Chapter 1. Introduction

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1.1 - Welcome

Welcome to the Columbia River Salmon Passage (CRiSP) Harvest Model—a user-friendly version of the forecasting portion of the Pacific Salmon Commission (PSC) Chinook Model. Now you can use the same model scientists from the Pacific Salmon Commission used in 1995 to explore the potential consequences of chinook salmon harvest regulations.

Although the CRiSP Harvest Model is not completely up-to-date with the current model used by the PSC, it contains the most important features of the model and allows users to gain appreciation for the complexities and difficulties of Pacific salmon harvest management. This manual provides step-by-step instructions for examining a variety of processes involved in salmon management. Our hope is that by using the model to simulate management actions, users will learn about these processes.

This first chapter includes a general overview and brief history of the CRiSP Harvest Model. It also includes a section describing mathematical modeling. The second chapter is a detailed Users Manual that will serve as a reference for operating the program. Chapter Three describes several lessons, or tutorials, that demonstrate step-by-step procedures for learning about the fishery processes. Chapter Four includes a brief description of the model theory. Finally, Chapter Five provides a list of over 350 web sites related to salmon management.

1.2 - General Description

CRiSP Harvest is a user-friendly, interactive chinook salmon harvest forecasting model. It is based on the forecasting portion of the Pacific Salmon Commission (PSC) Chinook Model, which is written in Microsoft QuickBasic™ and runs under the PC MS-DOS platform. CRiSP Harvest is written in the C++ language and was originally designed to run on Sun workstations using the UNIX operating system. A Windows 95/NT version has been under development since 1996.

The PSC Chinook Model was developed by the PSC Chinook Technical Committee to examine alternative management approaches to implement the PSC chinook rebuilding program (the next section contains a brief history of the model). The model is capable of simulating a large number of years, stocks (hatchery and natural), and fisheries (troll, net, and sport) (Table 1.1 and Table 1.2). A key feature of the model is the interaction between stocks through annual catch ceilings imposed upon fisheries that harvest multiple stocks. As stocks rebuild or decline at different rates over time, relative harvest rates in ceilinged fisheries also change. Single stock models cannot simulate this type of interaction.

Simulations are divided into two time periods: (1) a calibration period; and (2) a management simulation period. The calibration period runs from 1979 through the last year for which model parameters can be estimated (usually one year behind the current year). The simulation period runs from the current year to any future year (usually about 10-15 years in the future). The PSC Chinook Model produces information to help evaluate the effects of changes in brood year survival rates and several management actions:

- pre-recruitment (i.e., age one) survival projections
- pre-spawning survival (i.e., inter-dam losses)
- enhancement activities
- catch ceilings (catch quotas)
- harvest rate strategies
- size limits.

Parameters must be estimated and the model must be calibrated to produce useful results. The calibrated parameters provided with this version of the model were obtained from the PSC Chinook Technical Committee and were based on the best available information through 1995. These parameters are stored in temporary files in ASCII text format which can be read by CRiSP Harvest without modification.

Production parameters for both hatchery and natural stocks are estimated from historical data. Ocean survival rates for ages one through five are assumed fixed (at 0.5, 0.6, 0.7, 0.8, and 0.9, respectively) for all stocks. Survival rates to age one (also called Environmental Variability, or “EV,” scalars) are estimated during the calibration process. Other parameters are estimated by a technique known as “cohort analysis” or “virtual population analysis.” This type of analysis involves the reconstruction of an annual series of abundance estimates using catch and escapement data and making assumptions about natural and incidental mortalities. Once each cohort has been reconstructed, the following parameters are estimated:

- Cohort size for each age class at the beginning of each year
- Age specific harvest rates for each fishery
- Maturity schedule for all ages
- Estimates of incidental fishing mortalities.

The model is calibrated by finding a suite of stock and year-specific smolt to age one survival rates (EV scalars) that results in model outputs that most closely match user specific terminal run sizes, escapements, or catches for individual stocks during the base period. The user specifies the EV scalars for the simulation period, often taken to be the average of the base period values. The model results are known to be sensitive to the selection of the EV scalars for the simulation period.

Management changes are evaluated by changing key parameters, such as future catch ceilings or harvest rates, and rerunning the model. In the QuickBasic™ version of the PSC Chinook Model, parameters are changed by opening appropriate ASCII data files and changing the appropriate data fields. This process also involves changing file names in control files. A 25 year simulation with 30 stocks and 25 fisheries takes three to five minutes using a PC computer with a 486 microprocessor. Output data are displayed by downloading to data files which must be imported into other analysis programs, such as a spreadsheet.

CRiSP Harvest allows the operator to change parameters and view results interactively. Parameter values can be changed by using the mouse or keyboard. Results can be presented in graphical form on the screen immediately after a simulation run (graphs can also be printed), or can be downloaded to data files for archiving or further analysis.

Table 1.1 Fisheries included in CRiSP Harvest Model.

Number	Fisheries	Abbreviation
1	Alaska Troll	Alaska T
2	Northern B.C. Troll	North T
3	Central B.C. Troll	Centr T
4	West Coast Vancouver Island Troll	WCVI T
5	Washington/Oregon Troll	WA/OR T
6	Strait of Georgia Troll	Geo St T
7	Alaska Net	Alaska N
8	Northern B.C. Net	North N
9	Central B.C. Net	Centr N
10	West Coast Vancouver Island Net	WCVI N
11	Juan de Fuca Net	J De F N
12	North Puget Sound Net	PgtNth N
13	South Puget Sound Net	PgtSth N
14	Washington Coast Net	Wash Cst N
15	Columbia River Net	Col R N
16	Johnstone Strait Net	John St N
17	Fraser River Net	Fraser N
18	Alaska Sport	Alaska S
19	North/Central B.C. Sport	Nor/Cen S
20	West Coast Vancouver Island Sport	WCVI S
21	Washington Ocean Sport	Wash Ocn S
22	North Puget Sound Sport	PgtNth S
23	South Puget Sound Sport	PgtSth S
24	Strait of Georgia Sport	Geo St S
25	Columbia River Sport	Col R S

Table 1.2 Stocks included in CRiSP Harvest Model

Number	Stocks	Abbreviation
1	Alaska South SE	AKS
2	Northern/Central B.C.	NTH
3	Fraser River Early	FRE
4	Fraser River Late	FRL
5	West Coast Vancouver Island Hatchery	RBH
6	West Coast Vancouver Island Natural	RBT
7	Upper Strait of Georgia	GSQ
8	Lower Strait of Georgia Natural	GST
9	Lower Strait of Georgia Hatchery	GSH
10	Nooksack River Fall	NKF
11	Puget Sound Fingerling	PSF
12	Puget Sound Natural Fingerling	PSN
13	Puget Sound Yearling	PSY
14	Nooksack River Spring	NKS
15	Skagit River Wild	SKG
16	Stillaguamish River Wild	STL
17	Snohomish River Wild	SNO
18	Washington Coastal Hatchery	WCH
19	Columbia River Upriver Brights	URB
20	Spring Creek Hatchery	SPR
21	Lower Bonneville Hatchery	BON
22	Fall Cowlitz River Hatchery	CWF
23	Lewis River Wild	LRW
24	Willamette River	WSH
25	Spring Cowlitz Hatchery	CWS
26	Columbia River Summers	SUM
27	Oregon Coastal	ORC
28	Washington Coastal Wild	WCN
29	Snake River Wild Fall	LYF
30	Mid Columbia River Brights	MCB

1.3 - Brief History of the PSC Chinook and CRiSP Harvest Models

During the negotiations which led to the Pacific Salmon Treaty in 1985, efforts to reach agreement on chinook management focused on strategies which would rebuild depressed natural stocks within an agreed-upon time period. At the technical level, several micro-computer models were developed to provide a method of consistently and objectively analyzing alternative options under consideration during the negotiations.

The computer models were designed to analyze how various combinations of fisheries management actions would affect rebuilding. Prior to the development of the models, information on the production levels for natural chinook stocks was often limited to measurements of catch and escapement in or near the corresponding river of origin. Direct estimates of a significant component of overall production (i.e., harvest levels in ocean and near-shore mixed stock fisheries) were often not available for the natural stocks of interest. By integrating chinook life history assumptions with coded-wire-tag (CWT) recovery data, the models permitted the simulation of ocean and terminal harvest and escapement patterns.

The models simulated the process of rebuilding under hypothetical fishery policies that reduced harvest rates over time. As spawning escapements of depressed stocks increased to optimum levels, production increased. By maintaining fishery regimes, such as harvest ceilings, as run sizes progressively increased, rebuilding accelerated.

The models were initially designed to evaluate alternative fishery management regimes with respect to their implications for successfully rebuilding depressed chinook stocks by 1998. They progressed from simple cohort analyses designed to evaluate overall harvest rates and patterns of exploitation for single stocks or groups of stocks, to a “Multiple Stock Model” which incorporated multiple fisheries, stocks and brood years as well as stock-recruitment production functions. Intermediate steps included a simple “Forward Cohort Analysis” and a “Single Stock” multiple brood and fishery model (also including the stock-recruitment function).

While the “Single Stock” model achieved the goal of providing a set of mutually acceptable rules for evaluating proposals under consideration when the Pacific Salmon Treaty was being negotiated, it did not adequately represent results expected when several stocks were involved. Under the single stock approach, the progressive reductions in harvest rates in fisheries with ceilings resulting from increasing stock size over the course of the rebuilding cycle are transferred entirely to the single stock in the Model. In reality, the harvest rate changes in pre-terminal fisheries would be influenced by the abundance of the aggregate of stocks available. However, while the abundance of depressed components of the aggregate would be expected to increase as a result of increased escapement, the abundance of many components would remain relatively stable. As a result, the single stock approach would tend to underestimate the time required for rebuilding; it would present an overly optimistic picture of the effects of future reductions in harvest rates resulting from increased production.

Application of the Model to describe these mechanisms requires the assumption that proportional changes in total model fishery catch are represented by the actual changes in the real world catch. It also assumes that the stock composition in the Model catch reflects the relative contribution of these stocks to the actual catch (the abundance of unrepresented stocks is assumed to be constant).

If these assumptions are not met, the ceiling or quota mechanism on rebuilding will produce incorrect rebuilding schedules. The quota or ceiling mechanism will take effect at different harvest levels for each particular stock depending on the abundance of other stocks in the catch. For example, the rate at which a particular stock rebuilds may be accelerated by the presence of other stocks in the ceiling fisheries. If these other stocks respond to management measures at a faster rate, their abundance is increased and the relative contribution of the stock of interest to the fishery is reduced. This effect is similar to that resulting from enhancement where the increased abundance of hatchery fish will “saturate” the fishery under a fixed harvest ceiling and dilute the impact on wild stocks resulting in an increased savings of wild fish to escapement.

More detailed stratification of fisheries was required to respond to a number of policy questions that were raised over time. The resolution needed for modeling may vary from issue to issue, depending upon the questions to be addressed and the availability of necessary data. The final Model used for the Pacific Salmon Treaty negotiations in 1984 incorporated four stocks and nine fisheries. The Model was modified in 1987 to enable it to simulate up to 25 fisheries and 26 stocks. In 1993 and 1994 the number of stocks was increased to 29 and 30, respectively.

By 1987, the effects of incidental mortality losses to the chinook rebuilding program had increasingly become a matter of concern as management agencies implemented various changes to fishing regulations to increase benefits under the fishery regimes established through the Pacific Salmon Commission. The Model has been modified to more realistically reflect incidental mortality losses and permit the evaluation of regulations such as non-retention restrictions and size limit changes.

The Model was recoded into Microsoft QuickBasic™ language beginning in 1986 and was revised in a number of important ways to better meet needs under implementation of the Pacific Salmon Treaty.

The listing of the Snake River Fall Chinook stock as “endangered” under the US Endangered Species Act generated interest in harvest management decisions from stakeholders outside the normal harvest management “family.” In 1993 the University of Washington School of Fisheries, with funding from the Bonneville Power Administration, began creating a user-friendly version of the PSC Chinook Model. The goal was to create a tool that both scientists and the general public could use to explore the effects of various harvest management regulations on chinook stock rebuilding.

The new user-friendly model, called the CRiSP Harvest, was initially created under the UNIX operating system and was completed in 1995. Since that time a PC version has been under development to make the model more accessible to the general public. The version described in this manual is still considered a beta (or test) version, so you may encounter problems, or bugs, as you use the program.

The PSC Chinook Technical Committee (CTC) continues to modify the Chinook Model as more information becomes available. This information will be incorporated into the model structure and input data so that the model reflects the current understanding of the dynamics of chinook populations and fisheries. At this time (August 1997) there is no consensus among the CTC members on a calibrated model. The CRiSP Harvest Model described in this manual is based on the last agreed upon model in 1995.

1.4 - CRiSP Harvest Validation

CRiSP Harvest is designed to produce outputs that are identical to those produced by the PSC Chinook Model, assuming both are given the same input data. At each step of CRiSP Harvest development, the input files for the PSC Chinook Model were adjusted, either by changing the data input files or by adjusting portions of the QuickBasic™ code, to reflect the features incorporated into CRiSP Harvest.

Both models print catch and escapement output files in identical ASCII format. To compare these outputs, CRiSP Harvest was run on a Sun SparcStation and a QuickBasic™ version was run on a Gateway 2000 Nomad 450DXL-200 using an Intel 50MHz 486DX2 processor. ASCII files produced by the QuickBasic™ version were downloaded to a floppy disk and imported into the Sun workstation. A “diff” command was executed on appropriate output file pairs to identify any differences between the two files. If differences were encountered, both versions (QuickBasic™ and C++) were run side-by-side with debugging routines to find code errors.

Models were considered validated when no output fields differed by more than a value of one (1), assumed to be rounding errors due to different calculating precisions of the two machines. In all validations, rounding errors did not accumulate.

1.5 - Overview of Mathematical Modeling

What is Mathematical Modeling?

Just about everyone would like to know what the future holds. Some consult tarot cards, tea leaves, crystal balls, and telephone psychics. Others take a more systematic approach—they examine the recent past to understand processes and determine trends that may give insight into the future. In short, they form ideas about how the world works, and from those ideas generate predictions about what will happen in the future. These ideas constitute an abstraction of the real world and form a “model” of a “system” of interrelated components.

Mathematical modeling is a technique for understanding the dynamics of a system and for predicting future outcomes within the system. From a simplified perspective, any system is composed of two fundamental things:

- elements that have certain qualities and properties
- relationships and actions that explain how these elements interact and change

For example, consider the “system” that encompasses a baseball game during a single play. A short list of the elements might be: pitcher, hitter, fielder, bat, and playfield, and a short list of the relationships could be: hitting, flight, gravity, catching, throwing, running, and tagging. A reasonable modeling effort allows for different outcomes: batter is out, batter is safe, batter hits a home run, etc. depending on how the relationships between the elements (based on their properties) are manifest. In sports talk, we might say that batter A has a .323 average and is more likely to get a hit than batter B with a .265 average. In system talk, this batter has different properties that affect his interactions with the other elements on the field that make him more likely to get a hit.

In another example, consider a household budget. There are elements such as income, expenses, savings, etc. and relationships that allocate certain proportions or fixed amounts of the income to the expenses.

In CRiSP Harvest, the basic elements are the fisheries and the stocks. The relationships include the processes by which fishing reduces the stock, production and growth, etc. The properties of these elements and the relationships between them are controlled by the many parameters in the model such as Harvest Rates and production parameters.

Why Use Mathematical Models?

Abstractions of reality

Mathematical models are an abstraction of the system they represent. It allows the model user to study and understand the relationships between the elements of the system without having to actually manipulate the system. For example, in the CRiSP Harvest model it would be impossible to evaluate escapement of a stock based on catch ceilings at five different levels in any one year. The catch ceiling is set at one level for the year and then the boats go out and that is it. There can be no “what if?” kinds of questions without the model.

Abstraction allows for the simplification of the system because it is not necessary or even desirable for it to be exact or replicate the exact mechanisms. In CRiSP Harvest, the properties of the fishers and the stocks are explained in simplified mathematical terms so that their essential qualities are characterized in a concrete manner. For example, the fisher is presumed to catch fish at a certain rate and the details of exactly how many are being caught at any given time are unimportant.

In the case of the baseball player A, all we need to know are the odds that the batter will get a hit. Our model is simply his/her average: .323. That is a gross simplification of a huge number of things: A’s hand-eye coordination, the types of fields (s)he plays on, A’s strength, the pitchers technique, diet, coaching, health, etc. We model A’s hitting ability so that we can make some kind of prediction of whether or not A will get a hit the next time at bat.

Models have a purpose

A model has a purpose. Consider making two different types of model airplanes from kits. One is designed to look like a real airplane and the other is designed to fly. The one that looks like a real airplane shows the geometric relationship between the parts of the plane and apart from that is quite different than the plane it represents (it has fewer parts, is made of different materials, etc.) When we look at it we say, “That is an airplane,” or perhaps: “That is a DC-10.” At the very least, it is not a dinosaur or a doll’s house!

The balsa-wood plane on the other hand crudely represents a real airplane and may have only a handful of parts, but was designed for function over form.

In the case of the CRiSP Harvest model, the uses and purposes include:

- educate users on the state of the system and the interactions between the elements (stocks and fisheries)
- assist in developing experiments

- evaluate sensitivity of model elements and relationships to different parameters (for example catch ceiling changes or other policy changes)
- predict stock levels and catches based on different scenarios

See “Brief History of the PSC Chinook and CRiSP Harvest Models” on page 1.7 for an overview of the purposes for which the model was designed.

Modeling Concepts and Practice

There are two very important steps in the creation of a model: calibration and validation. They help make the model more usable and believable.

What is Model Calibration?

Model calibration is the process by which the parameters that characterize the model’s elements and relationships are determined. The calibration process is dynamic and allows new information to be incorporated. In the case of the baseball player who is hitting .323, after he has batted for another game, his average is re-computed to incorporate the new information. The player is now re-calibrated in light of his last game’s performance.

In the case of the household budget, there might be a transportation category where bus fare, gas for the car, parking and automobile maintenance is all consolidated. Each month the household evaluates their expenses related to transportation to see if their budget model is accurate. If it is consistently off the mark and changes to expenses can not be made, then it is time to recalibrate the model.

CRiSP Harvest is recalibrated periodically by fisheries scientists. They use updated catch information, escapement estimates and other data from the field to re-establish parameter values.

What is Model Validation?

One type of model validation is to compare its predictions with another model of the same system. If the differences are slight enough or non-existent then conclude that the model is valid in terms of representing the other model. This was an important procedure for the CRiSP Harvest model because it was based on the PSC Chinook Model and the model developers wanted to be certain that it produced the exact same results.

A more important type of model validation is the process of determining how well the model represents the real system and, consequently, how useful it is in predicting the future. In the baseball example, we might like to know how well a simple batting average model calibrated at the end of every week predicts the batting average during the coming week. If the batter is very consistent, a simple batting average model probably is valid for predicting future performance. However, if the batter is a streak hitter and goes through cycles of hot and cold hitting, a simple batting average may not be an acceptable model. In this case, a more complicated model may be needed that predicts whether the batter will be in his hot or cold cycle during the coming week.

Fishery models can be validated by comparing future predictions with real outcomes. For example, a model calibrated through 1995 can be used to predict escapements and catches in 1996. Once the 1996 season is over, the predictions can be compared to the real-world outcome to see how well the model performed.

Real world model validation is very difficult given the complexity of the systems involved. If a model can not be validated, sometimes, the individual parts are validated and the whole is deemed acceptable provided that the representation of the mechanisms and processes that hold the parts together is acceptable to the community who are building and/or using the model. This is the case when complete model validation cannot be done for some reason (it may be prohibitively expensive, require too much time, etc.) but the value of a working model is significant.

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