for impacts only upon local stocks, FRAM may be modeling that fishery for mixed stocks with "pre-terminal" impacts upon other non-local stocks.

The FRAM estimated catch of non-local stocks within one terminal area will change the terminal run size of those stocks to other terminal areas. This could change the basis of the local regional harvest management agreements (i.e., changes relative to minimum wild escapement). For example, a new FRAM catch input for total catch in coastal region "A" terminal fishery will change the total local terminal run size to coastal region "B". Without any changes to the terminal area fishery schedules (constant harvest rates), the total catch in region "B" changes and must then also be re-modeled through FRAM (to capture changed non-local impacts). This, in turn, will change the terminal run size for region "A" fisheries. Generally three manual external iterations between TAMM and FRAM have been needed to stabilize the "ripple effect" throughout the various coastal terminal areas.

The above iteration process is built into the FRAM code for Puget Sound stocks; however, because the addition of coastal coho terminal fisheries to the FRAM base period occurred recently, the steps to institute an internal FRAM iteration process for those fisheries have not been completed.] FRAM's iteration process allows for Puget Sound coho fishery TAMM inputs to be provided in terms of:

- a fixed catch (as a FRAM or TAMM-origin input),
- effort scalar (as a FRAM or TAMM-origin input),
- harvest rate on terminal area abundance (TAA) (TAMM-origin input only), or
- harvest rate on extreme terminal run size (ETRS) (TAMM-origin input only).

The fixed catch and effort scalar input control mechanisms correspond directly to FRAM input types while the harvest rate options are unique to the TAMM. The harvest rate control mechanisms operate as percent of TAA or percent of ETRS. The TAA harvest rates are applied to the sum of the escapement of all local-area stocks and the terminal catch of local and non-local stocks (e.g., "dip-ins"). The ETRS rates are applied to the sum of the escapement and terminal catch of local stocks only.

Each terminal area is defined by the specific rule FRAM uses for calculation of fishery specific TAA or ETRS abundance. These rules define what fishery catches and stock escapements are part of the fishery-specific abundances that the ETRS or TAA harvest rates act upon. Correspondingly, the calculation of the fishery's harvest rate input for pre-season modeling must be consistent with the definitions of the TAA or ETRS style run reconstructions.

For a terminal fishery containing only local stocks, both methods should produce the same catch by stock results. For a mixed-stock fishery, the associated catch of non-local stocks is calculated by FRAM using the average proportion of total catch observed during the base period (adjusted for present levels of abundance). Iterations between the terminal areas' harvest rate fisheries upon local stocks and the base period's data defining those fisheries as mixed stock are performed internally by FRAM.

7.1.1 Coho TAMM-FRAM interaction

Figure 3 illustrates the iterative process coho FRAM uses to solve the problem of fisheries impacting stocks which may be simultaneously "local" and "non-local", depending upon the fishery. This process addresses the ripple effect of "terminal area" fisheries changing the run size of stocks to other "terminal" areas. There are 41 Puget Sound ETRS and TAA abundance unit definitions (Table 7.2). These abundances are determined by summing catch of designated local fisheries and escapement of designated local stocks. The designations are presented to FRAM by the TAAETRSnum.txt file (Table 7.3).

The structure of the TAAETRSnum.txt file is:

1. first number – TAA or ETRS unit definition number,
2. second number – total number of stocks contributing to escapement,
3. followed by stock id codes,
4. following number – total number of fisheries contributing to catch,
5. followed by fishery id codes,
6. "04" & "05" - designating time steps 4 and 5
7. "00" - designates ETRS type abundance and harvest rate calculations, or,
8. "01" - designates TAA type abundance and harvest rate calculations.

FRAM computes the estimated catch in the TAMM terminal fisheries using the harvest rate inputs from the spreadsheet and the appropriate ETRS or TAA estimate. The ratio of the TAMM catch estimate and calculated FRAM catch is used to calculate the TAMMScaler variable for each fishery and time step evaluated in the iterative loop. All the FishScalar variables for the TAMM fisheries are recalculated using the ratio for the next iteration.

FRAM begins by reading either %ETRS (harvest rate) or %TAA from the TAMM spreadsheet and calculating the TAMM estimated catch. If a TAMM fishery is flagged for ETRS type calculations, then:

$$(58)\quad TAMMCatch_{f,t} = \sum\left(LocalEscapement_{f,t} + LocalCatch_{f,t}\right) \times \%ETRS_{f,t} \times \frac{\sum\left(LocalCatch_{f,t} + NonLocalCatch_{f,t}\right)}{\sum LocalCatch_{f,t}}$$

If TAMM is flagged for TAA type calculations, then:

$$(59)\quad TAMMCatch_{f,t} = \sum\left(LocalEscapement_{f,t} + LocalCatch_{f,t} + NonLocalCatch_{f,t}\right) \times \%TAA_{f,t}$$

The TAMMScalar variable used for scaling the FRAM FishScalar variables for the next iteration is calculated using equation 60:

(60)
$$TAMMScalar_{f} = \frac{TAMMCatch_{f}}{\sum Catch_{s,f}}$$

The new FRAM FishScalar variable for each fishery and time step is calculated using equation 61 when another iteration is needed.

(61)
$$FishScalar_{f,t} = FishScalar_{f,t(i)} \times TAMMScalar_{f,t}$$

At the beginning of each iteration the time step 4 cohort sizes are reset to the original value from the initial FRAM run. The normal FRAM catch calculations are then done for time steps 4 and 5 using the new FishScalar parameters for the TAMM fisheries. The iterative loop is done 5 times for coho without checking the TAMMScalar variables against convergence criteria as is done in the Chinook TAMM iterations. The coho calculations converge very quickly and 5 repetitions are adequate for all situations.

The magnitude of terminal area fisheries plays the key role in determining the TAA or ETRS abundance in equations 58 and 59. As catch of the local stock in a terminal fishery increases with higher harvest rates, the corresponding catch of non-local stocks increases, thus increasing the TAA (same situation for catch of non-local stocks in the coastal discussion). This also applies when using ETRS harvest rates. In essence, as TAA increases fishery effort increases. This FRAM phenomenon is even more apparent where both treaty Indian and non-Indian net fisheries co-exist within the same terminal fishery area. For example, the absence of either the treaty Indian or non-Indian catch component, where it was normally present, reduces the TAA run size with the ripple effect of decreasing the expected catches of local and non-local stocks in the remaining fishery based upon harvest rates. The opposite is also true; for example increasing the treaty Indian harvest rate increases the TAA and thus increases the non-Indian catch even though the non-Indian harvest rate remained constant. The ripple effect also changes the expected catch in all other harvest rate based terminal fisheries impacting the same stocks.

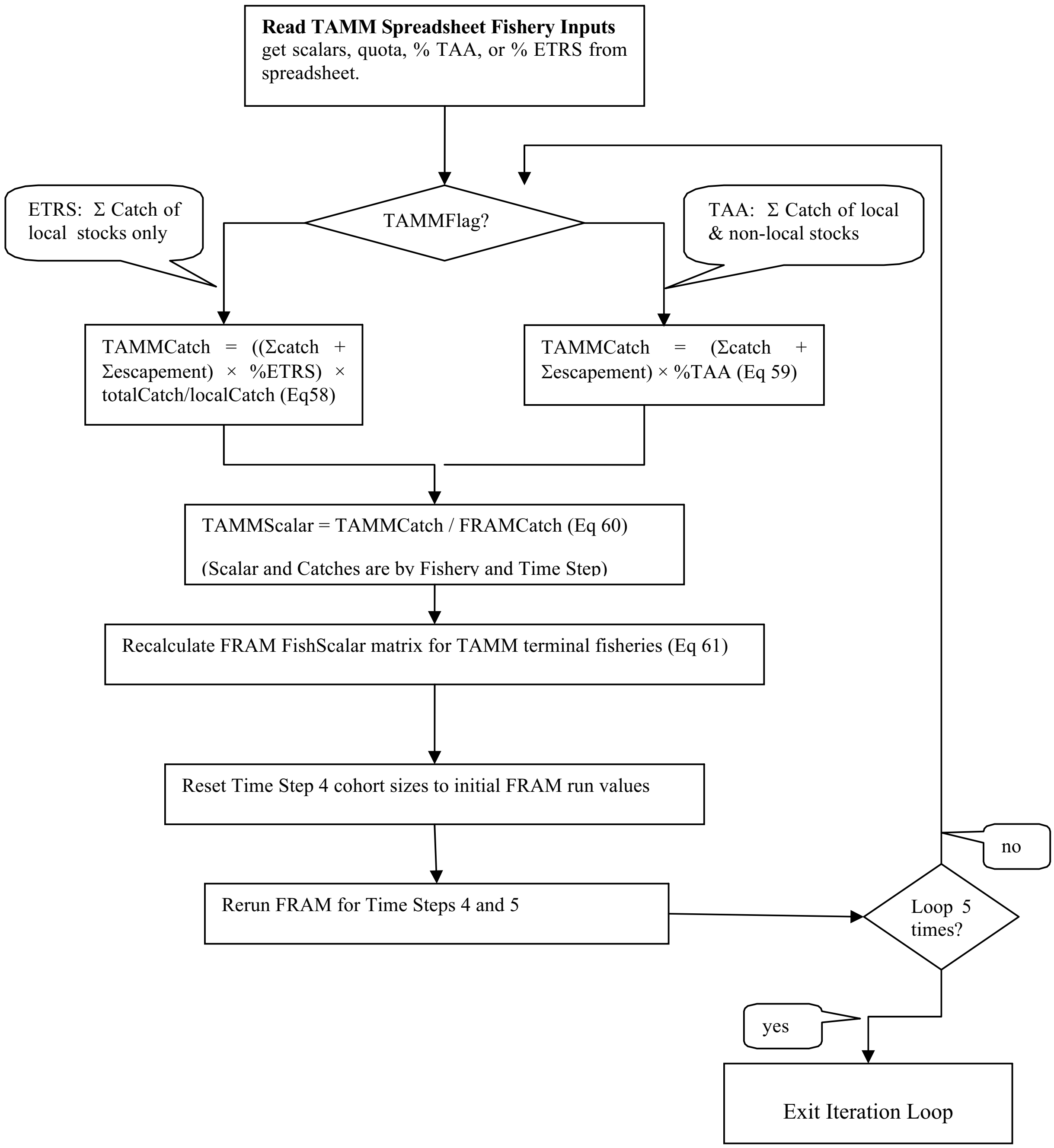

Figure 3. Flow chart for Coho TAMM and FRAM terminal catch comparison.

Table 7-2. Coho TAMM TAA and ETRS name and number of stocks and fisheries within.

Definition #	TAA or ETRS Units	Number of Stocks	Number of Fisheries
1	Skagit NT TAA	12	5
2	Stilly-Snoh TAA	10	6
3	Hood Canal T TAA	20	15
4	SPS TAA	46	25
5	SPS Ar 10 TAA	16	8
6	SPS Ar 11 TAA	8	5
7	SPS Ar 13 TAA	22	16
8	Nook/Sam TAA	16	3
9	Straits TAA	16	9
10	Skagit Wild ETRS	4	4
11	Skagit ETRS	12	4
12	Stilly TAA	4	1
13	Snoh ETRS	4	2
14	Tulalip H TAA	2	2
15	HC Wld (no 9A,12A) ETRS	6	10
16	SPS Nisq H&W TAA	4	3
17	HC 9A H&W ETRS	4	2
18	Nooksack TAA no sport	6	2
19	E JDF TAA	4	2
20	Dung Bay T TAA	4	3
21	Elwha TAA	4	2
22	W. JDF TAA	2	2
23	HC 9A H&W TAA	4	2
24	Quil Bay 12A TAA	6	4
25	Hdspt Hatchery ETRS	2	0
26	Skokomish R TAA	4	2
27	TAA LaWA	4	2
28	TAA DuwamGrn	6	2
29	TAA So Sound Net Pens only	2	1
30	TAA Puyallup	4	2
31	TAA Ar 13A H&W	4	2
32	ETRS So Sound Net Pens	2	0
33	Skagit T TAA	12	6
34	HC 12CD TAA	8	5
35	Hood Canal NT TAA	20	10
36	Area 10E TAA	4	2
37	Area 11A TAA	4	4
38	Deep SPS TAA	6	6
39	Dung Bay NT TAA	4	2
40	Quil R TAA	6	2
41	Nook/Sam TAA with sport	16	5

Table 7-3. Coho TAAETRSnum.txt file, designating FRAM stock and fishery numbers for calculation of Puget Sound fishery specific TAA and ETRS abundance levels.

1, 12,17,18,19,20,21,22,23,24,25,26,27,28,05,101,102,103,104,105,04,05,01 "Skagit NT TAA"

2, 10,29,30,31,32,33,34,35,36,37,38,06,109,110,111,112,113,114,04,05,01 "Stilly-Snoh TAA"

3, 20,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,15,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,04,05,01 "Hood Canal T TAA"

4,46,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,25,119,120,121,122,123,124,125,126,130,131,132,133,134,137,138,139,140,141,142,143,144,145,146,147,148,04,05,01 "SPS TAA"

5, 16,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,08,119,120,121,122,123,124,125,126,04,05,01 "SPS Ar 10 TAA"

6, 8,83,84,85,86,87,88,89,90,05,130,131,132,133,134,04,05,01 "SPS Ar 11 TAA"

7, 22,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,16,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,04,05,01 "SPS Ar 13 TAA"

8, 16,01,02,03,04,05,06,07,08,09,10,11,12,13,14,15,16,03,96,97,98,04,05,01 "Nook/Sam TAA"

9, 16,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,09,82,83,84,85,86,89,90,94,95,04,05,01 "Straits TAA"

10, 4,17,18,23,24,04,103,104,105,108,04,05,00 "Skagit Wild ETRS"

11, 12,17,18,19,20,21,22,23,24,25,26,27,28,04,103,104,105,108,04,05,00 "Skagit ETRS"

12, 4,29,30,31,32,01,113,04,05,01 "Stilly TAA"

13, 4,35,36,37,38,02,114,117,04,05,00 "Snoh ETRS"

14, 2,33,34,02,111,112,04,05,01 "Tulalip H TAA"

15, 6,45,46,55,56,59,60,10,155,156,157,158,161,162,163,164,165,166,04,05,00 "HC Wld (no 9A,12A) ETRS"

16, 4,67,68,69,70,03,147,148,150,04,05,01 "SPS Nisq H&W TAA"

17, 4,41,42,43,44,02,155,156,04,05,00 "HC 9A H&W ETRS"

18, 6,01,02,03,04,05,06,02,98,99,04,05,01 "Nooksack TAA no sport"

19, 4,115,116,121,122,02,86,89,04,05,01 "E JDF TAA"

20, 4,107,108,109,110,03,82,83,94,04,05,01 "Dung Bay T TAA"

21, 4,111,112,113,114,02,84,95,04,05,01 "Elwha TAA"

22, 2,117,118,02,85,90,04,05,01 "W. JDF TAA"

23, 4,41,42,43,44,02,155,156,04,05,01 "HC 9A H&W TAA"

24, 6,47,48,49,50,51,52,04,157,158,162,164,04,05,01 "Quil Bay 12A TAA"

25, 2,53,54,00,04,05,00 "Hdspt Hatchery ETRS"

26, 4,57,58,59,60,02,161,166,04,05,01 "Skokomish R TAA"

27, 4,99,100,101,102,02,125,128,04,05,01 "TAA LaWA"

28, 6,95,96,97,98,103,104,02,126,127,04,05,01 "TAA DuwamGrn"

29, 2,65,66,01,144,04,05,01 "TAA So Sound Net Pens only"

30, 4,83,84,85,86,02,134,135,04,05,01 "TAA Puyallup"

31, 4,73,74,81,82,02,141,142,04,05,01 "TAA Ar 13A H&W"

32, 2,65,66,00,04,05,00 "ETRS So Sound Net Pens"

33, 12,17,18,19,20,21,22,23,24,25,26,27,28,06,101,102,103,104,105,108,04,05,01 "Skagit T TAA"

34, 8,53,54,55,56,57,58,59,60,05,159,160,161,165,166,04,05,01 "HC 12CD TAA"

35, 20,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,10,153,154,155,156,157,158,159,160,161,162,04,05,01 "Hood Canal NT TAA"

36, 4,91,92,93,94,02,123,124,04,05,01 "Area 10E TAA"

37, 4,83,84,85,86,04,132,133,134,135,04,05,01 "Area 11A TAA"

38, 6,61,62,63,64,65,66,06,143,144,145,146,149,151,04,05,01 "Deep SPS TAA"

39, 4,107,108,109,110,02,82,83,04,05,01 "Dung Bay NT TAA"

40, 6,47,48,49,50,51,52,02,162,164,04,05,01 "Quil R TAA"

41, 16,01,02,03,04,05,06,07,08,09,10,11,12,13,14,15,16,05,96,97,98,99,100,04,05,01 "Nook/Sam TAA with sport"

7.2 Chinook TAMM

The Chinook TAMM provides the following key functions:

1. Puget Sound terminal fishery inputs to FRAM.

2. Catch/mortality calculations in the terminal fishery modules for Puget Sound terminal fisheries.

3. Forecast (usually pre-season terminal run size) proportions and adipose mark rates for Puget Sound hatchery and natural stocks.

4. Reports (tables) showing fishery impacts, catch distributions, exploitation rates, and escapements ,which are needed management criteria for key Puget Sound hatchery and natural Chinook stocks and sub-stocks.

It is through the use of the Chinook TAMM that total fishery impacts upon key Puget Sound management stocks can be estimated and reported. Puget Sound fishery inputs are initially entered into the Chinook TAMM where they are aggregated into the fishery units used by FRAM and passed to FRAM via a "tami" file. After FRAM calculates the impacts of FRAM fisheries upon Puget Sound FRAM stock units, the results are passed back to TAMM via three "tamx" transfer files containing: (1) terminal marine and freshwater run sizes, (2) total mortality for all stocks and stock-specific AEQ total mortality for Puget Sound stocks, and (3) stock-specific landed catch for Puget Sound stocks. TAMM apportions the run size and fishery impacts from the Puget Sound stock outputs in the tamx transfer files by the pre-season forecast proportions and terminal fishery details reported in "input' sections of the TAMM.

Chinook TAMM remains a critical element of pre-season Puget Sound fishery modeling. It is the tool used to split the FRAM stock groupings into their Puget Sound sub-components, whose impacts determine allowable fishery levels during the pre-season planning processes. Table 7-4 shows FRAM stocks units with their corresponding TAMM stock units. Abundance levels of every Puget Sound Chinook hatchery and natural population are entered into the TAMM. These abundances are not passed to FRAM but are used within TAMM to proportionally allocate FRAM fishery impacts to FRAM stocks into the appropriate Puget Sound stock sub-component (of the FRAM aggregate). TAMM then calculates the harvest impacts from all Puget Sound TAMM fisheries to obtain the full set of fishery-specific impacts for all the population sub-components.

The Chinook base period data (as in the older versions of the coho base period) aggregates terminal area fisheries for FRAM modeling at a broader scale than used for management of Puget Sound fisheries. For example, Chinook FRAM does not model individual river freshwater terminal sport or freshwater net fisheries. Table 7-5 shows FRAM fishery units with their corresponding TAMM fishery units. Of major importance is TAMM's complete set of freshwater sport (FRAM fishery #72) and net (FRAM fishery #73) fisheries. The Chinook TAMM provides the ability to not only model the individual Puget Sound marine and freshwater net fisheries, but to do so for smaller time scales associated with fisheries directed at Chinook, pink, coho, chum, or steelhead. In addition, test fisheries and fisheries in sub-areas can be included.

Table 7-4. Chinook Puget Sound FRAM and TAMM Stocks.

Un-marked Stock #	FRAM Puget Sound Stock Names	TAMM Puget Sound stock components (per 2005 Planning Cycle)
1	Nooksack-Samish summer/fall	Nooksack R & Samish R: composite of all hatchery & natural
		Glenwood Springs Hatchery
3	North Fork Nooksack early (spring)	Nooksack R spring hatchery & natural stocks
5	South Fork Nooksack early (spring)	
7	Skagit summer/fall fingerling	Skagit River summer/fall fingerling hatchery & natural stocks
9	Skagit summer/fall yearling	Skagit River summer/fall yearling hatchery & natural stocks
11	Skagit spring yearling	Skagit River spring hatchery & natural stocks
13	Snohomish summer/fall fingerling	Snohomish R summer/fall fingerling hatchery & natural stocks
15	Snohomish summer/fall yearling	Snohomish R summer/fall yearling hatchery & natural stocks
		Skykomish R natural as percent of Snohomish R natural
17	Stillaguamish summer/fall fingerling	Stillaguamish River summer/fall natural
19	Tulalip summer/fall fingerling	Tulalip Hatchery
21	Mid S. Puget Sound fall fingerling	Gorst Ck Hatchery
		Grovers Ck Hatchery
		Lake Washington hatchery and natural (Cedar River) stocks
		Green River, hatchery & natural stocks
		Puyallup River, hatchery & natural components
23	UW Accelerated fall fingerling	University of Washington Hatchery
25	Deep S. Puget Sound fall fingerling	McAllister Creek Hatchery
		Nisqually River, hatchery & natural stocks
		Minter Creek Hatchery
		Chambers Creek Hatchery
		Deschutes River & Capital Lake hatchery stocks
		Coulter Creek & Misc Area 13D-K hatchery stocks
27	South Puget Sound fall yearling	Contribution amount from each South Sound hatchery
29	White River spring fingerling	White River spring hatchery & natural stocks
31	Hood Canal fall fingerling	Area 12C-D natural
		Skokomish R, hatchery & natural stocks
		Area 12B, mid-Hood Canal natural
		Hoodsport Hatchery
33	Hood Canal fall yearling	Hood Canal fall yearling
35	Juan de Fuca Tribs. fall fingerling	Hoko R, hatchery & natural stocks
		Dungeness early, hatchery & natural stocks
		Elwha, composite hatchery & natural
65	White River spring yearling	Not modeled in TAMM

Table 7-5. Chinook Puget Sound FRAM and TAMM Fisheries.

FRAM Fishery #	FRAM Puget Sound Fisheries	TAMM Fishery Components of FRAM Fisheries.
36	Area 7 Sport	Area 7 Sport
37	NT San Juan Net (Area 6A,7,7A)	NT San Juan Net (Area 6A,7,7A)
38	T San Juan Net (Area 6A,7,7A)	T San Juan Net (Area 6A,7,7A)
39	NT Nooksack-Samish Net	NT Nooksack-Samish Net
40	T Nooksack-Samish Net	T Nooksack-Samish Marine Net
		T Nooksack-Samish Freshwater Net
41	T Juan de Fuca Troll (Area 5,6,7)	T Juan de Fuca Troll (Area 5,6,7)
42	Area 5/6 Sport	Area 5/6 Sport
43	NT Juan de Fuca Net (Area 4B,5,6,6C)	NT Juan de Fuca Net (Area 4B,5,6,6C)
44	T Juan de Fuca Net (Area 4B,5,6,6C)	T Juan de Fuca Net (Area 4B,5,6,6C)
45	Area 8 Sport [1]	Area 8 Sport [1]
46	NT Skagit Net (Area 8)	NT-Pink, and NT-Chum
47	T Skagit Net (Area 8)	T Marine: Chinook, Pink, Coho, Chum,
		and Steelhead directed.
		T Coho Evaluation, and T Bay Test Fishery
48	Area 8D Sport	Area 8D Sport
49	NT Stilly-Snohomish Net (Area 8A)	NT 8A pink, NT 8A coho, and NT 8A chum
50	T Stilly-Snohomish Net (Area 8A)	T 8A Chinook, T 8A pink, T 8A coho directed,
		T 8A chum and steelhead, and 8A test fishery
51	NT Tulalip Bay Net (Area 8D)	NT Tulalip Bay Net (Area 8D)
52	T Tulalip Bay Net (Area 8D)	T Tulalip Bay Net (Area 8D)
53	Area 9 Sport	Area 9 Sport
54	NT Area 6B/9 Net	NT Area 6B/9 Net
55	T Area 6B/9 Net	T Area 6B/9 Net
56	Area 10 Sport	Area 10 Sport
57	Area 11 Sport	Area 11 Sport
58	NT Area 10/11 Net	NT Area 10/11 Net
59	T Area 10/11 Net	T Area 10/11 Net, and Area 10/11 test fisheries
60	NT Area 10A Net	NT Area 10A Sport
61	T Area 10A Net	T Area 10A Net, and Area 10A test fishery
62	NT Area 10E Net	NT Area 10E Sport
63	T Area 10E Net	T Area 10E Net
64	Area 12 Sport	Area 12 Sport
65	NT Hood Canal Net (Area 12,12B,12C)	NT Marine: Chinook, coho, & chum
		NT 9A, 12A: coho, and chum
66	T Hood Canal Net (Area 12,12B,12C)	T Marine: Chinook, coho, chum
		T 9A, 12A: Chinook, coho, chum

table continued on next page

Table 7-5 (continued). Chinook Puget Sound FRAM and TAMM Fisheries

FRAM Fishery #	FRAM Puget Sound Fisheries	TAMM Fishery Components of FRAM Fisheries.
67	Area 13 Sport	Area 13 Sport
68	NT Deep South Puget Sound Net	NT Deep S. Puget Sound Net (Area 13,13D-K)
69	T Deep South. Puget Sound Net	T Deep S. Puget Sound Net (Area 13,13D-K)
70	NT Area 13A Net	NT Area 13A Net
71	T Area 13A Net	T Area 13A Net
72	Freshwater Sport	Freshwater sport fisheries modeled in TAMM include:
		Aggregated Bellingham Bay tributaries (Nooksack, Samish, etc),
		Skagit R, Stillaguamish R., Snohomish R., Lake Washington,
		Lake Sammamish, Duwamish-Green R., Puyallup R., Carbon R.,
		Nisqually R., McAllister Ck., Chambers Ck., Minter Ck.,
		DeschutesR/Capital Lake, Kennedy/Johns/misc. "13B" Creeks,
		Skokomish R., Misc. Area 12B tributaries, Quilcene R.,
		Misc. Area 12C/D tributaries, Dungeness R., Elwha R., and
		Hoko R.
		Mark Selective FW sport fisheries have included:
		Carbon R., Puyallup R., Skykomish R., and Nooksack R.
73	Freshwater Net	Freshwater net fisheries modeled in TAMM include: [2]
		T Skagit R: Chinook, Pink, Coho, Chum, Steelhead;
		T Skagit R Coho Evaluation, Skagit R Test Fishery;
		T Swinomish Channel;
		T Stillaguamish R: Chinook, pink, coho, chum;
		T Snohomish R commercial, Snohomish R test;
		T Skokomish R: Chinook, coho, and chum;
		T Hoodsport Hatchery Seine:
		T Lake Washington, T Lake Sammamish; T Duwamish/Green R;
		Puyallup R test fishery, T Puyallup R; T Minter Ck;
		White R Springs impacts: 11A/Puyallup R net, C&S in White R;
		T McAllister Ck; T Nisqually R; T Chambers (13C & 83H)

Notes:
* (T = Treaty; NT = Nontreaty)
1 Sport areas 8-1 and 8-2 were combined and input into Fishery 45 as Area 8 Sport.
2 Puget Sound TAMM includes: Area 11A with Puyallup River; Area 13C with Chambers Creek.

7.2.1 Chinook TAMM-FRAM interaction

The Chinook TAMM-FRAM iteration process is shown in Figure 4 with details in Figures 5-7. The iteration process is needed to account for the circular affect of harvest in one terminal fishery affecting the harvest, terminal run size, and escapement in other terminal areas. The iteration process is considered completed when the FRAM-based terminal fishery catches convergence with the TAMM-based catches for six Puget Sound net fishery Total Terminal Areas (TTA) (Table 7-6; Figure 4 and 6). Two special case catch calculation options for Nooksack/Samish and Tulalip Hatchery fall Chinook stocks can be flagged in the TAMM and processed through FRAM via the "tami" input file. The Nooksack/Samish case is a harvest accounting between treaty and non-treaty fishers where the terminal fishery catches are set at the level that achieves 50:50 sharing of harvestable catch in combined pre-terminal and terminal fisheries (Figure 5). The Tulalip Hatchery case calculates the treaty net fishery catch that harvests the entire terminal run remaining after the non-treaty terminal fishery input is calculated (Figure 5).

Table 7-6. Total Terminal Areas (TTA) in Puget Sound Net fisheries.

Nooksack Fall
Skagit Fall
Stillaguamish/Snohomish/Tulalip Fall
Tulalip Fall
Hood Canal Fall
Nooksack Spring

For each of the TTAs shown in Table 7-6, the Chinook TAMM uses terminal escapement:

(62) $$TamkEsc_{TTA} = \sum_{s} Escape_{s,a,t}$$

where s is FRAM stocks within each TTA; and terminal catch:

(63) $$TamkCat_{TTA} = \sum_{f} Catch_{s,a,f,t}$$

where f is FRAM fisheries within each TTA; to recalculate terminal run size:

(64) $$TamkTTR_{TTA} = TamkEsc_{TTA} + TamkCat_{TTA} - FWSpt_{TTA} + MSA_{TTA}$$

using freshwater sport catch (*FWSpt*),which includes fisheries upstream from the TAA, and marine sport savings (*MSA*), which credits partial closure of a marine sport area (0 in recent years).

When the terminal run size changes, the TAMM expected catches will change according to the specified harvest rate (Figure 5):

(65) $$TamkEst_{TTA,t} = TamkTTR_{TTA} \times TamkPsHr_{TAA,t} \text{ if using harvest rates or}$$

(66) $$TamkEst_{TTA,t} = TamkPsHr_{TAA,t} \text{ if using quotas.}$$

There is a ripple effect through all terminal fisheries including harvest sharing between the treaty Indian and non-Indian fisheries (Figure 7). The FRAM program reruns the terminal fishery time steps until the difference between the TAMM expected fishery impacts (*TamkEst*) and FRAM estimates (*TamkCat*) are within ±0.1% of each other (i.e., *TamkScale* = 1.0001 or 0.0009):

(67) $$TamkScale_{TTA,t} = {TamkEst_{TTA,t}} \Big/ {TamkCat_{TTA,t}}$$

or the difference between the two (*Diff*) is less than four fish (Figure 6):

(68) $$Diff = abs\left(TamkEst_{TTA,t} - TamkCat_{TTA,t}\right).$$

In each iteration, the FRAM fishery scalars (*FishScalar*) are adjusted by the *TamkScale* variable that was used for the evaluation of the convergence criteria above.

(69) $$(FishScalar_{f,t})_{i+1} = (FishScalar_{f,t})_{i} \times TamkScale_{TTA,t} .$$

The new FRAM fishery scalars are then used to produce the revised FRAM catch estimates (equation 3) in the next iteration:

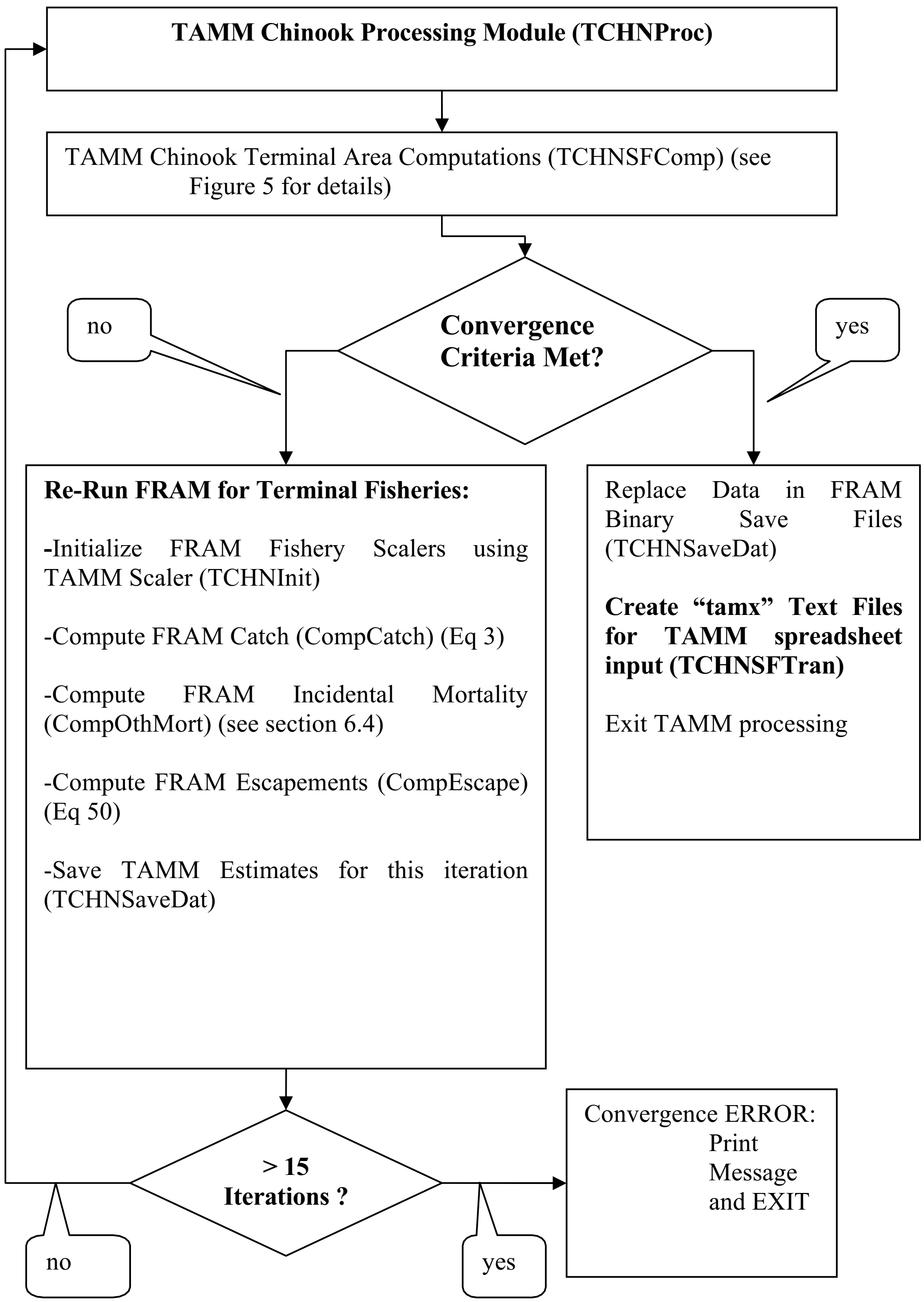

Figure 4. Flow chart for Chinook TAMM Processing Module.

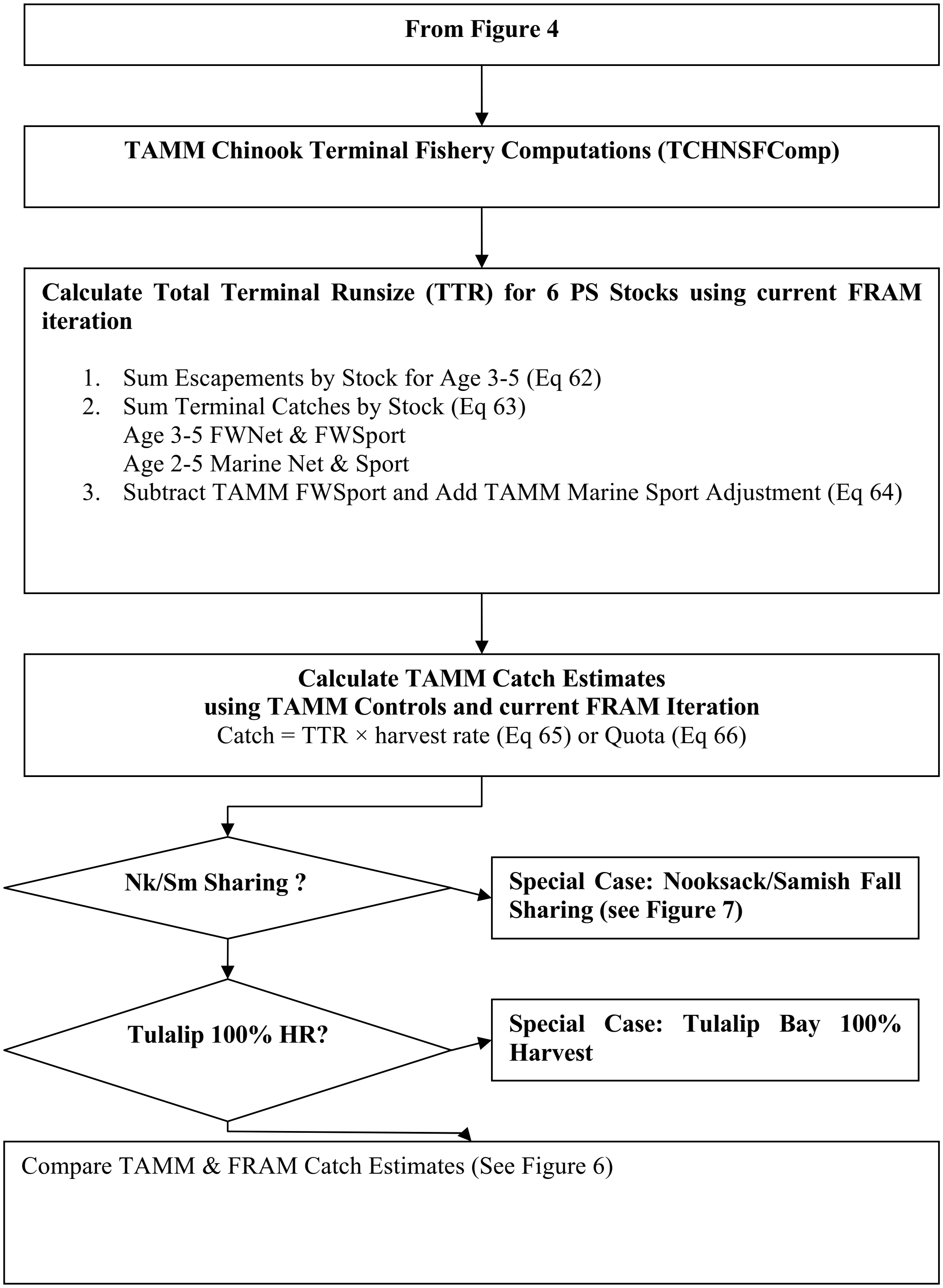

Figure 5. Flow chart for Chinook TAMM Computations and Comparisons.

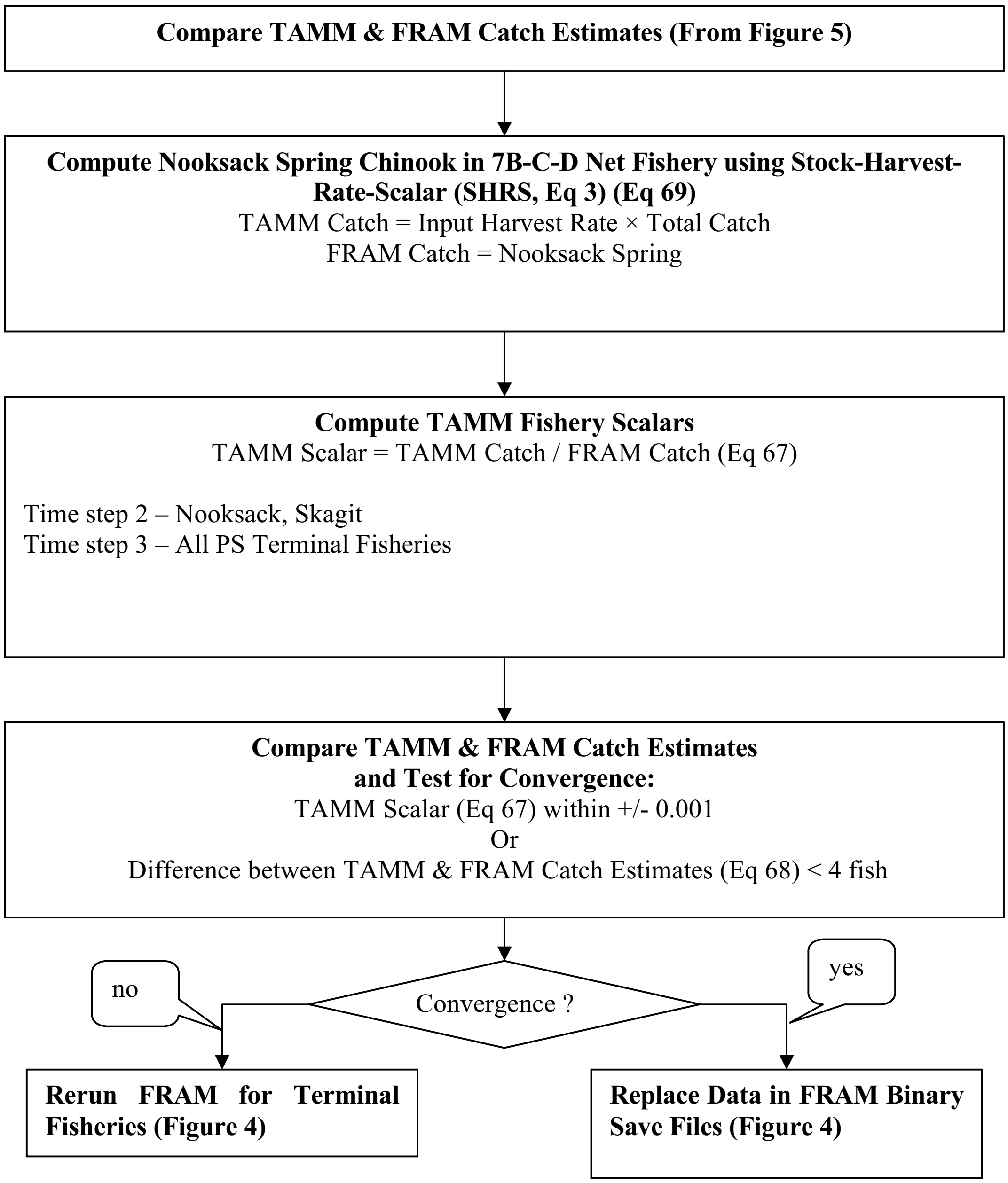

Figure 6. Flow chart for Chinook TAMM and FRAM Terminal Catch Comparisons.

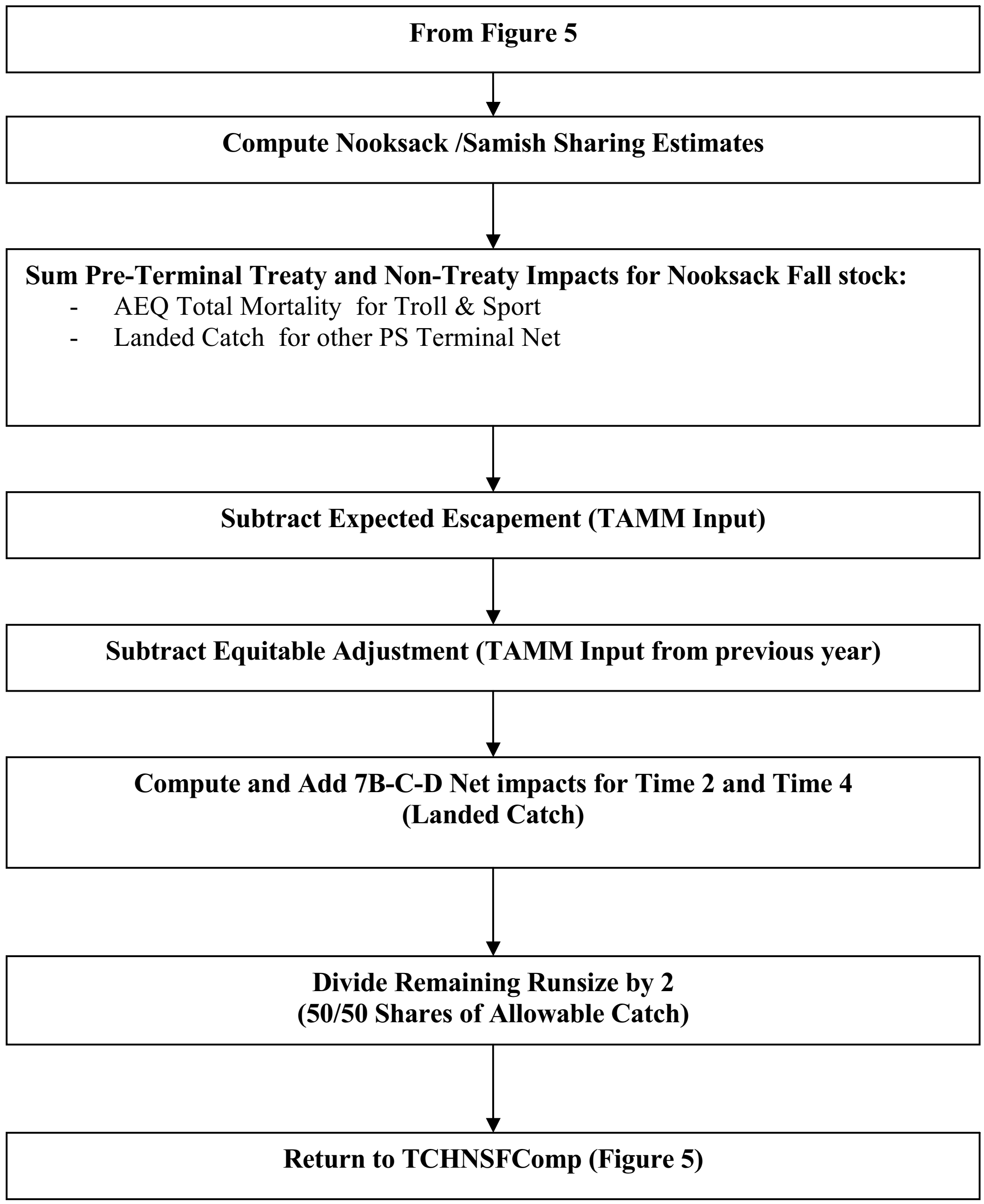

Figure 7. Flow chart for Nooksack/Samish Sharing Calculations.

8. PRE-SEASON MODEL INPUT DEVELOPMENT

The process for developing FRAM model inputs for assessing upcoming fishing season options begins with the forecasting of hatchery and wild stock abundances and proportions of each that are unmarked or adipose fin clipped. Fishery inputs for FRAM are generally developed later in the pre-season process beginning with the Council meeting in early March. Fishery-related mortality parameters such as release mortality rates, drop-off, drop-out, and mark-selective fishery parameters are reviewed and confirmed at the start of the annual management cycle. Many of these rates do not change from year to year; some are the result of manager agreements made in previous years based on research study results. In the cases where research study results may be lacking such as unmarked retention error in mark-selective fisheries, interim values are established following technical staff discussions and manager agreement.

8.1 Stock Abundance

A variety of methods are used to forecast the abundance of coho and Chinook. These forecasts are usually developed by local/regional staff during one or more technical meetings where relevant forecasting information is exchanged. The abundance forecasts vary in units-of-measure. For example, there are forecasts of salmon returning to a terminal area (which implies some accounting for pre-terminal fishery levels), forecasts of ocean abundance (which is commonly landed catch plus escapement), and forecasts of abundance prior to any fishing impacts (which includes natural mortality and non-landed fishery related mortality). Forecasts based on expectations of fish returning to the terminal area need to account for pre-terminal fishing impacts, or for Chinook, impacts that occurred in previous seasons. Each of these different types of forecasts need to be converted to the "unit of measure" used by FRAM, which is the abundance of each stock prior to fishing vulnerability and natural mortality. For both coho and Chinook, the FRAM stock abundances are input as a scalar where the forecasted number of fish prior to fishing is divided by the average FRAM base period abundance for each stock at each age. The input scalars account for those fish that die due to natural mortality per the constant rates set during the development of the base period data during the cohort analysis process.

8.1.1 Coho

The coho forecasts provided by local/regional technical staff are computed by various methods (Table 8.1). Common forecasting methods include jack-to-adult relationships using the previous year's jack returns (age-2 fish) to estimate age-3 adult return (e.g., Oregon Production Index) or smolt production estimates for hatchery or wild-origin fish expanded by an average marine survival rate. Forecasts can be in terms of ocean abundance (i.e., all catch and escapement), return to a terminal area, or production index relative to the 1986-91 base period from a representative population within a region._ Most of the coho forecasts are now produced in terms of ocean abundances that are expanded by 1.232 to account for natural mortality and provide an estimate of abundance in FRAM pre-fishing impact units. Any non-landed fishery-related mortality that occurs is ignored in this ocean abundance-to-total abundance FRAM conversion step.

Table 8-1. FRAM input abundance scalar development methods for coho abundance forecasts.

Production Region	Forecast Method	Forecast Type	FRAM Input *StockScalar* Development Method
Canada	Production Scalar × Surv Rt Scalar	Outlook Scalar from Base	Scalar as is
	Production × Survival Rate	Ocean Abundance	Ocean Abundance × 1.232
Washington Coast	Smolt × Ave. Marine Surv Rt	Ocean Abundance	Ocean Abundance × 1.232
	Ave. Term Run × Ave. PreTerm ER	Ocean Abundance	Ocean Abundance × 1.232
Puget Sound	Ave. Return/Spawner	Ocean Abundance	Ocean Abundance × 1.232
	Smolt × Ave. Marine Survival Rate	Ocean Abundance	Ocean Abundance × 1.232
	Ave. Return	Ocean Abundance	Ocean Abundance × 1.232
Columbia River	Oregon Production Index (OPI)	Ocean Abundance	Ocean Abundance × 1.232
Oregon Coast	Oregon Production Index (OPI)	Ocean Abundance	Ocean Abundance × 1.232
CA/SoOR Coast	Rogue/Klamath Hatchery × Surv Rt	Ocean Abundance	Ocean Abundance × 1.232

8.1.2 Chinook

The methods used to convert the forecasts made by the local/regional staff to FRAM inputs vary depending on the type of forecast (Table 8-2). Forecasts for Columbia River stocks are usually in terms of age-specific returns to the river mouth using brood year sibling relationships on the number of age-specific Chinook that returned the previous season. Puget Sound stock forecasts are commonly recent year averages of Chinook returning to terminal net fisheries and escapement areas east of the western end of the Strait of Juan de Fuca (called "4B" run size). The Puget Sound forecasts are a mixture of age-specific forecasts and forecasts that assume all fish caught are four-years old (e.g. South Puget Sound Hatchery fall Chinook yearlings). Forecasts of Snohomish, Stillaguamish and Tulalip Hatchery Chinook are made in terms of age-specific abundances prior to fishing that can be directly converted to FRAM abundance scalars.

Several methods have been developed that are used to convert the various Chinook forecasts to a FRAM input abundance scalar.

Method 1. Abundance Estimated from CWT Analysis
This method generates total abundance by applying pre-terminal fishery effort scalars, adult equivalency, and maturation rates from recent year CWT studies to age-specific terminal area forecasts. This method provides the most direct, independent estimates of abundance, especially if the CWT studies cover the years used to forecast the terminal run. Snohomish, Stillaguamish, and Tulalip Hatchery Chinook forecasts are based on this method.

Method 2. Abundance Estimated from Change in Pre-terminal Fishery Exploitation Rate (without CWT studies)
This method is similar to Method 1 except that changes in pre-terminal exploitation rates are estimated from fishery effort scalars from FRAM post-season validation runs covering the years included in the forecasts. In most cases, the terminal run size scalar is adjusted to account for pre-terminal fishery impacts, natural mortality, and maturation rates. For Puget Sound hatchery fall Chinook yearling,

terminal run size scalars are calculated from the number/pounds of fish released in the base period compared to the number/pounds released four years prior to the forecast year. Puget Sound fall Chinook stocks use the program RECON.bas (see Chinook FRAM Base Data Development Report) to generate these FRAM abundance scalars.

Method 3. Abundance Estimated from Base Year to Current Year Terminal Run Size Proportions
For this method, the FRAM abundance scalar input would be the ratio of the predicted terminal run size to the average terminal run in the base period. This method assumes that the average pre-terminal exploitation rates have not changed from the base period of the model and is likely to overestimate the abundance unless adjustments are made to account for reduced pre-terminal fishing impacts from the model base data.

Table 8-2. FRAM input abundance scalar development methods for Chinook abundance forecasts.

Production Region	Forecast Method	Forecast Type	FRAM Input *StockScalar* Development Method
Canada	Brood Year-Sibling	Terminal Run	Method 3
Puget Sound	Ave. Return/Spawner	Terminal Run	Method 2 or 3
	Ave. Return/Smolt Rel	Terminal Run	Method 2 or 3
	Ave. Return	Terminal Run	Method 2 or 3
	Cohort/Spawner	Pre-fishing cohort	Method 1
Columbia River	Brood Year-Sibling	Terminal Run	Method 3
Oregon Coast	Ave. Return	Terminal Run	Method 3

All three of these methods can yield FRAM abundance scalars that produce FRAM run abundance results that are different than the forecasts, and may require manual adjustments to the scalars. This is common for forecasts of terminal area run size. To review, Method 1-3 based abundance scalars are run through FRAM configured with a "likely" fishery structure for the upcoming management year (the previous year's FRAM preseason fishing season package will usually suffice). When the terminal run size estimated from FRAM is substantially different (> 5%) (NOTE: What is substantially different?) from the preseason forecast, the FRAM abundance scalars are adjusted iteratively until the FRAM produces a terminal run size estimate that is similar to the terminal run forecast produced by the local/regional staff. This manual adjustment process establishes "ball-park" level precision on terminal run size and is not performed to fine-tune small differences in run size or adipose mark proportions between a FRAM output and the preseason forecast.

8.2 Fisheries

Fisheries are modeled using FRAM input methods that usually do not vary between yearly preseason model runs. The options for modeling fisheries are discussed above in Section 4 under "Fishery Catch Mortality". Generally, Council-managed coho fisheries and Chinook fisheries North of Cape Falcon are modeled and managed as landed catch quotas (Table 8-3). Chinook fisheries South of Cape Falcon are modeled using exploitation rate scalars and managed primarily by season structure. Fisheries outside of Council jurisdiction are modeled using a variety of the FRAM methods available except the ceiling method, which has not been used in recent years. Inside fisheries are modeled as quotas managed as a landed catch expectation, as effort scalars, or as terminal area harvest rates used during TAMM processing.

8.2.1 Coho

Council-managed non-retention fisheries for coho are modeled using external estimates of mortalities generated from historical coho to Chinook ratios of landings when retention of both species was allowed (Section 6.4; Method 1). In some fisheries, like the troll fisheries South of Cape Falcon, these external mortality estimates are adjusted downward to account for shifts in effort away from the species that cannot be retained.

Table 8-3. FRAM input methods for coho retention fisheries.

Fishery Region	Fishery Input Type	Fishery Input Origin
Alaska	Effort Scalar or Quota	PFMC-STT/No.Falcon Staff
Canada		
Troll	Effort Scalar or Quota	PFMC-STT/No.Falcon Staff
Net	Effort Scalar or Quota	PFMC-STT/No.Falcon Staff
Sport	Effort Scalar or Quota	PFMC-STT/No.Falcon Staff
PFMC North of Cape Falcon	Quota	PFMC-STT/No.Falcon Staff
PFMC South of Cape Falcon	Quota	PFMC/STT
Puget Sound		
Troll	Quota	No. Falcon Staff
Net	Pre-Terminal: Quota, Terminal: Quota, Effort Scalar or Harvest Rate	No. Falcon Staff
Sport	Effort Scalar or Quota	No. Falcon Staff
WA Coast/Columbia R	Effort Scalar or Quota	No. Falcon Staff

8.2.2 Chinook

Input methods used for Chinook-retention fisheries during recent year's preseason runs are shown in Table 8-4. Generally, effort or exploitation rate scalars are used for those fisheries that have relatively low Chinook stock representation in FRAM, such as in Alaska, Northern Canada, Central Oregon, and California. For fisheries with a high proportion of catches from FRAM stocks, any of the FRAM input methods can be used. Input type can depend on the management regime, as with Council area fisheries north of Cape Falcon, which are managed for a Total Allowable Catch (i.e., quota). Chinook FRAM relies on exploitation rate scalars derived from the Pacific Salmon Commission (PSC) Chinook model as inputs for Alaskan and most Canadian fisheries. The PSC model has better stock representation in these northern fisheries and consequently is assumed to provide a better representation of fishing effort changes relative to the base period, which is common to both models. The PSC model fishery inputs for the current year are usually not available until late in the Council's preseason process. Until the new inputs are available, very preliminary values, or values from the previous year must be used which creates greater uncertainty during the annual assessment process.

Table 8-4. FRAM input methods for Chinook retention fisheries.

Fishery Region	Fishery Input Type	Fishery Input Origin
Alaska	Effort Scalar	PSC Chinook Model
Canada		
Troll	Effort Scalar	PSC Chinook Model
Net	Effort Scalar	PSC Chinook Model
Sport	Effort Scalar-North; Quota-South	PSC Chinook Model; PFMC-STT/No.Falcon Staff
PFMC North of Cape Falcon	Quota	PFMC-STT/No.Falcon Staff
PFMC South of Cape Falcon	Effort Scalar	PFMC-STT (KOHM)
Puget Sound		
Troll	Quota	No. Falcon Staff
Net	Pre-Terminal: Quota, Terminal: Quota, Effort Scalar or Harv Rate	No. Falcon Staff
Sport	Quota or Effort Scalar	No. Falcon Staff
WA Coast/Columbia R	Quota or Effort Scalar	No. Falcon Staff

For Council-managed fisheries South of Cape Falcon, exploitation rate scalars calculated from fishing effort data are used for inputs to the model. Scalars are calculated from the expected number of vessel fishing days for troll fisheries, and the angler-trips for sport fisheries, divided by 1979-81 base period average effort levels.

For "inside" fisheries that are not Council-managed, including those in Puget Sound and in freshwater fisheries, FRAM fishery input methods for retention fisheries include quota (as a fixed catch), effort scalars (e.g., Puget Sound marine sport) or terminal fishery harvest rates used during TAMM processing (e.g., Puget Sound terminal net).

Chinook non-retention fishery impacts are primarily modeled using estimates of sub-legal and legal size encounters (Section 6.4; Method 2).

9. POSTSEASON MODEL USAGE

Although FRAM is primarily used for preseason fishery impact assessment, FRAM is also used in a "postseason" mode. These postseason model runs can be used for two purposes; as a tool to validate/evaluate the model's performance by comparing model estimates to independently derived estimates and to evaluate the performance of the fishery management system towards meeting conservation objectives for key stocks.

Postseason FRAM runs contain actual catches (or effort scalars) and estimates of actual stock abundances. The postseason estimates of total abundances of each stock are the most difficult to derive. In most cases, this estimate of the number of fish available prior to any fishing are derived from expanding the number of fish returning to a terminal area by preterminal fishery expansion factors. These preterminal fishery expansion factors are estimated from fishing-year CWT recovery data and/or from effort scalars derived from comparing effort during the base period to effort during the fishing year for each FRAM fishery strata. For Chinook FRAM, the postseason model runs, which are called "validation" runs, are developed during the model calibration process (See Chinook FRAM Base Data Development for details). For Coho FRAM, a "Backwards" FRAM subroutine was developed that uses iterations of FRAM to derive initial stock abundances. Basically, the procedure involves estimation of the set of stock abundance scalars that best explains observed escapements and reported catches through an iterative process involving modification of stock abundance scalars specified in a FRAM command file The Backwards FRAM subroutine can also be used to derive hypothetical CWT recoveries for FRAM stock units that were not tagged for specific fishing year (See Section 13 in Coho FRAM Base Data Development for details).

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11. APPENDICES

Appendix 1. Coho FRAM Stocks

Production Region	Unmarked Stock #	Abbreviated Name	Coho Stock Name
NOOKSM	1	nkskrw	Nooksack River Wild
NOOKSM	3	kendlh	Kendall Creek Hatchery
NOOKSM	5	skokmh	Skookum Creek Hatchery
NOOKSM	7	lumpdh	Lummi Ponds Hatchery
NOOKSM	9	bhambh	Bellingham Bay Net Pens
NOOKSM	11	samshw	Samish River Wild
NOOKSM	13	ar77aw	Area 7/7A Independent Wild
NOOKSM	15	whatch	Whatcom Creek Hatchery
SKAGIT	17	skagtw	Skagit River Wild
SKAGIT	19	skagth	Skagit River Hatchery
SKAGIT	21	skgbkh	Baker (Skagit) Hatchery
SKAGIT	23	skgbkw	Baker (Skagit) Wild
SKAGIT	25	swinch	Swinomish Channel Hatchery
SKAGIT	27	oakhbh	Oak Harbor Net Pens
STILSN	29	stillw	Stillaguamish River Wild
STILSN	31	stillh	Stillaguamish River Hatchery
STILSN	33	tuliph	Tulalip Hatchery
STILSN	35	snohow	Snohomish River Wild
STILSN	37	snohoh	Snohomish River Hatchery
STILSN	39	ar8anh	Area 8A Net Pens
HOODCL	41	ptgamh	Port Gamble Net Pens
HOODCL	43	ptgamw	Port Gamble Bay Wild
HOODCL	45	ar12bw	Area 12/12B Wild
HOODCL	47	qlcnbh	Quilcene Hatchery
HOODCL	49	qlcenh	Quilcene Bay Net Pens
HOODCL	51	ar12aw	Area 12A Wild
HOODCL	53	hoodsh	Hoodsport Hatchery
HOODCL	55	ar12dw	Area 12C/12D Wild
HOODCL	57	gadamh	George Adams Hatchery
HOODCL	59	skokrw	Skokomish River Wild
SPGSND	61	ar13bw	Area 13B Misc. Wild
SPGSND	63	deschw	Deschutes R. (WA) Wild
SPGSND	65	ssdnph	South Puget Sound Net Pens
SPGSND	67	nisqlh	Nisqually River Hatchery
SPGSND	69	nisqlw	Nisqually River Wild
SPGSND	71	foxish	Fox Island Net Pens

Appendix 1. Coho FRAM Stocks (continued)

Production Region	Unmarked Stock #	Abbreviated Name	Coho Stock Name
SPGSND	73	mintch	Minter Creek Hatchery
SPGSND	75	ar13mw	Area 13 Miscellaneous Wild
SPGSND	77	chambh	Chambers Creek Hatchery
SPGSND	79	ar13mh	Area 13 Misc. Hatchery
SPGSND	81	ar13aw	Area 13A Miscellaneous Wild
SPGSND	83	puyalh	Puyallup River Hatchery
SPGSND	85	puyalw	Puyallup River Wild
SPGSND	87	are11h	Area 11 Hatchery
SPGSND	89	ar11mw	Area 11 Miscellaneous Wild
SPGSND	91	ar10eh	Area 10E Hatchery
SPGSND	93	ar10ew	Area 10E Miscellaneous Wild
SPGSND	95	greenh	Green River Hatchery
SPGSND	97	greenw	Green River Wild
SPGSND	99	lakwah	Lake Washington Hatchery
SPGSND	101	lakwaw	Lake Washington Wild
SPGSND	103	are10h	Area 10 H inc. Ebay,SeaAq NP
SPGSND	105	ar10mw	Area 10 Miscellaneous Wild
SJDFCA	107	dungew	Dungeness River Wild
SJDFCA	109	dungeh	Dungeness Hatchery
SJDFCA	111	elwhaw	Elwha River Wild
SJDFCA	113	elwhah	Elwha Hatchery
SJDFCA	115	ejdfmw	East JDF Miscellaneous Wild
SJDFCA	117	wjdfmw	West JDF Miscellaneous Wild
SJDFCA	119	ptangh	Port Angeles Net Pens
SJDFCA	121	area9w	Area 9 Miscellaneous Wild
MAKAHC	123	makahw	Makah Coastal Wild
MAKAHC	125	makahh	Makah Coastal Hatchery
QUILUT	127	quilsw	Quillayute R Summer Natural
QUILUT	129	quilsh	Quillayute R Summer Hatchery
QUILUT	131	quilfw	Quillayute River Fall Natural
QUILUT	133	quilfh	Quillayute River Fall Hatchery
HOHRIV	135	hohrvw	Hoh River Wild
HOHRIV	137	hohrvh	Hoh River Hatchery
QUEETS	139	quetfw	Queets River Fall Natural
QUEETS	141	quetfh	Queets River Fall Hatchery
QUEETS	143	quetph	Queets R Supplemental Hat.
QUINLT	145	quinfw	Quinault River Fall Natural
QUINLT	147	quinfh	Quinault River Fall Hatchery

Appendix 1. Coho FRAM Stocks (continued)

Production Region	Unmarked Stock #	Abbreviated Name	Coho Stock Name
GRAYHB	149	chehlw	Chehalis River Wild
GRAYHB	151	chehlh	Chehalis River (Bingham) Hat.
GRAYHB	153	humptw	Humptulips River Wild
GRAYHB	155	humpth	Humptulips River Hatchery
GRAYHB	157	gryhmw	Grays Harbor Misc. Wild
GRAYHB	159	gryhbh	Grays Harbor Net Pens
WILLAPA	161	willaw	Willapa Bay Natural
WILLAPA	163	willah	Willapa Bay Hatchery
COLRIV	165	colreh	Columbia River Early Hatchery
COLRIV	167	youngh	Youngs Bay Hatchery
COLRIV	169	crorew	Lower Col Oregon Wild
COLRIV	171	washew	Washington Early Wild
COLRIV	173	washlw	Washington Late Wild
COLRIV	175	colrlh	Columbia River Late Hatchery
OREGON	177	orenoh	Oregon North Coastal Hat.
OREGON	179	orenow	Oregon North Coastal Wild
OREGON	181	orenmh	Oregon No. Mid Coastal Hat.
OREGON	183	orenmw	Oregon No. Mid Coastal Wild
OREGON	185	oresmh	Oregon So. Mid Coastal Hat.
OREGON	187	oresmw	Oregon So. Mid Coastal Wild
OREGON	189	oranah	Oregon Anadromous Hatchery
OREGON	191	oraqah	Oregon Aqua-Foods Hatchery
ORECAL	193	oresoh	Oregon South Coastal Hat.
ORECAL	195	oresow	Oregon South Coastal Wild
ORECAL	197	calnoh	California North Coastal Hatch
ORECAL	199	calnow	California North Coastal Wild
ORECAL	201	calcnh	California Central Coastal Hat.
ORECAL	203	calcnw	California Central Coastal Wild
GSMLND	205	gsmndh	Georgia Strait Mainland Hat.
GSMLND	207	gsmndw	Georgia Strait Mainland Wild
GSVNCI	209	gsvcih	Georgia Strait Vanc. Is. Hat.
GSVNCI	211	gsvciw	Georgia Strait Vanc. Is. Wild
JNSTRT	213	jnstrh	Johnstone Strait Hatchery
JNSTRT	215	jnstrw	Johnstone Strait Wild
SWVNCI	217	swvcih	SW Vancouver Island Hat.
SWVNCI	219	swvciw	SW Vancouver Island Wild
NWVNCI	221	nwvcih	NW Vancouver Island Hatchery

Appendix 1. Coho FRAM Stocks (continued)

Production Region	Unmarked Stock #	Abbreviated Name	Coho Stock Name
NWVNCI	223	nwvciw	NW Vancouver Island Wild
FRSLOW	225	frslwh	Lower Fraser River Hatchery
FRSLOW	227	frslww	Lower Fraser River Wild
FRSUPP	229	frsuph	Upper Fraser River Hatchery
FRSUPP	231	frsupw	Upper Fraser River Wild
BCCNTL	233	bccnhw	BC Central Coast Hat./Wild
BCNCST	235	bcnchw	BC North Coast Hatchery/Wild
TRANAC	237	tranhw	Trans Boundary Hatchery/Wild
NIASKA	239	niakhw	Alaska No. Inside Hat./Wild
NOASKA	241	noakhw	Alaska No. Outside Hat./Wild
SIASKA	243	siakhw	Alaska So. Inside Hat./Wild
SOASKA	245	soakhw	Alaska So. Outside Hat./Wild

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

Unmarked Stock #	Stock Name	Abbreviated Name	CWT Broods Included*
1	Nooksack-Samish summer/fall	NkSm FlFi	77, 79
3	North Fork Nooksack early (spring)	NFNK Sprg	OOB - 84, 88 (N. Fk.)
5	South Fork Nooksack early (spring)	SFNK Sprg	OOB - 84, 88 (N. Fk.)
7	Skagit summer/fall fingerling	Skag FlFi	76, 77
9	Skagit summer/fall yearling	Skag FlYr	76
11	Skagit spring yearling	Skag SpYr	OOB - 85, 86, 87, 90
13	Snohomish summer/fall fingerling	Snoh FlFi	OOB - 86, 87, 88
15	Snohomish summer/fall yearling	Snoh FlYr	76
17	Stillaguamish summer/fall fingerling	Stil FlFi	OOB - 86, 87, 88-90
19	Tulalip summer/fall fingerling	Tula FlFi	OOB - 86, 87, 88
21	Mid S. Puget Sound fall fingerling	USPS FlFi	78,79
23	UW Accelerated fall fingerling	UW-A FlFi	77-79
25	Deep S. Puget Sound fall fingerling	DSPS FlFi	78,79
27	South Puget Sound fall yearling	SPSo FlYr	78,79
29	White River spring fingerling	Whte SpFi	OOB – 91-93
31	Hood Canal fall fingerling	HdCl FlFi	78,79
33	Hood Canal fall yearling	HdCl FlYr	78,79
35	Juan de Fuca Tribs. fall fingerling	SJDF FlFi	78,79
37	Oregon Lower Columbia River Hatchery	Oregn LRH	78,79
39	Wash. Lower Columbia River Hatchery	Washn LRH	77,79
41	Lower Columbia River Wild	Low CR Wi	77-78
43	Bonneville Pool Hatchery tule	BP H Tule	76-79
45	Columbia Upriver summer	Upp CR Su	76,77
47	Columbia Upriver bright	Col R Brt	75-77
49	Washington Lower River spring	WaLR Sprg	77
51	Willamette spring	Will Sprg	76-78
53	Snake River fall	SnakeR Fl	OOB - 84, 85, 86
55	Oregon North Migrating fall	Ore No Fl	76-78
57	West Coast Vancouver Island Total	WCVI Totl	74-77
59	Fraser Late	Fraser Lt	OOB - 81, 82, 83
61	Fraser Early	Fraser Er	78,79, OOB -, 86
63	Lower Georgia Strait fall	Lwr Geo St	77, 78
65	White River spring yearling	Whte SpYr	OOB – 91-93
67	Lower Columbia Natural Tule	LwrColN	77-79

69	Central Valley-Sacramento River	CtrVal	OOB - 98-99
71	Washington North Coast	WA N Cst	77-78
73	Willapa Bay	Wilpa	OOB – 83-85
75	Hoko	Hoko	OOB – 85-87

*OOB = Out-of-base stock.

Appendix 3. Coho FRAM Fisheries

Fishery Abbreviation	Fishery Number	Coho FRAM Fishery Long Name
No Cal Trm	1	North California Coast Terminal Catch
Cn Cal Trm	2	Central California Coast Terminal Catch
Ft Brg Spt	3	Fort Bragg Sport
Ft Brg Trl	4	Fort Bragg Troll
Ca KMZ Spt	5	KMZ Sport (Klamath Management Zone)
Ca KMZ Trl	6	KMZ Troll (Klamath Management Zone)
So Cal Spt	7	Southern California Sport
So Cal Trl	8	Southern California Troll
So Ore Trm	9	South Oregon Coast Terminal Catch
Or Prv Trm	10	Oregon Private Hatchery Terminal Catch
SMi Or Trm	11	South-Mid Oregon Coast Terminal Catch
NMi Or Trm	12	North-Mid Oregon Coast Terminal Catch
No Ore Trm	13	North Oregon Coast Terminal Catch
Or Cst Trm	14	Mid-North Oregon Coast Terminal Catch
Brkngs Spt	15	Brookings Sport
Brkngs Trl	16	Brookings Troll
Newprt Spt	17	Newport Sport
Newprt Trl	18	Newport Troll
Coos B Spt	19	Coos Bay Sport
Coos B Trl	20	Coos Bay Troll
Tillmk Spt	21	Tillamook Sport
Tillmk Trl	22	Tillamook Troll
Buoy10 Spt	23	Buoy 10 Sport (Columbia River Estuary)
L ColR Spt	24	Lower Columbia River Mainstem Sport
L ColR Net	25	Lower Columbia River Net (Excl Youngs Bay)
Yngs B Net	26	Youngs Bay Net
LCROrT Spt	27	Below Bonneville Oregon Tributary Sport
Clackm Spt	28	Clackamas River Sport
SandyR Spt	29	Sandy River Sport
LCRWaT Spt	30	Below Bonneville Washington Tributary Sport
UpColR Spt	31	Above Bonneville Sport
UpColR Net	32	Above Bonneville Net
A1-Ast Spt	33	Area 1 (Illwaco) & Astoria Sport
A1-Ast Trl	34	Area 1 (Illwaco) & Astoria Troll
Area2TrlNT	35	Area 2 Troll Non-treaty (Westport)
Area2TrlTR	36	Area 2 Troll Treaty (Westport)
Area 2 Spt	37	Area 2 Sport (Westport)
Area3TrlNT	38	Area 3 Troll Non-treaty (LaPush)
Area3TrlTR	39	Area 3 Troll Treaty (LaPush)

Appendix 3. Coho FRAM Fisheries (continued)

Fishery Abbreviation	Fishery Number	Coho FRAM Fishery Long Name
Area 3 Spt	40	Area 3 Sport (LaPush)
Area 4 Spt	41	Area 4 Sport (Neah Bay)
A4/4BTrlNT	42	Area 4/4B (Neah Bay PFMC Regs) Troll Non-treaty
A4/4BTrlTR	43	Area 4/4B (Neah Bay PFMC Regs) Troll Treaty
A 5-6C Trl	44	Area 5, 6, 6C Troll (Strait of Juan de Fuca)
Willpa Spt	45	Willapa Bay (Area 2.1) Sport
Wlp Tb Spt	46	Willapa Tributary Sport
WlpaBT Net	47	Willapa Bay & FW Trib Net
GryHbr Spt	48	Grays Harbor (Area 2.2) Sport
SGryHb Spt	49	South Grays Harbor Sport (Westport Boat Basin)
GryHbr Net	50	Grays Harbor Estuary Net
Hump R Spt	51	Humptulips River Sport
LwCheh Net	52	Lower Chehalis River Net
Hump R C&S	53	Humptulips River Ceremonial & Subsistence
Chehal Spt	54	Chehalis River Sport
Hump R Net	55	Humptulips River Net
UpCheh Net	56	Upper Chehalis River Net
Chehal C&S	57	Chehalis River Ceremonial & Subsistence
Wynoch Spt	58	Wynochee River Sport
Hoquam Spt	59	Hoquiam River Sport
Wishkh Spt	60	Wishkah River Sport
Satsop Spt	61	Satsop River Sport
Quin R Spt	62	Quinault River Sport
Quin R Net	63	Quinault River Net
Quin R C&S	64	Quinault River Ceremonial & Subsistence
Queets Spt	65	Queets River Sport
Clrwtr Spt	66	Clearwater River Sport
Salm R Spt	67	Salmon River (Queets) Sport
Queets Net	68	Queets River Net
Queets C&S	69	Queets River Ceremonial & Subsistence
Quilly Spt	70	Quillayute River Sport
Quilly Net	71	Quillayute River Net
Quilly C&S	72	Quillayute River Ceremonial & Subsistence
Hoh R Spt	73	Hoh River Sport
Hoh R Net	74	Hoh River Net
Hoh R C&S	75	Hoh River Ceremonial & Subsistence
Mak FW Spt	76	Makah Tributary Sport
Mak FW Net	77	Makah Freshwater Net
Makah C&S	78	Makah Ceremonial & Subsistence

Appendix 3. Coho FRAM Fisheries (continued)

Fishery Abbreviation	Fishery Number	Coho FRAM Fishery Long Name
A 4-4A Net	79	Area 4, 4A Net (Neah Bay)
A4B6CNetNT	80	Area 4B, 5, 6C Net Nontreaty (Strait of JDF)
A4B6CNetTR	81	Area 4B, 5, 6C Net Treaty (Strait of JDF)
Ar6D NetNT	82	Area 6D Dungeness Bay/River Net Nontreaty
Ar6D NetTR	83	Area 6D Dungeness Bay/River Net Treaty
Elwha Net	84	Elwha River Net
WJDF T Net	85	West JDF Straits Tributary Net
EJDF T Net	86	East JDF Straits Tributary Net
A6-7ANetNT	87	Area 7, 7A Net Nontreaty (San Juan Islands)
A6-7ANetTR	88	Area 7, 7A Net Treaty (San Juan Islands)
EJDF FWSpt	89	East JDF Straits Tributary Sport
WJDF FWSpt	90	West JDF Straits Tributary Sport
Area 5 Spt	91	Area 5 Marine Sport (Sekiu)
Area 6 Spt	92	Area 6 Marine Sport (Port Angeles)
Area 7 Spt	93	Area 7 Marine Sport (San Juan Islands)
Dung R Spt	94	Dungeness River Sport
ElwhaR Spt	95	Elwha River Sport
A7BCDNetNT	96	Area 7B-7C-7D Net Nontreaty (Bellingham Bay)
A7BCDNetTR	97	Area 7B-7C-7D Net Treaty (Bellingham Bay)
Nook R Net	98	Nooksack River Net
Nook R Spt	99	Nooksack River Sport
Samh R Spt	100	Samish River Sport
Ar 8 NetNT	101	Area 8 Skagit Marine Net Nontreaty
Ar 8 NetTR	102	Area 8 Skagit Marine Net Treaty
Skag R Net	103	Skagit River Net
SkgR TsNet	104	Skagit River Test Net
SwinCh Net	105	Swinomish Channel Net
Ar 8-1 Spt	106	Area 8.1 Marine Sport
Area 9 Spt	107	Area 9 Marine Sport (Admiralty Inlet)
Skag R Spt	108	Skagit River Sport
Ar8A NetNT	109	Area 8A Stillaguamish/Snohomish Net Nontreaty
Ar8A NetTR	110	Area 8A Stillaguamish/Snohomish Net Treaty
Ar8D NetNT	111	Area 8D Tulalip Bay Net Nontreaty
Ar8D NetTR	112	Area 8D Tulalip Bay Net Treaty
Stil R Net	113	Stillaguamish River Net
Snoh R Net	114	Snohomish River Net
Ar 8-2 Spt	115	Area 8.2 Marine Sport
Stil R Spt	116	Stillaguamish River Sport
Snoh R Spt	117	Snohomish River Sport

Appendix 3. Coho FRAM Fisheries (continued)

Fishery Abbreviation	Fishery Number	Coho FRAM Fishery Long Name
Ar 10 Spt	118	Area 10 Marine Sport (Seattle)
Ar10 NetNT	119	Area 10 Net Nontreaty (Seattle)
Ar10 NetTR	120	Area 10 Net Treaty (Seattle)
Ar10ANetNT	121	Area 10A Net Nontreaty (Elliott Bay)
Ar10ANetTR	122	Area 10A Net Treaty (Elliott Bay)
Ar10ENetNT	123	Area 10E Net Nontreaty (East Kitsap)
Ar10EnetTR	124	Area 10E Net Treaty (East Kitsap)
10F-G Net	125	Area 10F-G Ship Canal/Lake Washington Net Treaty
Duwm R Net	126	Green/Duwamish River Net
Duwm R Spt	127	Green/Duwamish River Sport
L WaSm Spt	128	Lake Washington-Lake Sammamish Tributary Sport
Ar 11 Spt	129	Area 11 Marine Sport (Tacoma)
Ar11 NetNT	130	Area 11 Net Nontreaty (Tacoma)
Ar11 NetTR	131	Area 11 Net Treaty (Tacoma)
Ar11ANetNT	132	Area 11A Net Nontreaty (Commencement Bay)
Ar11ANetTR	133	Area 11A Net Treaty (Commencement Bay)
Puyl R Net	134	Puyallup River Net
Puyl R Spt	135	Puyallup River Sport
Ar 13 Spt	136	Area 13 Marine Sport (South Puget Sound)
Ar13 NetNT	137	Area 13 Net Nontreaty (South Puget Sound)
Ar13 NetTR	138	Area 13 Net Treaty (South Puget Sound)
Ar13CNetNT	139	Area 13C Net Nontreaty (Chambers Bay)
Ar13CNetTR	140	Area 13C Net Treaty (Chambers Bay)
Ar13ANetNT	141	Area 13A Net Nontreaty (Carr Inlet)
Ar13ANetTR	142	Area 13A Net Treaty (Carr Inlet)
Ar13DNetNT	143	Area 13D Net Nontreaty (South Puget Sound)
Ar13DNetTR	144	Area 13D Net Treaty (South Puget Sound)
A13FKNetNT	145	Area 13F-13K Net Nontreaty (South PS Inlets)
A13FKNetTR	146	Area 13F-13K Net Treaty (South PS Inlets)
Nisq R Net	147	Nisqually River Net
McAlls Net	148	McAllister Creek Net
13D-K TSpt	149	13D-13K Tributary Sport (South PS Inlets)
Nisq R Spt	150	Nisqually River Sport
Desc R Spt	151	Deschutes River Sport (Olympia)
Ar 12 Spt	152	Area 12 Marine Sport (Hood Canal)
1212BNetNT	153	Area 12-12B Net Nontreaty (Upper Hood Canal)
1212BNetTR	154	Area 12-12B Net Treaty (Upper Hood Canal)
Ar9A NetNT	155	Area 9A Net Nontreaty (Port Gamble)
Ar9A NetTR	156	Area 9-9A Net Treaty (Port Gamble/On Reservation)

Appendix 3. Coho FRAM Fisheries (continued)

Fishery Abbreviation	Fishery Number	Coho FRAM Fishery Long Name
Ar12ANetNT	157	12A Net Nontreaty (Quilcene Bay)
Ar12ANetTR	158	12A Net Treaty (Quilcene Bay)
A12CDNetNT	159	12C-12D Net Nontreaty (Lower Hood Canal)
A12CDNetTR	160	12C-12D Net Treaty (Lower Hood Canal)
Skok R Net	161	Skokomish River Net
Quilcn Net	162	Quilcene River Net
1212B TSpt	163	12-12B Tributary FW Sport
Quilcn Spt	164	12A Tributary FW Sport (Quilcene River)
12C-D TSpt	165	12C-12D Tributary FW Sport
Skok R Spt	166	Skokomish River Sport
FRSLOW Trm	167	Lower Fraser River Stock Terminal Catch
FRSUPP Trm	168	Upper Fraser River Stock Terminal Catch
Fraser Spt	169	Fraser River/Estuary Sport
JStrBC Trl	170	Johnstone Straits Troll
No BC Trl	171	Northern British Columbia Troll
NoC BC Trl	172	North Central British Columbia Troll
SoC BC Trl	173	South Central British Columbia Troll
NW VI Trl	174	NW Vancouver Island Troll
SW VI Trl	175	SW Vancouver Island Troll
GeoStr Trl	176	Georgia Straits Troll
BC JDF Trl	177	British Columbia Juan de Fuca Troll
No BC Net	178	Northern British Columbia Net
Cen BC Net	179	Central British Columbia Net
NW VI Net	180	NW Vancouver Island Net
SW VI Net	181	SW Vancouver Island Net
Johnst Net	182	Johnstone Straits Net
GeoStr Net	183	Georgia Straits Net
Fraser Net	184	Fraser River Gill Net
BC JDF Net	185	British Columbia Juan de Fuca Net
JStrBC Spt	186	Johnstone Strait Sport
No BC Spt	187	Northern British Columbia Sport
Cen BC Spt	188	Central British Columbia Sport
BC JDF Spt	189	British Columbia Juan de Fuca Sport
WC VI Spt	190	West Coast Vancouver Island Sport
NGaStr Spt	191	North Georgia Straits Sport
SGaStr Spt	192	South Georgia Straits Sport
Albern Spt	193	Alberni Canal Sport
SW AK Trl	194	Southwest Alaska Troll

Appendix 3. Coho FRAM Fisheries (continued)

SE AK Trl	195	Southeast Alaska Troll
NW AK Trl	196	Northwest Alaska Troll
NE AK Trl	197	Northeast Alaska Troll
Alaska Net	198	Alaska Net (Areas 182:183:185:192)

Appendix 4. Chinook FRAM Fisheries, and the proportion of catch attributed to FRAM modeled Chinook stocks from 2007 calibration

Fishery #	Fishery Name	FRAM Stock Portion Of Modeled Catch
1	Southeast Alaska Troll	0.5790
2	Southeast Alaska Net	0.2410
3	Southeast Alaska Sport	0.2720
4	North/Central British Columbia Net	0.5856
5	West Coast Vancouver Island Net	0.5489
6	Strait of Georgia Net	0.6611
7	Canada Juan de Fuca Net (Area 20)	0.9178
8	North/Central British Columbia Sport	0.8454
9	North/Central British Columbia Troll	0.6355
10	West Coast Vancouver Island Troll	0.9201
11	West Coast Vancouver Island Sport	1.0000
12	Strait of Georgia Troll	0.5319
13	North Strait of Georgia Sport	1.0000
14	South Strait of Georgia Sport	1.0000
15	BC Juan de Fuca Sport	0.9967
16	NT Cape Flattery-Quillayute Troll (Area 3-4)	0.9909
17	T Cape Flattery-Quillayute Troll (Area 3-4)	0.9618
18	Cape Flattery-Quillayute Sport (Area 3-4)	1.0000
19	Cape Flattery-Quillayute Net (Area 3-4)	1.0000
20	NT Grays Harbor Troll (Area 2)	1.0000
21	T Grays Harbor Troll (Area 2)	0.6776
22	Grays Harbor Sport (Area 2)	0.8352
23	NT Grays Harbor Net	0.1759
24	T Grays Harbor Net	0.0418
25	Willapa Net	0.5572
26	NT Columbia River Troll (Area 1)	1.0000
27	Columbia River Sport (Area 1)	0.8842
28	Columbia River Net	2.1063
29	Buoy 10 Sport	1.0000
30	Orford Reef-Cape Falcon Troll (Central OR)	0.9289
31	Orford Reef-Cape Falcon Sport (Central OR)	0.9129
32	Horse Mountain-Orford Reef Troll (KMZ)	0.7365
33	Horse Mountain-Orford Reef Sport (KMZ)	1.0000
34	Southern California Troll	0.9847
35	Southern California Sport	1.0000
36	Area 7 Sport	1.0000
37	NT San Juan Net (Area 6A,7,7A)	1.0000
38	T San Juan Net (Area 6A,7,7A)	1.0000
39	NT Nooksack-Samish Net	1.0000
40	T Nooksack-Samish Net	1.0000
41	T Juan de Fuca Troll (Area 5,6,7)	1.0000

Appendix 4. Chinook FRAM Fisheries, and the proportion of catch attributed to FRAM modeled Chinook stocks from 2007 calibration (continued)

Fishery #	Fishery Name	FRAM Stock Portion Of Modeled Catch
42	Area 5/6 Sport	1.0000
43	NT Juan de Fuca Net (Area 4B,5,6,6C)	1.0000
44	T Juan de Fuca Net (Area 4B,5,6,6C)	1.0000
45	Area 8 Sport [a]	1.0000
46	NT Skagit Net (Area 8)	1.0000
47	T Skagit Net (Area 8)	1.0000
48	Area 8D Sport	1.0000
49	NT Stilly-Snohomish Net (Area 8A)	1.0000
50	T Stilly-Snohomish Net (Area 8A)	1.0000
51	NT Tulalip Bay Net (Area 8D)	1.0000
52	T Tulalip Bay Net (Area 8D)	1.0000
53	Area 9 Sport	1.0000
54	NT Area 6B/9 Net	1.0000
55	T Area 6B/9 Net	1.0000
56	Area 10 Sport	1.0000
57	Area 11 Sport	1.0000
58	NT Area 10/11 Net	1.0000
59	T Area 10/11 Net	1.0000
60	NT Area 10A Net	1.0000
61	T Area 10A Net	1.0000
62	NT Area 10E Net	1.0000
63	T Area 10E Net	1.0000
64	Area 12 Sport	1.0000
65	NT Hood Canal Net (Area 12,12B,12C)	1.0000
66	T Hood Canal Net (Area 12,12B,12C)	1.0000
67	Area 13 Sport	1.0000
68	NT Deep S. Puget Sound Net (13,13D-K)	1.0000
69	T Deep S. Puget Sound Net (13,13D-K)	1.0000
70	NT Area 13A Net	1.0000
71	T Area 13A Net	1.0000
72	Freshwater Sport	1.0000
73	Freshwater Net [b]	1.0000

Notes: * (T = Treaty; NT = Non-treaty)

[a] Sport areas 8-1 and 8-2 were combined and input into Fishery 45.

[b] In Puget Sound, fishery 73 combines Area 11A with Puyallup River; Areas 9A, 12A, 12D with Hood Canal; Area 13C with Chambers Creek.

Appendix 5. Time period and age-specific rates used by FRAM to simulate coho and Chinook natural mortality

Coho	Time Steps				
Age	1. Jan. to June	2. July	3. August	4. Sept.	5. Oct. to Dec.
3	0.117504	0.020618	0.020618	0.020618	0.020618

Chinook	Time Steps			
Ages	1. Oct. to April	2. May to June	3. July to Sept.	4. Oct. to April
2	0.2577	0.0816	0.1199	0.2577
3	0.1878	0.0577	0.0853	0.1878
4	0.1221	0.0365	0.0543	0.1221
5	0.0596	0.0174	0.0260	0.0596

Appendix 6. Glossary

Adult Equivalent (AEQ) - The potential for a fish of a given age to contribute to the mature run (spawning escapement) in the absence of fishing. Because of natural mortality and unaccounted losses, not all unharvested fish contribute to spawning escapement. For example, a two-year-old Chinook has a lower probability of surviving to spawn, in the absence of fishing, than does a five-year-old, and these two age classes have different "adult equivalents".

Base Period - A set of brood years from which CWT data are used to estimate exploitation rates, maturation rates, and stock abundances. The years used for the base period differ by species and stock. Brood years are chosen based on consistent coded-wire tagging of stocks, consistent CWT sampling of fisheries, and the relatively consistent execution of fisheries during the return years. Some Chinook stocks in the model were not tagged during the base period; recoveries of these stocks (called "out-of-base" stocks) are adjusted to account for changes in exploitation rates relative to the base period.

Catch Ceiling - A fishery catch limitation expressed in numbers of fish. A ceiling fishery is managed so as not to exceed the ceiling; actual catch is expected to fall somewhere below the ceiling.

Catch Quota - A fishery catch allocation expressed in numbers of fish. A quota fishery is managed to catch the quota; actual catch is expected to be slightly above or below the quota.

Chinook/Coho Non-retention (CNR) - Time periods when salmon fishing is allowed, but the retention of Chinook (or coho) salmon is prohibited.

Cohort Analysis - A sequential population analysis technique that is used during model calibration to reconstruct the exploited life history of coded-wire tag groups.

Cohort Size (initial) - The total number of fish of a given age and stock at the beginning of the fishing season.

Coded-Wire-Tag (CWT) - Coded micro-wire tags that are implanted in juvenile salmon prior to release. Historically, a tagged fish usually had the adipose fin removed to signal tag presence. Fisheries and escapements are sampled for tagged fish. When recovered, the binary code on the tag provides specific information about the tag group (e.g., location and timing of release, special hatchery treatments, etc.).

Drop-off Mortality - Mortality of salmon that "drop-off" sport or troll fishing gear before they are landed and die from their injuries prior to harvest or spawning.

Drop-out Mortality - Mortality of salmon that die in a fishing net and "drop-out" prior to harvest or salmon that disentangle from a net while it is in the water and die from their injuries prior to harvest or spawning.

Exploitation Rate (ER) - Total fishing mortality rate in a fishery expressed as the sum of all fishery-related mortalities divided by that sum plus escapement.

Exploitation Rate Scalar - A multiplier used to estimate fishery impacts by adjusting the base period exploitation rates. Exploitation rate scalars can be stock and fishery specific, but generally they are applied to all stocks in a fishery.

FRAM - The Fishery Regulation Assessment Model is a simulation model developed for fishery management and used to estimate the impacts of Pacific Coast salmon fisheries on Coho and Chinook stocks of interest to fishery managers.

Harvest Rate (HR) - Catch or total fishing mortality in a fishery expressed as a proportion of the total fish abundance available in a given fishing area at the start of a time period.

Hooking Mortality - Mortality of salmon that are caught and released by sport or troll hook-and-line gear and die from their injuries prior to harvest or spawning.

Marked Recognition Error - The probability that a marked fish will be inadvertently released.

Model Calibration - Model process involving base period data which (1) scales the coded-wire tag recoveries to represent a stock, (2) allocates non-landed catch mortality to stocks, and (3) reconstructs the cohort in order to compute exploitation rates, maturation rates, and stock abundance.

Model Simulation - Use of the model to vary the calibrated fish population abundance and fishing rates to portray the effects, on the stocks and fisheries, of different sets of sport and commercial fishery regulations.

Non-landed Mortality - This category of fishery-related mortality includes hook-and-line drop-off, net gear drop-out, hooking mortality, and occasionally other sources of mortality such as unreported or illegal catch.

Non-Indian Fisheries - Fisheries conducted by fishers who are not members of the twenty-four Belloni or Boldt Case Area Tribes.

Pre-terminal - In FRAM, a "pre-terminal" fishery is one that operates on both mature and immature fish.

Shaker Mortality – "Shakers" - This term is synonymous with hooking mortality and represents fish that are released from recreational and troll hook-and-line fisheries, either because they are outside of the regulatory size limits or because the species is not allowed to be kept.

Terminal - In FRAM, a "terminal" fishery is one that operates only on mature fish. These fisheries tend to be adjacent to a stock's stream of origin and harvest returning adult fish.

Terminal Area Management Modules (TAMM) - Spreadsheets external to but integrated with FRAM that are used to: (1) provide input for FRAM simulations regarding projected Puget Sound terminal area catches or stock-specific impacts; (2) compute mortality and escapements of individual stock components of the larger Puget Sound FRAM stock aggregates; and (3) create output reports that summarize simulated regulations, stock exploitation rates, allocation accounting, and escapement estimates.

Treaty Indian Fisheries - Fisheries conducted by members of the twenty-four Belloni or Boldt Case Area Tribes.

Unmarked Retention Error (or Retention Error Rate) - The probability that an unmarked fish will be retained inappropriately in a selective fishery (e.g. , fisher fails to identify mark, fisher fails to comply with release requirement).

Validation - An evaluation of how well the model predicts variables of interest (e.g., terminal runs, catch by stock, and stock composition) when post-season estimates of stock abundance and fishery catches are used as input data. Validation is intended to evaluate performance of the model. In other words, does the model yield correct stock-specific impacts using, as inputs, actual stock size and fishery catch information.

Appendix Table 7-1. Important FRAM model output reports produced for the PFMC's Preseason Reports II and III during the salmon fishery planning process.

Table Name	Stocks or Fisheries Referenced	FRAM Report Name or Statistic Source
Table 5. Projected key stock escapements (thousands of fish) or management criteria adopted by the Council for ocean fishery options.		
	Stock specific (Chinook) projected ocean escapement	Terminal Run Size Report
	Columbia Lower River Natural Tules (E.R. from Coweeman.xls, combining FRAM output and freshwater impacts)	Terminal Run Size Report Stock Catch by Fishery Report
	Snake River Fall Chinook Index (SRFI) for all ocean fisheries (Index calculated in SRFI.xls spreadsheet, combining PSC model and FRAM model outputs)	Exploitation Rate Comparison Report
	Key coho stocks: ocean escapement or various E.R. estimates (see Appendix Table 5-11 for table names within coho TAMM)	FRAM output reports as summarized within coho TAMM
Table 6. Preliminary projections of chinook and coho harvest impacts for ocean salmon fishery management measures adopted by the Council.		
	Regional ocean fisheries aggregates	Fishery Summary Report
Table 7. Expected coastwide lower Columbia natural (LCN), Oregon coastal natural (OCN), Rogue/Klamath (RK) coho, and lower Columbia River (LCR) natural tule Chinook exploitation rates by fishery for ocean fisheries management measures adopted by the Council. (see Appendix Table 5-11 for table names within coho TAMM)		
	Regional ocean fisheries aggregates	FRAM output reports as summarized within coho TAMM Coweeman.xls spreadsheet for LCR tule stock E.R.
Table 8. Projected coho mark rates for fisheries under base period fishing patterns (%marked)		
	Regional fisheries from Canada, Puget Sound, Washington, and Oregon	Stock Catch by Fishery Report as summarized in MarkRateTable.xls.

[a] Preseason Report II Analysis of Proposed Regulatory Options for XXXX Ocean Fisheries and Preseason Report III Analysis of Council Adopted Management Measures for XXXX Ocean Salmon Fisheries where XXXX = management year.

[b] ER = Exploitation Rate

[c] In Preseason Report III only

Appendix Table 7-2. Primary model output summary reports referenced by the NOF Co-Managers during the PFMC pre-season salmon fishery planning process.

Report Name	*Stocks or Fisheries Referenced*	*Evaluation Statistic*	*Report Production*
Coho Reports:			
Table 1: Description of Fishery Regulations and Summary of Coho Catch Targets			
	Total mortality for pre-terminal fishery aggregates and for Puget Sound fisheries	# of fish	TAMM report
Table 2s: Coho Fishery Impact Summary Highlights (management criteria, total ER[a/], spawner escapement)			
	Puget Sound and WA coastal stock specific mortality by fishery	# of fish	TAMM report
Table 4: Summary of Coho Exploitation Rates by Fishery Aggregate			
	Puget Sound stocks (total ER), and WA coastal stocks (pre-terminal ER)	Regional ERs	TAMM report
Table 7: Coho Run Sizes for Salmon Technical Team Reference			
	Ocean escapement of Southern U.S. coho stock aggregates	# of fish	TAMM report
Table C: Columbia River Coho Fishery Impact Summary (catch by fishery aggregates, ocean esc., marine E.R.s)			
	Columbia River Early and Columbia River Late coho stocks	# of fish	TAMM report
Table OR: Total Mortality and Exploitation Rates for OCN and Rogue/Klamath (statistics by fishery aggregates)			
	Oregon Coastal Natural and unmarked Rogue/Klamath	# of fish & ERs	TAMM report
Table T: Thompson and Upper Fraser Coho Fishery Impact Summary (statistics by fishery aggregates)			
	Ocean escapement and marine ERs for Canadian Upper Fraser wild coho	# of fish & ERs	TAMM report
Chinook Reports:			
Table 1: Description of Fishery Regulations and Summary of Chinook Catch Targets			
	Total mortality for pre-terminal fishery aggregates and for Puget Sound fisheries	# of fish	TAMM report
Table 2: Exploitation Rates and Natural Escapement of Selected Puget Sound Chinook Stocks (MSF[b/] compatible)			
	ESA listed Puget Sound stock unit model prediction and management criteria	ERs & esc.	TAMM report
Snake River Fall Chinook Index (SRFI) for all ocean fisheries			
	From PSC and PFMC fisheries: Total predict ER divided by base period ER	Impact ratio	SRFI.xls
Total mortality adult equivalent exploitation rates (catch/catch + ocean escapement) and Terminal Run Size			
	Columbia River stocks with focus upon Coweeman (Lower Columbia River wild tulees)	Total ER	Coweeman.xls

a/ ER = Exploitation Rate
b/ MSF = Mark-Selective Fishery