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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Chapter 2. Users Manual

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2.1 - Installation

System Requirements

Make sure your computer meets these requirements before installing CRiSP Harvest Model on your PC. Read the **readme.txt** file included with the distribution for any special requirements.

Required Hardware:

- IBM or compatible computer
- 486/66 or better
- 3.5" floppy disk drive
- Two button mouse
- 8 MB of RAM
- 10 MB available hard disk space
- VGA monitor (color not required)
- Printer (optional)

Required Software:

- Windows 95 or Windows NT
- Text editor (optional)

Installation

Installation from floppy disks

1. Run Windows 95 (or Windows NT).
2. Insert CRiSP Harvest Disk 1 into the floppy drive.
3. Click the Windows 95 Start button and choose Run.
4. In the dialog box, type **a:\setup**. If your floppy drive is not **a:**, substitute the appropriate letter for **a:**
5. Choose OK.
6. Follow the SETUP program's directions. Unless otherwise directed, the setup program will install all the CRiSP Harvest files in a folder labeled **c:\program files\cbr**. See the section entitled "File Structure" for a complete description of the files.

Installation of a downloaded self-extracting file

1. Run Windows 95 (or Windows NT).

2. Run Netscape or other WWW browser.

3. From
    http://www.cqs.washington.edu/crisp/crisp2pc.html
    follow instructions for downloading.

4. Choose destination directory on your system and save the **crisph.exe**
    file on your hard drive.

5. Double click on this self-extracting file or launch it from a Run dialog box.
    This creates an Install directory and sub-directories.

6. Open the **install\disk1** directory and double-click the **setup.exe**
    icon.

7. Follow on-screen instructions.

Other Platforms

A separate version of CRiSP Harvest is available to run on the UNIX
platform. No Macintosh version is available.

2.2 - Getting Started

File Structure

CRiSP Harvest is composed of files that fall broadly into four categories:

1. An executable file (**crisph.exe**) that is the main computation engine.

2. One or more control files (**proto.opt** is the default) that tells the computation engine what data files to use for that session of running the model.

3. Several data files that allow you to simulate various biological and fishing processes. These are in a sub-directory named **input.**

4. Other files not integral for running the model such as those used by the help engine, the help engine itself and the output files (***.prn** files).

None of these files can be edited from within the executable program. However, many of the data imported from the various data files can be changed interactively through the Graphical User Interface (GUI) to simulate and run different types of future management scenarios. For example, catch quotas and hatchery smolt production can be changed through the GUI. The basic model configuration (e.g. number of stocks and fisheries, years to be modeled, data for past years) cannot be changed interactively.

When the executable program starts, it first looks for an ***.opt** file to tell it what data to use. If no ***.opt** file is specified by you, it uses the default ***.opt** file, named **proto.opt**.

The file structure has been maintained for backwards compatibility with other versions of the model that have run on different platforms and/or with different features.

Launching CRiSP Harvest

Whenever CRiSP Harvest is launched, the management scenario specified in the ***.opt** (see "Files of type *.opt" on page 2.55) and associated files is run and output files are produced.

Once the CRiSP Harvest window is open, it is possible to interact with the map, icons and graphs to alter the parameters and rerun the model. Below are the options for launching the model for the first time. Subsequent interactions are described in the sections that follow.

To start CRiSP Harvest from the Program Folder

■ Click the Start button.

- Select Programs.
- Click on the CRiSP Harvest icon:

To start CRiSP Harvest from the Run dialog box

- Click the Start button.
- Select Run.
- In the dialog box type:

  "c:\program files\cbr\crisp harvest\crisph.exe"
  (or another path if you did not use the default installation path).
  Note: the location of quotation marks is important!
- Click OK to start the program.

To run CRiSP Harvest in "No Graphics" mode

For scientific applications that require running more than one scenario, it is often convenient to run CRiSP Harvest without using the GUI. When run in this "No Graphics" mode, the output files specified in the ***.opt** file are still produced automatically. Note that it is important to keep track of output files because there is no other way of examining model output.

- Follow the instructions for running CRiSP Harvest from the Windows Run dialog box and add the **-ng** flag following the ***.exe** file name. For example:

  "c:\program files\cbr\crisp harvest\crisph.exe" -ng

To specify a ***.opt** *file*

- Follow the instructions for running CRiSP Harvest from the Windows Run dialog box and add the flag **-f*** following the file name, where * is the name of the desired ***.opt** file. For example:

  "c:\ ... \crisph.exe" -fmyfile.opt

  There is a default *.opt file called **proto.opt** that is used if none is specified. See "Files of type *.opt" on page 2.55 for details on this file.

Other options

Multiple flags can be used together. For example to run the model with a specific ***.opt** file and in no graphics mode:

"c:\ ... \crisph.exe" -fmyfile.opt -ng

2.3 - The Map

The map shows the approximate geographic location of the 25 fisheries and 30 stocks used in the model. Fisheries are designated by boat icons ⚓ and stocks by fish icons 🐟 . Remember that this model only contains chinook stocks and fisheries that are of concern to the Pacific Salmon Commission.

For discussion purposes, mouse, pointer, and click operations are described for the default settings. As you become more comfortable with the model, you may want to alter them to suit your needs.

Identifying Location

As the mouse pointer is moved over the map, the approximate latitude (LAT) and longitude (LON) of the pointer is given in the right portion of the status bar LAT: 59.01 LON: 103.94 (located below the map).

Identifying Fisheries and Stocks

Move the mouse pointer over the desired icon. The name of the highlighted icon is displayed in the left portion of the status bar.

Creating a Sub-Map

1. Place the mouse pointer at the upper left corner of the region you want to include in the sub-map.
2. Left-click and drag the mouse pointer to the lower right corner of the desired region.
3. Release the mouse button.

   The new sub-map is drawn and has all the features of the main map window.

Returning to the Full Map

1. Move the mouse pointer so it is NOT located over a stock or fishery icon.
2. Right-click.

Automatic Stock and Fishery Information

1. Click on the Context Sensitive Help 🔍❓ button to select it (background whitens 🔍❓) to enable the automatic information system.
2. Move the mouse pointer over a stock or fishery icon so that it is selected with a black highlight. The CRiSP Harvest Manual appears in a separate window and automatically opens a description of that stock or fishery. If

the window is already open, the content is updated to reflect the new request.

☞ At this time, not all stocks and fisheries have information datafiles.

Turning off Automatic Stock and Fishery Information

1. Click on the Context Sensitive Help ![button] button to select it (background darkens ![icon]) to disable the automatic information system.

2. Click on the close window button (![icon]) in the upper right-hand corner of the information window if you want it to close the Help system.

Finding Fisheries Harvesting A Given Stock

1. Enable Stock Circles (default) by clicking on the Stock Circles button ![icon] to select it (background lightens and a circle is displayed with the fish ![icon]). Disable this by clicking the button again.

2. Left-click on a stock icon. A circle is drawn around all fishery icons harvesting that stock. The diameter of the circle is proportional to the sum of the age specific harvest rates for that stock in that fishery.

☞ Right-click a stock icon to open an Abundance Graph for the stock.

Finding Stocks Harvested By A Given Fishery

1. Enable Fishery Circles (default) by clicking on the Fishery Circles button ![icon] to select it (background lightens and a circle is displayed with the hook ![icon]). Disable this by clicking the button again.

2. Left-click on a fishery icon. A circle is drawn around all stocks harvested by that fishery. The diameter of the circle is proportional to the sum of the age specific harvest rates for that stock in that fishery.

☞ Right-clicking on a fishery icon opens an Abundance Index Graph for that fishery.

Closing the Map Window

Left-click on the Map button ![icon] so that it appears dulled: ![icon] .

Opening the Map Window

Left-click on the dulled Map button ![icon] to darken it ![icon] .

2.4 - Drop-Down Menus

All CRiSP Harvest commands are available on a drop-down menu. Many of the commands are also available on the toolbar (described in the next section). More details on these operations is described in "Model Operations" on page 2.34

Menu	Item	What It Does
File	Print Map..	Prints the current screen.
	Mouse Tool	Opens a dialog box for setting mouse button controls.
	Exit	Exits CRiSP Harvest.
Fishery	PNV..	Opens a dialog box for adjusting "Proportions Non Vulnerable" for each fishery. PNVs are used to simulate changes in size limits in the fisheries. For example, increasing the size limit will increase the proportion of some age classes that are no longer vulnerable to retention by the fishery.
	CNR..	This is currently under development. When implemented, it will open a dialog box for adjusting "Chinook Non-Retention" mortality parameters in some fisheries.
	Catch Ceilings..	Opens a dialog box for adjusting catch ceilings (quotas) in fisheries that have this type of management control. For example, use it to set future catch ceilings in the ocean troll fisheries.
	Fishery Graphs	Opens a sub-menu for producing graphs of fishery statistics over time, including: Abundance Index, Catches (Total, Pre-terminal and Terminal) and Incidental Mortality (Total, Sublegal and Legal). Graphs generated are for the currently selected fishery.

Menu	Item	What It Does
Stock	Inter-Dam Loss..	Opens a dialog box for adjusting the "Inter-Dam Loss" rates for three Columbia River stocks. The IDLs are actually the survival rates from the time the fish leave the river fisheries and arrive on the spawning grounds. Warning: at present only three stocks actually have IDL. The fact that all stocks display is a bug to be corrected in a future release.
	EV Scalars..	Opens a dialog box for adjusting the annual "Environmental Variability" Scalars for each stock. The EV Scalars can be thought of as brood year survival rates that determine the relative spawning success each year.
	Enhancement..	Opens a dialog box for adjusting parameters associated with hatchery stocks.
	Maturation Rates...	Opens a dialog box for adjusting maturation rates for each of the stocks (i.e., the fraction of each age class that returns to spawn in a given year).
	Stock Graphs	Opens a sub-menu for producing graphs of stock statistics over time including: Abundances, Escapements, CNR mortalities (Sublegal and Legal), Catches (Total, Preterminal and Terminal), True Term Run. Graphs generated are for the currently selected stock.
Harvest	Harvest Rate Scalars..	Opens a dialog box for adjusting annual stock/fishery specific harvest rates. For example, to simulate changes in fishery regulations (e.g., time/area closures) that increase or decrease harvest rates relative to the base period.
	Base Period Harvest Rates..	Opens a dialog box displaying the stock/age/fishery specific harvest rates during the base period (1979-1982). These values cannot be changed. Use Harvest Rate Scalars to adjust harvest rates relative to base period values.
	Mortality Graphs	Opens a sub-menu for producing graphs of Total and Incidental mortality by stock and fishery. Graphs generated are for the currently selected stock and fishery.

Menu	Item	What It Does
Run	Scenario	Runs the model in a scenario mode—a single instance of the model in deterministic mode (i.e., all parameters are fixed).
	Monte Carlo..	Opens a dialog box where the model is run in a Monte Carlo model. One or more "games" (a game is one instance of the model) are run using a different set of Brood Year Survival Rates (EV Scalars) during each run. The EV Scalars are selected randomly from designated probability distributions. **Note: This mode of model operation is still under development for the PC platform**.
	Calibrate	Calibrates the model to observed data. Calibration runs require special configuration files that most users will not have.
Help	Contents	Opens a window giving the table of contents of the CRiSP Harvest help files: README, FAQ, Model Overview, and CRiSP Harvest manual. Click on a subject to read about it.
	Glossary	Opens a window giving definitions for CRiSP Harvest terminology (Chapter 2. User's Manual, Appendix 2.4).
	About CRiSP Harvest	Gives the version number of the model.

2.5 - The Toolbar

The table below describes the various features of the toolbar.

Button	Name	What It Does
Alaska T	Default Fishery	Selects the default fishery. When drop-down menu items are selected, they open with the default fishery selected.
Alaska South SE	Default Stock	Selects the default stock. When drop-down menu items are selected, they open with the default stock selected.
	Print	Prints the current view.
	Stock Circles	When enabled, clicking on a fishery icon on the map draws hatched red circles around all stocks harvested by that fishery. The size of each circle is roughly proportional to the amount of the harvest. Right click also displays abundance data (default).
	Fishery Circles	When enabled, clicking on a stock icon on the map draws hatched green circles around all fisheries that harvest that stock. The size of each circle is roughly proportional to the amount of the harvest. Right click also displays abundance index (default).
	Help	When enabled, moving the mouse pointer over a stock or fishery icon will bring up information about that stock or fishery.
	Map On/ Off	Minimizes (hides) the map section of the screen.
	Run	Runs the model in scenario mode.
	Mouse-Pointer	Lets you set the functions of the left and right mouse buttons.

2.6 - Graph Windows

Most outputs from a simulation run can be displayed in a graph—usually one or more state variables plotted against time (years). Graph windows can be brought up directly and multiple graphs can be displayed at any time. A typical graph window (shown below) has several buttons and two information boxes. A vertical dashed line separates the calibration (to the left) and simulation (to the right) time periods.

Opening Graphs

Opening Graphs from the main menu

1. Choose a Fishery and/or Stock on the toolbar (see "The Toolbar" on page 2.27 for changing these).

2. Choose from the submenus under Graphs on the Fishery, Stock and Harvest menus.

Opening Graphs from the map

1. Click on the map according to the Mouse Tools settings. These settings are described more in the section entitled "The Map" on page 2.22.
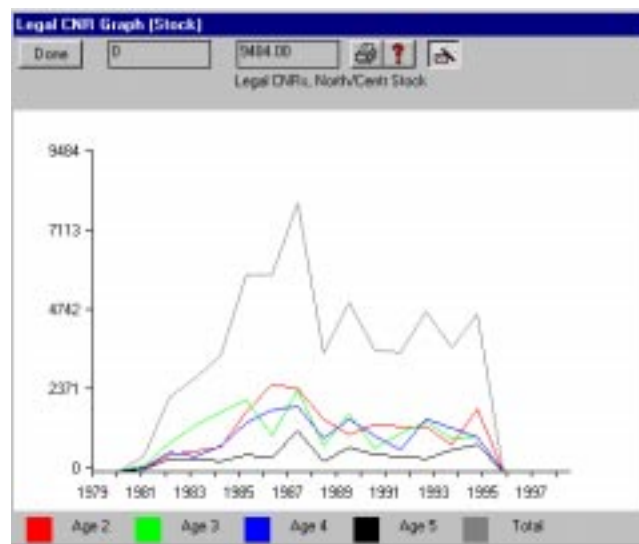
Buttons and Boxes

Button	Name	What It Does
Done	Done	Closes the Graph window.
	X-axis value box	Displays the x-axis (ordinate) value of the mouse pointer as it is moved over the graph.
	Y-axis value box	Displays the y-axis (abscissa) value of the mouse pointer as it is moved over the graph.
	Print	Print the current view.
	Help	At this time this feature is not available. To get help, use the Help button on the main Toolbar.
	Auto-update	When enabled (shown), graphs update automatically when mouse is moved over a new fishery or stock icon.

Graph Windows Operations

Estimate Y-Axis Values

Move the mouse pointer into the graph region. The approximate Y-axis value at the tip of the mouse pointer is displayed in the Y-axis value box. The accuracy of the value depends on the scale of the y-axis.

Estimate X-Axis Values

Move the mouse pointer into the graph region. The approximate X-axis value at the tip of the mouse pointer is displayed in the X-axis value box. The accuracy of the value depends on the scale of the X-axis. Generally, the X-axis displays the year and the value displayed in the X-axis display box is the closest year value.

Rescaling The Y-Axis

Left-click on the graph to make the Y-axis scale larger (i.e., show a smaller range of values). Right-click on the graph to decrease the scale (i.e., show a larger range of values).

Closing a Graph Window

Left-click on the Done Button [Done] .

Printing a Graph Window

Click on the Print Button 🖶 .

Getting Help for Graph Windows

This feature(❓) is not implemented in this version.

Automatic Graph Updates

When this is selected (default 📈) any open graphs update automatically when the mouse is moved over a controlling icon on the map. There are basically three categories of graphs: "Fishery", "Stock", and "Harvest". The Fishery and Harvest graphs are updated when the mouse pointer is moved over a fishery icon. The Stock and Harvest graphs are updated when the mouse pointer is moved over a stock icon. This is disabled by de-selecting the icon.

2.7 - Dialog Boxes

Dialog boxes open when sub-menu items with ".." at the end of the name are chosen from the main drop-down menus. The exceptions to this are "Print.." and "Mouse Tool" on the File menu. "Print.." opens a box where you are apprised of printing status. "Mouse Tool" opens a dialog box.

Dialog boxes have several features in common. They are exemplified by the Harvest Rate Scalars dialog box shown here. All of its elements are summarized in the table on the next page.
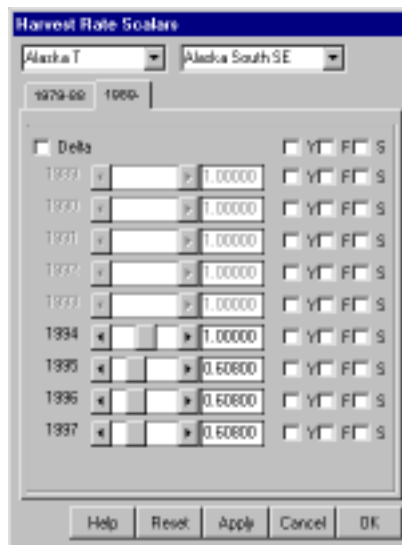
In general, these dialog boxes are used to change parameter values. For example, the Proportion Not Vulnerable (PNV) of Age 2 fish in 1996 for the Alaska Troll Fishery can be specifically altered from the default values read into the model at start-up from the ***.pnv** file (see "Getting Started" on page 2.20). When the dialog boxes are opened they show the default values. The parameter values are altered individually or in groups by one or more of the following methods:

- moving sliders
- clicking on scrollbar arrows
- typing in value boxes
- grouping different parameters so that the change of a single value affects other values absolutely or relatively.

The table that follows shows how these controls work.

Feature	Name	Description (using Harvest Rate Scalars dialog box as an example)
Alaska T ▾	Fishery	Choose a Fishery to which Harvest Rate Scalars will apply. The drop-down menu has the entire list of Fisheries recognized by the model. When a Fishery is highlighted you can use up and down keys to scroll up and down the list. Note: It is possible to select combinations of Fishery and Stock that never interact.
Alaska South SE ▾	Stock	Choose a Stock to which Harvest Rate scalars will apply. The drop-down menu has the entire list of Stocks recognized by the model. When a Stock is highlighted you can use up and down keys to scroll up and down the list. Note: It is possible to select combinations of Fishery and Stock that never interact.
1979-88 1989-	Year groups	Toggle on the tabs to display different year groupings. (Putting them all on display at once could make the dialog boxes very large!)
☐ Delta	Delta	When checked, all linked values change linearly instead of proportionally, adding the difference between the new and old value to all linked values
1992	Dulled Year	The Harvest Rate Scalars for this year are part of the calibration data and can not be adjusted from the dialog box
1994	Bold Year	The Harvest Rate Scalars for this year can be adjusted by using the Slider, Value box, Y box, F box and S box methods described below.
◄ � ►	Slider	Use the slider to adjust the Harvest Rate Scalars (displayed in the Value box) with the mouse pointer. Left-click and hold left and right arrows to adjust the value, or click and drag the central slider to the desired value.
0.60800	Value Box	Displays current value of the Harvest Rate Scalar for that Year for the particular stock shown in the Stock Select area and the fishery shown in the Fishery Select area unless the Y, F, and/or S box is selected on that line. These values persist between uses of the dialog box if Apply or OK is chosen during this run of the model.

Feature	Name	Description (using Harvest Rate Scalars dialog box as an example)
☐ Y	Y box	Check box used to set the Harvest Rate Scalars for a group of years to a common value in the selected Fisher(y/ies) and Stock(s). When selected, all checked years are adjusted as a group to the shared value set the next time any one of them is altered. The Y box at the top of the column selects or de-selects the entire range (all years) of Y boxes. This box can be used in conjunction with other check boxes. The settings of the Y boxes do not persist in-between uses of the dialog box.
☐ F	F box	Check box used to set the Harvest Rate Scalars for a group of Fisheries to a common value for the selected year(s) and the selected Stock(s). It is analogous to the Y box described above.
☐ S	S box	Check box used to set the Harvest Rate Scalars for a group of Stocks to a common value for the selected year(s) and the selected fisheries. It is analogous to the Y box described above.
Help	Help	Opens the Manual in a separate window.
Reset	Reset	Resets the dialog box to the last applied values. Note that this does not reset values to those from the input files used when the program was first launched.
Apply	Apply	Incorporates changes into the next model run.
Cancel	Cancel	Resets and closes the dialog box.
OK	OK	Incorporates changes in the next model run and closes the dialog box.
☐ Forced	Forced box	Only appears in the Catch Ceilings dialog box (Fishery menu). Used to make the modeled catch equal to the catch ceiling even if the unconstrained catch is below the ceiling. In practice, Forced catches are generally used for the calibration period to force the catches to equal the observed catches. Unforced catches are more likely to be used for simulations.

2.8 - Model Operations

Introduction

Once the model has been launched, you can interactively adjust various parameters and run the model as frequently as desired in Scenario mode. This section describes in detail how to interactively adjust model parameters. To alter parameters for several modeling sessions, we advise altering the input files directly and saving these under separate names. The model can then be run with a specific ***.opt** file that identifies the parameter files that you want to use (see "Files of type *.opt" on page 2.55 and "File Structure" on page 2.20). For help on using individual model features see "Dialog Boxes" on page 2.31, "The Toolbar" on page 2.27, and "Drop-Down Menus" on page 2.24.

Fishery Menu

Changing PNVs (Proportion Non-Vulnerable)

The Proportion Non-Vulnerable is the proportion of a cohort that is below the legal size limit. The tacit assumption is that all stocks have the same growth rate so these values vary by year, age and fishery.

1. Choose PNV.. from the Fishery menu.
2. Choose a fishery from the drop-down sub-menu next to the default fishery.
3. Choose a year from the drop-down sub-menu next to the default year.
4. Change and apply values according to the methods described in "Dialog Boxes" on page 2.31.

   Reminder: PNV values during the calibration period (1979-1993) can not be changed.

Changing CNR Mortalities

Chinook Non-retention (CNR) mortalities are incidental mortalities that occur when a fishery is targeting on other salmon species (e.g., coho). These mortalities usually are restricted to the few troll fisheries. This feature is not available in this release. You must alter the ***.cnr** file directly if you want to alter CNR values.

Changing Catch Ceilings

Catch ceilings are the principle tool for managing many fisheries. They represent the numerical upper limit on the number of fish that can be caught during a given year.

1. Choose Catch Ceilings.. from the Fishery menu.
2. Choose a fishery from the fishery list.
3. Left-click the Ceilings button to get a list of sliders for controlling catch ceilings.
4. Change and apply values according to the methods described in "Dialog Boxes" on page 2.31.

   Reminder: Catch Ceilings during the calibration period (1979-1993) can not be changed.

Graphing Abundance Index for a Fishery

The Abundance Index for a given fishery in a given year is a scalar value comparing the catch under the simulated regulations to what catch would have been if the base period harvest rates had been used.

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a fishery on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Fishery Graphs from the Fishery menu.
3. Choose Abundance Index from the Fishery Graphs sub-menu.
4. To view another fishery, repeat steps 1 through 3 above.

Graphing Catches for a Fishery

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a fishery on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Fishery Graphs from the Fishery menu.
3. Choose Catches from the Fishery Graphs sub-menu.
4. Choose Total, Preterminal, or Terminal from the Catches sub-menu.
   ■ "Total" refers to the "Preterminal" plus "Terminal" catches.
5. To view another fishery, repeat steps 1 through 4 above.

Graphing Incidental Mortality for a Fishery

"Incidental Mortality" refers to fish that die as a result of the fishing process, but are not part of the legal catch or harvest. These mortalities include shakers (i.e., chinook that are hooked and brought up to the boat but are released ("shaken") because they are not of legal size) and CNRs (Chinook Non-Retention mortalities are both legal and sub-legal chinook that are hooked and brought up to the boat during coho fisheries at times when all chinook are not legal to land and sell). Shakers and CNRs have increased natural mortality rates due to the handling process.

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a fishery on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Fishery Graphs from the Fishery menu.
3. Choose Total, Sublegal, or Legal from the Incidental Mortality sub-menu.
   ▪ Total refers to the "shakers" plus Chinook Non-Retention mortalities.
4. To view another fishery, repeat steps 1 through 3 above.

Stock Menu

Changing Inter-Dam Loss

Inter-Dam Loss (IDL) is applied to Columbia River stocks that spawn upstream from one or more dams. This is also called pre-spawning mortality.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Inter-Dam Loss.. from the Stock menu.
3. Change and apply values according to the methods described in "Dialog Boxes" on page 2.31.

   Reminder: IDL values during the calibration period (1979-1993) can not be changed.

Changing EV Scalars

The EV (Environmental Variability) Scalars represent brood year survival rates to age one.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose EV Scalars.. from the Stock menu.
3. Change and apply values according to the methods described in "Dialog Boxes" on page 2.31.

   Reminder: EV Scalars during the calibration period (1979-1993) can not be changed.

Changing Stock Enhancements

Hatchery fish production is assumed to stay at a level equal to the average production between 1979-1981. Any levels above or below this level are considered enhancement changes (positive or negative). For each year, you can adjust the number of Age 1 fish that the hatchery produces. Since there may be limitations on the number of spawners that can be used for hatchery production and/or the hatchery efficiency in producing age 1 fish, other sliders are available for adjusting these parameters.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Enhancement.. from the Stock menu.

3. Change and apply values according to the methods described in "Dialog Boxes" on page 2.31.

Changing Maturation Rates

Maturation rates refer to the proportion of a stock that is mature and ready to return to the spawning ground. These are age and stock specific and can vary between years. Because the model does not allow for age six fish, the maturation rate for age five fish should always be 1. The mature portion of a cohort is considered the terminal run.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Maturation Rates.. from the Stock menu.
3. Change and apply values according to the methods described in "Dialog Boxes" on page 2.31.

Graphing Start of Year Abundances

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Stock Graphs from the Stock menu.
3. Choose Abundances from the sub-menu.

Graphing Escapements

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Escapements from the sub-menu.

Graphing CNR Mortalities

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose CNR from the sub-menu.
3. Choose Sublegal or Legal from the sub-menu.

Graphing Legal Catches

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose Catches from the sub-menu.
3. Choose Total, Preterminal or Terminal from the sub-menu.

Graphing True Terminal Run Sizes

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose True Term Run from the sub-menu.

Harvest Menu

Base Period Harvest Rates

The Base Period Harvest Rates are determined during parameter estimation and model calibration. They represent the average harvest rates on each age class of each stock in each fishery during the period 1979-1982. They cannot be changed by the user. This tool is only for viewing these values.

Changing Harvest Rate Scalars

The Harvest Rate Scalars are used to simulate the effects of changes in fishery policies that disproportionately impact different stocks relative to the base period (e.g. changing the timing of the fishing period may impact the stocks differently).

1. Choose Harvest Rate Scalars.. from the Harvest menu.
2. Change and apply values according to the methods described in "Dialog Boxes" on page 2.31.

    Reminder: During simulation runs to compare different harvest rate strategies, HR Scalars during the calibration period (1979-1993) can not be changed.

Graphing Stock/Fishery Specific Mortality

See "Graph Windows" on page 2.28 for details on graph windows.

1. Choose a stock on the Toolbar (See "The Toolbar" on page 2.27).
2. Choose a fishery on the Toolbar (See "The Toolbar" on page 2.27).
3. Choose Mortality Graphs from the Harvest menu.
4. Choose Total or Incidental from the sub-menu.
    - "Incidental" mortalities include shakers and CNR mortalities.
    - "Total" mortalities include legal catches plus incidental mortalities.

Run Menu

Running the model in Scenario mode

The scenario mode runs a single instance of the model. When CRiSP Harvest is first launched it runs with the parameters specified in the ***.opt** file. The map and other GUI tools allow you to interpret the ***.opt** run, make changes to the parameters during the simulation period and make additional runs.

1. Adjust simulation period parameters as desired according to methods described under "Fishery Menu" on page 2.34, "Stock Menu" on page 2.36, and "Harvest Menu" on page 2.38.

2. Choose Scenario from the Run menu.

3. Evaluate results (see "Graph Windows" on page 2.28 and ?? something on model results).

Running the model in Monte Carlo mode

In Monte Carlo mode, results are determined stochastically (i.e., in a random manner) instead of deterministically. When run in deterministic mode (a scenario), model results are sensitive to the EV Scalars set for the simulation period. If one is optimistic about "Environmental Variability" (i.e., predicting good brood year survival rates), stocks have good production. Conversely, if one is pessimistic about future survival rates, stocks have poor production.

Under Monte Carlo mode, the EV Scalars for all stocks are selected in a random manner. Each random run is referred to as a "game." The EV Scalar for any game can be randomly selected using one of two methods: "bootstrapping" from the calibration period EV values in the ***.evo** file or drawing from a log-normal distribution fit to the calibration period EV values. The method is specified by the ***.monte** file identified in the ***.opt** file (see "Files of type *.opt" on page 2.55). The stock escapements for each game are stored and analyzed to provide a measure of the variability one might expect in the future.

1. Choose Monte Carlo from the Run menu.

2. Choose the number of games in the dialog box.

3. Click the Run Monte button.

A status bar in the dialog box shows the current game. Once all games are completed, a graph of escapements for the default stock is displayed. See "Graph Windows" on page 2.28 for details on using the graph windows.

2.9 - Modeling Management Alternatives

Overview

Human impacts on salmon stocks can be grouped into two broad categories—those that affect production and those that affect harvest. Production impacts include a broad range of watershed activities. A few examples are hatcheries and spawning channels that enhance reproductive success, dams that increase mortality of both upstream adult migrants and downstream smolt migrants, fish ladders that help improve upstream survival, bypass systems that help reduce downstream mortalities at dams, and logging practices that reduce available spawning habitat.

Harvest management involves both long- and short-term decisions. Over the long term, managers must decide on a general harvesting strategy. There are three basic types of harvest strategies—fixed catch, fixed harvest rate, and fixed escapement. Fixed catch means setting a quota for a fishery and keeping the same quota for several years. A fixed harvest rate policy takes a fixed percentage of the available run each year. Finally, a fixed escapement policy adjusts catches such that a given number of spawners return to the spawning grounds each year. Each type of long-term strategy usually involves establishing size limits, also. Within each long-term strategy are the annual decisions regarding specific times and areas where fishing can occur in order to meet the specific long-term strategy.

Each management action (e.g., setting catch ceilings, adjusting size limits, changing hatchery production) affects the fisheries and stocks in CRiSP Harvest. Some of these are easier to simulate than others. In practice, it is often most useful to compare alternatives to a "base case" or "status quo" scenario specified by the default ***.opt** file.

In the sections that follow, management actions are discussed in greater detail. Production alternatives include:

- Brood Year Survival Rates (page 2.44)
- Enhancement (page 2.45)
- Inter-Dam Loss (page 2.47).

Fishery alternatives include:

- Catch Ceilings (page 2.48)
- Harvest Rate Strategies (page 2.49)
- Fixed Escapements
- Size Limit Changes (page 2.51)

There are two different methods for modeling management alternatives: the "Interactive Method" and the "Input File Method". The Interactive Method uses the CRiSP Harvest toolbars, dialog boxes and menus for altering the parameters and assumes that you are familiar with these controls. Review the appropriate sections of the manual before following the procedures for this method.

Input File Methods require manipulating the files used by CRiSP Harvest *before* launching the model from the "Run" dialog box. This enables you to specify a particular ***.opt** file (see "File Structure" on page 2.20) which has detailed instructions on which files the model should use for each alternative. For more information on these files consult the appropriate sections of this manual (especially "Files used by CRiSP Harvest" on page 2.54).

Comparison of alternatives is done by creating output files for the different alternatives and/or comparing graphs of different output. For this reason, users who prefer the Interactive methods should be familiar with the file structure used by CRiSP Harvest and in particular be able to (see "Graph Windows" on page 2.28).

As noted in previous sections, many CRiSP Harvest parameters can not be changed while modeling alternative management strategies. These parameters are valid only when used in concert with other parameters from the same calibration run.

The following tables detail some of the limitations to Modeling Management alternatives:

- Table 2.1 summarizes which Fishery Alternatives can be used with a particular fishery.
- Table 2.2 summarizes which Production Alternatives can be used with particular stocks.
- Table 2.3 summarizes the parameters that can not be changed.

Table 2.1 Cross-reference of Fisheries and Fishery Alternatives available in CRiSP Harvest.

	Fishery	Fixed Catch	Fixed HR	Fixed Esc	Size Limits
1	Alaska Troll	x			
2	Northern B.C. Troll	x			x
3	Central B.C. Troll	x			x
4	West Coast Vancouver Island Troll	x			x
5	Washington/Oregon Troll	x			
6	Strait of Georgia Troll	x			x
7	Alaska Net	x			x
8	Northern B.C. Net	x			
9	Central B.C. Net	x			
10	West Coast Vancouver Island Net		x		
11	Juan de Fuca Net		x		
12	North Puget Sound Net		x		
13	South Puget Sound Net		x		
14	Washington Coast Net		x		
15	Columbia River Net		x	x	
16	Johnstone Strait Net		x		
17	Fraser River Net		x		
18	Alaska Sport	x			
19	North/Central B.C. Sport	x			
20	West Coast Vancouver Island Sport	x			
21	Washington Ocean Sport	x			
22	North Puget Sound Sport	x			
23	South Puget Sound Sport	x			
24	Strait of Georgia Sport	x			x
25	Columbia River Sport		x		

Table 2.2 Cross-reference of stocks and available Production Alternatives in CRiSP Harvest (EV = Environmental Variability Scalars; Enh = Enhancement; IDL = Inter-Dam Loss).

	Stock	Production Alternative		
		EV	**Enh**	**IDL**
1	Alaska South SE	x		
2	Northern/Central B.C.	x		
3	Fraser River Early	x		
4	Fraser River Late	x		
5	West Coast Vancouver Island Hatchery	x	x	
6	West Coast Vancouver Island Natural	x		
7	Upper Strait of Georgia	x		
8	Lower Strait of Georgia Natural	x	x	
9	Lower Strait of Georgia Hatchery	x	x	
10	Nooksack River Fall	x	x	
11	Puget Sound Fingerling	x	x	
12	Puget Sound Natural Fingerling	x		
13	Puget Sound Yearling	x	x	
14	Nooksack River Spring	x		
15	Skagit River Wild	x		
16	Stillaguamish River Wild	x		
17	Snohomish River Wild	x		
18	Washington Coastal Hatchery	x	x	
19	Columbia River Upriver Brights	x		x
20	Spring Creek Hatchery	x		x
21	Lower Bonneville Hatchery	x		
22	Fall Cowlitz River Hatchery	x		
23	Lewis River Wild	x		
24	Willamette River	x		
25	Spring Cowlitz Hatchery	x		
26	Columbia River Summers	x		
27	Oregon Coastal	x		
28	Washington Coastal Wild	x		
29	Snake River Wild Fall	x		x
30	Mid Columbia River Brights	x	x	x

Table 2.3 CRiSP Harvest parameters that can not be changed when modeling alternative management strategies.

Fixed Parameters	Years
Environmental Variability (EV) Scalars	1979-1994
Enhancement	1979-1994
IDL (Inter-Dam Losses, or pre-spawning mortality)	1979-1994
Catch Ceilings	1979-1994
Harvest Rate Scalars	1979-1994
PNV (Percent Non-Vulnerable)	1979-1994

Production Alternatives

Brood Year Survival

Brood year survival rates, also known as pre-recruitment survival rates or EV (Environmental Variability) Scalars, compensate for both environmental variation and any bias in the original production parameters. There is a lot of variability in the spawner-recruit relationship and these scalars take that into consideration. Thus, EV Scalars include factors associated with early life history rearing, downstream smolt survival and early ocean survival prior to age one.

Model results are very sensitive to assumptions regarding future survivals. You can evaluate effects of different assumptions regarding projected survival on stock specific rebuilding schedules by specifying different EV values.

The ***.evo** file produced during calibration contains (1) stock specific annual age one survival scalars and (2) the estimated EV values as survival projections for all subsequent years.

When Running in scenario mode, the model uses the appropriate value from the file and applies it during the simulation. When run in Monte Carlo mode there are two ways that the model can choose an EV scalar. It can "Bootstrap" the value from the set of values for that stock or it can draw from a distribution of the EV scalars that are fitted to a log normal distribution. The log normal values are assumed to be independent of each other. The form of this sampling is determined by the ***.monte** file, and the EV values used should be appropriate for the method being chosen.

Two options are available for changing the EV Scalars. Either create separate ***.evo** files for each option or use dialog box controls for modifying the EV Scalars immediately before running the model.

Analysis Procedure

Interactive Method:

1. Change run title in ***.opt** file (Line 1) to document the new conditions being modeled.

2. Change "PREFIX FOR SAVE FILE" in ***.opt** file so output files can be identified.

3. Check that output flags are set on lines 9* so that stock and fishery output is produced.

4. Save ***.opt** file under new file name.

5. Launch Model with new ***.opt** file.

6. Open the EV scalars dialog box from the Stock menu.

7. Edit the EV scalars (see "Dialog Boxes" on page 2.31).

8. Click OK.

9. Run the model.

Input File Method:

1. Change ***.evo** file by using an ASCII text editor.

2. Save ***.evo** under new file name.

3. Change ***.evo** file name in the ***.opt** file (Line 9a).

4. Change run title in ***.opt** file (Line 1).

5. Change "PREFIX FOR SAVE FILE" in ***.opt** file (can include a path).

6. Check that output flags are set on lines 9* so that stock and fishery output is produced.

7. Save ***.opt** file under new file name.

8. Launch Model with new ***.opt** file.

Interpretation of Results

The impacts of changes in EV Scalars can be observed by viewing the escapements of affected stocks. Remember that there is a time lag between the application of the scalar and the resultant escapement.

Look for effects of the change in catch in non-ceilinged fisheries with substantial harvest of the stock or in stock escapement statistics.

Enhancement

Production from enhancement activities can affect the performance of stocks and fisheries. The PSC chinook model incorporates enhancement through two primary means: (a) by including hatchery stocks in the model; and (b) by providing for supplementation of natural production. The Model assumes

that enhancement is maintained at base period average levels (1979-1981) unless instructed otherwise. It is the *changes* in enhancement that are evaluated.

The ***.enh** file has information on changes in enhancement schedules for hatchery and natural supplementation programs. Modifications of the ***.enh** values can be made either: (1) to incorporate actual changes in the enhancement schedule; (2) to assess possible changes in enhancement. All enhancement changes are relative to average levels during the 1979-1981 base period.

Analysis Procedure

Interactive Method:

1. Change run title in ***.opt** file (Line 1).
2. Change "PREFIX FOR SAVE FILE" in ***.opt** file (Line 9a).
3. Check other file names in ***.opt** file.
4. Save ***.opt** file under new file name.
5. Run Model with new ***.opt** file.
6. Open the Enhancements dialog box from the Stock menu.
7. Edit Enhancement values.
8. Click OK.
9. Run model.

Input File Method:

1. Change the ***.enh** file using an ASCII text editor.
2. Save modified ***.enh** file under new name.
3. Change run title in ***.opt** file (Line 1).
4. Change "PREFIX FOR SAVE FILE" in ***.opt** file (Line 9a).
5. Ensure ***.opt** file has the correct "NUMBER OF STOCKS WITH ENHANCEMENT" (Line 21).
6. Specify in ***.opt** file if density dependence is on or off (Line 21a). Enter 1 to indicate that production is considered to be density dependent for natural stocks that are supplemented by hatchery releases. Under most circumstances, this line will read 1.
7. Change ***.enh** file name in ***.opt** file (Line 21b).
8. Check other file names in ***.opt** file.
9. Save ***.opt** file under new file name.
10. Run model with new ***.opt** file.

Interpretation of Results

The most direct way of identifying changes is to look at the escapement of the enhanced stocks in graphs or output files. You can also look to see if the enhancement affected the catch and escapement of other stocks.

Inter-Dam Loss

Effects of post-fishery, pre-spawning mortality can be examined through use of ***.idl** files. The ***.idl** file contains estimates of pre-spawning survival that occurs after fisheries. Currently, this file only includes estimates of inter-dam loss for Columbia River stocks. Since most inter-dam loss occurs after all fisheries, inter-dam loss is essentially treated as escapement when calculating ocean and terminal area harvest rates. Estimated IDL values are used through the present year, then an average of all estimated values is used for future years.

Changes in estimates of inter-dam loss rates can be assessed by modifying this file. It should be noted, however, that the numbers in the ***.idl** files are actually estimates of total adult *survival* past all Columbia River dams.

Analysis Procedure

Interactive Method:
1. Change run title in ***.opt** file (Line 1).
2. Change "PREFIX FOR SAVE FILE' in ***.opt** file (Line 9a).
3. Check other file names in ***.opt** file.
4. Save ***.opt** file under new file name.
5. Launch Model with new ***.opt** file.
6. Open the Inter Dam Loss dialog box from the Stock menu.
7. Edit IDL values.
8. Click OK.
9. Run Model.

Input File Method:
1. Change ***.idl** file using an ASCII text editor.
2. Save modified ***.idl** file under new name.
3. Change ***.idl** file name in the ***.opt** file (Line 8a).
4. Change run title in ***.opt** file (Line 1).
5. Change "PREFIX FOR SAVE FILE' in ***.opt** file (Line 9a).
6. Check other file names in ***.opt** file.
7. Save ***.opt** file under new file name.

8. Launch Model with new **`*.opt`** file.

Interpretation of Results

Effects of changing inter-dam loss values are most evident in escapement statistics. In addition, changes will also be reflected in harvest rates of Columbia River stocks in the ***`prefixohr.prn`*** and ***`prefixthr.prn`*** output if these have been selected. Ocean and terminal harvest rates should decrease as inter-dam loss increases. Since the file actually contains estimates of inter-dam survival, this means that as the numbers in the file increase, harvest rates should also increase.

Fisheries Alternatives

Catch Ceilings

Catch ceilings are the primary means used by the PSC to reduce stock exploitation rates. The **`*.cei`** file is used: (1) to specify fisheries with ceilings; (2) to set ceiling levels (catch levels); and (3) to allow the user to force Model catches to equal the ceiling. Note: the catches given in the **`*.cei`** file and the model catches will not be equal. A scalar is applied to the simulation period modeled catches that is determined from the ratio of base period modeled catches and the preterminal and terminal catches. In a word, CRiSP Harvest does not recognize all available stocks that the given fishery harvests and accounts for this difference with this method.

Analysis Procedure

Interactive Method:
1. Change run title in **`*.opt`** file (Line 1).
2. Change "PREFIX FOR SAVE FILE" in **`*.opt`** file (can include a path).
3. If desired, check that output flags are set on lines 9* so that stock and fishery output is produced.
4. Save **`*.opt`** file under new file name.
5. Launch Model with new **`*.opt`** file.
6. Open Catch Ceilings dialog box from the Fishery menu.
7. Edit the Catch Ceilings (see "Dialog Boxes" on page 2.31).
8. Click OK.
9. Run the model.

Input File Method:
1. Make appropriate changes in the **`*.cei`** file using an ASCII text editor.

---

2. Save modified ***.cei** file under new name.

3. Change ***.cei** file name in the ***.opt** file (Line 26a).

4. Change run title in ***.opt** file (Line 1).

5. Change "PREFIX FOR SAVE FILE" in ***.opt** file (can include a path).

6. If desired, check that output flags are set on lines 9* so that stock and fishery output is produced.

7. Save ***.opt** file under new file name.

8. Launch Model with new ***.opt** file.

Interpretation of Results

Effects can be observed by viewing the escapements of affected stocks. Remember that there is a time lag between the application of the scalar and the resultant escapement.

Look for effects of the change in catch in non-ceilinged fisheries with substantial harvest of the stock or in stock escapement statistics. The impacts of changes in Catch Ceilings can be seen by comparing output files and/or graphs. First, check the effect on catch in the fishery. Next, check for effects on escapement or terminal run size of stocks caught in the fishery. CNR mortality could also change, depending on the method specified. To compare harvest rates to the base period, check the RT values for the fishery in the **prefixrt.prn** file.

Harvest Rate Strategies

For each stock, age, and fishery, Base Period Harvest Rates are the estimated average rate for the years 1979-1982. All other Harvest Rates in the model are scaled up or down from these base period rates by using Harvest Rate (HR) Scalars. HR Scalars are stock and fishery dependent and can be used to reflect changes in fishing patterns (e.g., time/area closures) designed to alter harvest rates on individual stocks. For example, delaying harvest in a fishery may reduce the harvest rate on early migrating stocks while increasing the harvest rate on late migrating stocks.

The HR Scalars can be used to examine a general set of questions regarding harvest rate strategies, including:

- How are harvest rates on particular stocks affected by harvest rate changes in terminal fisheries?
- How would specific harvest rate strategies affect rebuilding?
- How do shaping options differently impact particular stocks?

Such questions can be evaluated through the use of ***.fp** files (the "fp" suffix stands for "Fishery Policy"). HR Scalars are stock, fishery, and year

specific scalars that modify fishery exploitation/harvest rates relative to the base period; for example, an FP value of 0.75 would reduce base period exploitation/ harvest rates for a stock by 25%.

Currently, HR Scalars other than 1.0 are used to reflect: (1) changes in terminal fishing patterns from the base period for particular stocks; (2) the 25% reduction in harvest rates by Canadian net fisheries expected under Canadian management; (3) fishery indices estimated through exploitation rate analysis; and (4) differential impacts associated with fishery shaping options.

Analysis Procedure

Interactive Method:

1. Change run title in ***.opt** file (Line 1).
2. Change "PREFIX FOR SAVE FILE" in ***.opt** file (can include a path).
3. If desired, check that output flags are set on lines 9* so that stock and fishery output is produced.
4. Save ***.opt** file under new file name.
5. Launch Model with new ***.opt** file.
6. Open the Harvest Rate Scalars dialog box from the Harvest menu.
7. Change Harvest Rate Scalar values.
8. Click OK.
9. Run the model.

Input File Method:

1. Make appropriate changes in the ***.fp** file using an ASCII text editor.
2. Save modified ***.fp** file under new name.
3. Change ***.fp** file name in the ***.opt** file (Line 26a).
4. Change run title in ***.opt** file (Line 1).
5. Change "PREFIX FOR SAVE FILE" in ***.opt** file (can include a path).
6. If desired, check that output flags are set on lines 9* so that stock and fishery output is produced.
7. Save ***.opt** file under new file name.
8. Launch Model with new ***.opt** file.

Interpretation of Results

To see the effects of a harvest rate change, look for alterations in the catch and/or escapement abundances.

Fixed Escapements

Unlike pre-terminal fisheries, terminal fisheries target only stocks in a particular river. The most common strategy for in-river management is fixed escapement. An escapement goal is established for one or more stocks and catches are adjusted to meet the escapement goal.

The ***.riv** file specified on line 31 of the ***.opt** file details the exact method of applying in-river harvest strategies and details of this method. There are three different management types that can be used for fixed escapement: a weak stock strategy, a combined stock strategy and a fixed harvest rate strategy. Examples of each of these file types are shown in "Files of type *.riv" on page 2.77.

Analysis Procedure

Interactive Method: Not available

Input File Method:
1. Make appropriate changes in the ***.riv** file using an ASCII text editor.
2. Save modified ***.riv** file under new name.
3. Change ***.riv** file name in the ***.opt** file (Line 26a).
4. Change run title in ***.opt** file (Line 1).
5. Change "PREFIX FOR SAVE FILE" in ***.opt** file (can include a path).
6. If desired, check that output flags are set on lines 9* so that stock and fishery output is produced.
7. Save ***.opt** file under new file name.
8. Launch Model with new ***.opt** file.

Interpretation of Result

Compare a fixed escapement strategy with a base case run. Note that only Columbia River stocks can be affected by this alternative and that it affects only the Columbia River Net fishery.

Size Limit Changes (PNV)

Management agencies have altered minimum size limits when implementing PSC catch ceiling regimes. Changes in size limits affect incidental mortality losses since the proportion of the population that can be legally retained changes in response. Impacts of size limit changes can be evaluated through the use of ***.pnv** files.

The ***.bse** file specified in line 4 of the ***.opt** file contains data that defines the proportion of a population of a given age which is not vulnerable to

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each fishery. These proportion non-vulnerable (PNV) specifications remain fixed unless changed by the user. "PNV" is an abbreviation for "proportion non-vulnerable," a phrase that is slightly misleading since this file actually provides data on the proportion of each age class in a fishery that is recruited to the gear, but is below the legal size limit.

*.pnv files were originally created with the assistance of a LOTUS 123 spreadsheet file **pvcalc3.wk1**. The size distribution data in **pvcalc3.wk1** were compiled in 1986, based upon CWT recovery data that provided a means for positive aging and size at recovery. Where available, data for troll and seine recoveries were combined because troll fisheries tend to crop a substantial portion of larger fish from the population while recoveries by seine gear, believed to be the least size-selective gear type, provide size distribution of fish in the remaining population.

When a fishery size limit is input into **pvcalc3.wk1**, the total proportion of the population below the size limit is initially estimated using area-specific, length distribution data. The proportion initially estimated by the program includes a portion that is not yet recruited to the gear. Encounters of age 2 fish are adjusted so that the estimate of total encounters is consistent with estimates reported by the agencies. The final result is an estimate of the proportion of each age class in a fishery that is vulnerable to the gear but is below the legal size limit. This adjusted estimate is incorporated into the ***.pnv** file. The values in the ***.pnv** file are actual proportions, not changes relative to the base period. The ***.pnv** file is infrequently revised (usually only once a year).

A separate ***.pnv** file is created for each fishery in which one or more changes in the minimum size limit have occurred since the base period. The proportion in a ***.pnv** file replace those proportions in the ***.bse** file for each fishery specified by a ***.pnv** file.

Analysis Procedure

Interactive Method:

1. Change run title in ***.opt** file (Line 1).
2. Change "PREFIX FOR SAVE FILE" in ***.opt** file (can include a path).
3. Save ***.opt** file under new file name.
4. Launch Model with new ***.opt** file.
5. Open the PNV dialog box from the Fishery menu.
6. Edit PNV values.
7. Click OK.
8. Run model.

Input File Method:

1. Change appropriate column(s) in the **`*.pnv`** file using an ASCII text editor.

2. Save modified **`*.pnv`** file under new name.

3. Change corresponding **`*.pnv`** file name in the **`*.opt`** file (Line 23a-f).

4. If this is a new fishery, change "number of **`*.pnv`** changes" in **`*.opt`** file (Line 23).

5. Check that this number agrees with the number of **`*.pnv`** file names listed in the **`*.opt`** file

6. Change run title in **`*.opt`** file (Line 1).

7. Change "PREFIX FOR SAVE FILE" in **`*.opt`** file (can include a path).

8. If desired, check that output flags are set on lines 9* so that stock and fishery output is produced.

9. Save **`*.opt`** file under new file name.

10. Launch Model with new **`*.opt`** file.

Interpretation of Results

Examine incidental and total mortality output and graphs. Increases or decreases in incidental mortalities resulting from the size limit change can be seen directly in the incidental mortality files (***`prefix`tim.prn***, ***`prefix`sim.prn***, and ***`prefix`lim.prn***). Changes in non-retention fisheries will have other impacts throughout the Model output, for example, in escapement statistics.

Appendix: 2.1 - Files used by CRiSP Harvest

CRiSP Harvest uses the following files:

- **crisph.exe** - CRiSP Harvest executable code.
- **map.dat** - Map data file (coastline, rivers, icon locations).
- ***.opt** - Option file containing instructions for running the model.
- ***.bse** - Base data file (includes Spawner/Recruit Relationships).
- ***.stk** - Stock data file listing initial cohort sizes, maturation rates, adult equivalence factors, and stock/age/fishery specific harvest rates.
- ***.msc** - Maturation schedule file listing stocks that have variable maturation rates.
- ***.mat** - Maturation data file for stocks listed in ***.msc.**
- ***.evo** - EV (Environmental Variability) scalar file for calibrated and projected brood year survival rates.
- ***.idl** - Inter-Dam Loss file for adjusting pre-spawning survival rates.
- ***.enh** - Enhancement file to simulate changes in enhancement activities.
- ***.cnr** - Chinook non-retention file to simulate mortalities in chinook non-retention fisheries.
- ***.pnv** - Percent non-vulnerable files to simulate size limit changes (one file for each fishery with size limit changes).
- ***.fp** - Fishery policy file with data for adjusting stock/fishery/year specific harvest rates.
- ***.cei** - Catch ceiling file to simulate changes in catch ceiling management.
- ***.monte** - Monte Carlo control file.
- ***.config** - Monte Carlo output configuration file.
- ***.riv** - River management parameters.
- ***.dlg** - A Print information and configuration file.
- ***.prn** - An output file that can be printed.
- ***.zhp** - help file.
- ***.isu, *.dll** - other files used to run the model in Windows.

Files need not be in the same directory. When doing analyses that require many runs of the model with incremental changes in specific parameters, it is convenient to store groups of files in separate directories.

If alternative directories are used, the ***.opt** file must contain path information for all the input and output files. The following sections describe the file structure in more detail.

File Structure Details

Files of type `*.opt`

The `*.opt` file contains the instructions for running the PSC Model. The `*.opt` file specifies the options employed, the input file names (and their paths if necessary), the structure of the Model run, and the output to be produced. Each line of the `*.opt` file contains an instruction followed by a comma and accompanying text description. Please note that inputs are not case sensitive, e.g., Y and y are considered identical. Input routines will automatically extract the data appearing before the first comma in each line; therefore, there are no limitations on the types of characters allowed in description fields for each line. For instructions requiring a yes or no answer, the first character of the first word is automatically examined, so you can use a large variety of terms if desired (e.g., n, N, nope, nada, not on your life, etc. are all interpreted as N).

The `*.opt` file is quite complex but is the backbone of data structure for the model. The actual number of lines may vary from file to file depending on the exact configuration. A line-by-line description of an example file is given in Fig. 2.1. The file is backwards compatible with the PSC Model `*.opt` file.

```
1      Example simulation run using the 9525 calibration.
2      1979 ,            START YEAR FOR MODEL RUN
3      2017 ,            NUMBER OF YEARS - 1 OR the final year
4      input/clb9401.bse,  BASE DATA FILE NAME
5      input/clb9401.stk,  STOCK DATA FILE
6      N    ,            A CALIBRATION RUN (Y OR N)
6a     input/mat94.msc,  Fixed maturation schedule
7      30   ,            NUMBER OF STOCKS WITH EXISTING EV SCALARS
7a     input/9525.evo,   Name of EV Scalar file
8      Y    ,            USE IDL FILE
8a     input/clb9501.idl,  File name for IDL
9      Y    ,            SAVE STATISTICS IN DISK FILES
9a     proto,            Prefix for save files (a good way to distinguish
                         runs)
9b     1    ,            Catch statistics (1=YES)
9c     1    ,            Terminal run stats (1=YES)
9d     1    ,            Escapement statistics (1=YES)
9e     0    ,            Ocn expl rate stats (0=No; 1=Total Mortality Method;
                         2=Cohort Method)
9f     0    ,            Total exploitation rate stats (0=No; 1=Total
                         Mortality Method; 2=Cohort Method)
9g     0    ,            Mortalities by stock & fishery (1=Yes)
9h     0    ,            Incidental mortality stats (1=Yes)
9i     1    ,            ABUNDANCE INDICES (# fisheries; followed by fishery
                         #'s)
9i(1)  1    ,            Southeast Alaska troll
10     header,           REPORT GENERATION INSTRUCTIONS
11     N    ,            Stock composition (Y/N)
12     Y    ,            RT (Y/N)
13     N    ,            Catch (Y/N)
14     0    ,            Stock/Fishery (0=N; 1=Total; 2=Catch; 3=TIM)
15     n    ,            Incidental mortality loss (Y/N)
16     N    ,            Terminal catch (Y/N)
17     N    ,            Escapement (Y/N)
18     n    ,            Exploitation rate (N=No; C=Cohort Method; T=Total
                         Mortality Method)
19     0    ,            Compare statistics to base year (1=YES)
20     N    ,            Document model setup (Y/N)
21     8    ,            NUMBER OF STOCKS WITH ENHANCEMENT CHANGES
21a    1    ,            Density Dependence (1=On)
21b    input/clb9501.enh,  File namedest Coast Vancouver Island
23e    input/ntrclb.pnv,  PNV file name Northern BC Troll
23f    input/gssclb.pnv,  PNV file name Georgia Strait Sport
24     clb9501.fp,       STOCK SPECIFIC FP FILE NAME
25     3    ,            MINIMUM AGE FOR TERMINAL RUN STATS (3=Adults;
                         2=Jacks)
26     Y    ,            CEILING STRATEGIES
26a    input/clb9501.cei,  File name for ceiling strategy
27     1995 ,            FIRST SIMULATION YEAR
28     Y    ,            MONTE CARLO CONFIGURATION SPECIFIED
28a    input/9525.monte,  Monte Carlo configuration file
29     N    ,            SAVE STATISTICS FOR SLCMc
30     N    ,            IN-RIVER MANAGEMENT STRATEGIES
```

Fig. 2.1 Sample `*.opt` file. The line numbers do NOT appear in the actual file.

The line specifications for the ***.opt** file are given below. Unless otherwise noted, CRiSP Harvest requires the same formats and supports the same output options as the original PSC Chinook Model on which it is based.

Line 1:   Run Title (required). A run title provides a means to uniquely identify Model runs. The title can be up to 256 characters. There is no limitation on the types of characters that can be used.

Line 2:   Start Year (required). The start year must match the start year used for calibration, usually 1979.

Line 3:   Number of Years for Simulation (required). You can enter either: (a) the number of years (equal to the total number of years minus one since the model considers the first year to be zero; or (b) the last year for the simulation.

Line 4:   ***.bse** File Name (required). The ***.bse** file contains basic information regarding the numbers and names of stocks and fisheries. The same ***.bse** file is normally used for all simulations once a model is calibrated. You enter only the name of this file. The file is prepared automatically when the model is calibrated and there is no further need to modify it.

Line 5:   ***.stk** File Name (required). The ***.stk** file contains data for individual stocks. The same ***.stk** files is normally used for all simulations once a model is calibrated. Therefore, you enter only the name of this file. The file is prepared automatically when the model is calibrated and there is no need to modify it.

Line 6:   Calibration Run (required). This line specifies whether or not the instructions are for a calibration run or a simulation run. Most end-user runs are simulation runs not calibration runs. Enter N for simulation runs and include line 6a.

Line 6a: ***.msc** file name. This file must be specified for simulation runs. Results of annual exploitation rate analyses indicate that maturation schedules can vary substantially from year to year. This information can be incorporated into the Model through the use of an ***.msc** file. The ***.msc** file identifies stocks with annual estimates of year-specific maturation schedules and provides the name of the file that actually contains the maturation data (***.mat**). The ***.mat**, ***.bse**, and ***.stk** files must correspond to a particular Model calibration; you must insure that the same maturation schedules are used for both calibration and model runs so that results will be compatible. You should enter "NONE" if the model was calibrated with no annual variation in maturation schedules.

Line 7:   Number of Stocks With Existing EV Scalars (required). EV scalars are stock and year-specific survival factors of age 1 fish. For simulation runs, enter the number of stocks. All Model stocks should have EV scalars, so this number should be equal to the total number

of Model stocks (currently = 30). If this entry > 0 then include the following line in the ***.opt** file.

Line 7a: ***.evo** File Name. This file must be specified if Line 7 > 0. This file is produced during calibration. The ***.evo** file contains estimates of stock and brood specific productivity scalars up through the last year of available data (in 1995, up through the 1992 brood year), then uses estimates for all subsequent years. You can modify the EV's for years following the last estimated year using procedures described later. It is not necessary for the number of years of productivity scalars to be equal to the number of years of the simulation run as specified in the ***.opt** file (extra years of data at either end of the years in the simulation will be discarded).

Line 8: Use ***.idl** File (required). Enter Y or N as the model instruction for this line. This line should always read Y if Columbia River stocks are included.

Line 8a: ***.idl** File Name. If Y is entered on Line 8, enter the name of the ***.idl** file to use (see section 2.2.7 for format). If it reads N, this line should not be included in the ***.opt** file.

Line 9: Save Statistics (required). Enter Y or N as the model instruction for this line to control the generation of statistics in disk files. Disk files are useful for producing graphs or for computing differences in escapement or terminal run between model runs. If Line 9 reads Y, include the following lines in the ***.opt** file:

Line 9a: Prefix. Enter the prefix to be used to identify the disk files to be saved. The PSC Model will utilize up to 5 characters as the file identifier for each type of file specified in lines 9b through 9h. For example, if the prefix RUN92 is specified, then the ***.prn** output files will be named RUN92???.prn. (The default prefix is "PROTO")

Line 9b: Catch Statistics. Enter a 1 to save annual catch statistics for all fisheries on disk in file ***prefix*cat.prn**; enter 0 to skip generation of this disk file.

Line 9c: True Terminal Run Statistics. Enter a 1 to save true terminal run size annual statistics (i.e., terminal run size minus ocean net catches of age 4 and above) for all stocks on disk in the file ***prefix*trm.prn**; enter 0 to skip generation of this disk file.

Line 9d: Escapement Statistics. Enter a 1 to save annual escapement statistics for each stock on disk (saved in file ***prefix*esc.prn**); enter 0 to skip generation of this disk file. Statistics in this file will contain the size of adult escapements. [NOTE: When CRiSP Harvest is run in Monte Carlo mode, the median escapements are printed in this file.]

Line 9e: Ocean Exploitation Rate Statistics. This variable controls generation of annual adult equivalent exploitation rates by preterminal fisheries. Enter a 1 to save ocean exploitation rate statistics computed as a

proportion of catch plus escapement; enter a 2 to save ocean exploitation rates computed as a proportion of the total catch plus escapement plus incidental mortality loss; enter 0 to skip generation of this disk file. Statistics are generated for each stock and simulation year and saved in **prefixohr.prn**.

Line 9f: Total Exploitation Rate Statistics. This variable controls generation of annual adult equivalent exploitation rates by all fisheries. Enter a 1 to save total exploitation rate statistics computed as a proportion of catch plus escapement; enter a 2 to save total exploitation rates computed as a proportion of the total catch plus escapement plus incidental mortality loss; enter 0 to skip generation of this disk file. Statistics are generated for each stock and simulation year and saved in **prefixthr.prn**.

Line 9g: Mortalities By Stock and Fishery. This variable controls generation of annual stock-specific mortalities by fishery. Statistics are generated for each stock and simulation year and saved in a set of files named **prefix???.prn**, where ??? represents the stock abbreviation (in capital letters). Permitted values for this variables are:

0 = Do not generate stock/fishery data files

1 = Total mortality

2 = Catch

3 = Incidental mortality

11 = Total mortality in adult equivalents

12 = Catch in adult equivalents

13 = Incidental mortality in adult equivalents

You can generate statistics for a specific list of stocks by listing the desired stock abbreviations after the code using blank spaces as delimiters in the list. For example:

```
1 STL FRL (...) , (... comments)
```

For a list of stocks and their abbreviations see "Stock Abbreviations" on page 2.85.

Line 9h: Incidental Mortalities By Fishery. This variable controls generation of annual incidental mortality statistics by fishery. Enter a 1 to save incidental mortality statistics; enter 0 to skip generation of this disk file. Three files are generated containing incidental mortality statistics for each fishery and simulation year: (a) **prefixtim.prn** contains total incidental mortality statistics; (b) **prefixlim.prn** contains incidental mortality statistics for legal-sized fish; and (c) **prefixsim.prn** contains incidental mortality statistics for sub-legal sized fish.

Line 9i: Abundance Indices (required). Enter the number of fisheries for which abundance indices are to be generated. The Model will

compute an abundance index that represents the expected catch (given size limit regulations, cohort sizes of individual stocks and ages, and 1979-1982 base period average harvest rates). Total abundance indices for each fishery will be contained in disk file **`prefixabd.prn`**. Abundance by stock for each fishery requested will be in the file **`prefixcoh.prn`**. [**PSC Chinook Model only allowed 6 fisheries maximum per model run**]

If Line 9i > 0: Enter one line for each fishery for which an abundance index is to be computed. Each line consists of a fishery index number, followed by a comma and text description.

Line 10: Header (required). This line is included in the **`*.opt`** files just to increase readability by indicating the start of instructions for specifying formatted reports. All selected report types are combined into a single formatted report.

Line 11: Stock Composition Report (required). Use "Y" or "N" to instruct the model whether or not to generate stock composition reports. The disk file **`prefixPRP.prn`** will contain the stock composition report. [**NOTE: CRiSP Harvest does not support this option. Always enter "N" for CRiSP Harvest runs.**]

If Line 11 indicates "Y", then include the following lines in the **`*.opt`** file.

Line 11a:Number of fisheries for which stock composition estimates are to be generated (up to a maximum of 6).

Line 11b:Enter one line for each fishery for which stock composition estimates are to be computed. Each line consists of a fishery index number, followed by a comma and text description.

Line 12: RT factors (required). Enter "Y" or "N" to instruct the model whether or not to generate RT scalar reports. RT factors are computed for each fishery that is simulated to operate under a catch ceiling. RTs represent scalar values that are applied to base period fishery exploitation and harvest rates to generate catch ceilings (target catches) for all fisheries. The RT is calculated as the ratio (RT is an abbreviation for "ratio") of the catch ceiling to the catch you would obtain given base period harvest rates and specified FP factors (Line 25). If FPs are unchanged, then an RT value greater than 1 indicates a harvest rate that is above based period levels, while an RT value less than 1 indicates a harvest rate that is below base period levels.

Line 13: Catch (required). Enter "Y" or "N" to instruct the model whether or not to generate reports on annual catches by fishery. [**NOTE: CRiSP Harvest does not support this option. Always enter "N" for CRiSP Harvest runs.**]

Line 14: Stock/Fishery Reports (required). This variable controls generation of reports on the distribution of stock-specific mortalities. Permitted values for this variable are:

0 = Do not generate stock/fishery reports

1 = Total mortality

2 = Catch

3 = Incidental mortality

11 = Total mortality in adult equivalents

12 = Catch in adult equivalents

13 = Incidental mortality in adult equivalents

Reminder: If the variable in line 9g is not zero, it will override the value specified in this line to assure consistency in disk file and report data and to conserve memory.

At the end of the simulation run, if you specify an output device for the report, prompts will appear to allow selection of stocks for which these reports are to be generated. If you do not specify an output device (i.e., use the model default), these reports will not be generated. [**NOTE: CRiSP Harvest does not support this option. Always enter 0 for CRiSP Harvest runs.**]

Line 15:   Incidental Mortality Reports (required). Enter "Y" to instruct the model to generate reports on incidental mortality loss. Reports on total, legal, and sublegal mortalities will be generated if yes is specified. Enter "N" to skip generation of these reports. [**NOTE: CRiSP Harvest does not support this option. Always enter "N" for CRiSP Harvest runs.**]

Line 16:   Terminal Catch Report (required). Enter "Y" to instruct the model to generate reports on catches by terminal fisheries. Enter "N" to skip generation of this report. [**NOTE: CRiSP Harvest does not support this option. Always enter "N" for CRiSP Harvest runs.**]

Line 17:   Escapement Report (required). Enter "Y" to instruct the model to generate reports on adult spawning escapements by stock. Enter "N" to skip generation of this report. [**NOTE: CRiSP Harvest does not support this option. Always enter "N" for CRiSP Harvest runs.**]

Line 18:   Exploitation Rate Reports (required). Enter C(ohort) to select generation of adult equivalent exploitation rate reports based on catch plus escapement; enter T(otal) to select generation of adult equivalent exploitation rate statistics based on catch plus escapement plus incidental mortality; enter "N" to skip generation of these reports. If Cohort or Total is selected, reports on ocean and total exploitation rates will be generated by year and stock. [**NOTE: CRiSP Harvest does not support this option. Always enter "N" for CRiSP Harvest runs.**]

Line 19:   Compare to Base Year (required). This allows you to compare statistics to a single base year. If the line reads "Y", then a line must be added below to specify which year to use for the comparison. This option is seldom used; generally, you should specify "N". [**NOTE:**

CRiSP Harvest does not support this option. Always enter N for CRiSP Harvest runs.]

Line 19a: If line 19 indicates "Y", then include the year to use as the base, followed by a comma and a descriptor.

Line 20: Model Setup (required). This line should always read "Y". This will ensure that the output report includes a section that specifies all of the files and setup parameters for the Model run. [**NOTE: CRiSP Harvest does not support this option. Always enter N for CRiSP Harvest runs.]**

Line 21: Number of Enhanced Stocks (required). This line specifies the number of stocks with enhancement. If >0, then include the following lines:

Line 21a: Density Dependence. Enter 1 to indicate that production is considered to be density dependent for natural stocks that are supplemented by hatchery releases. Under most circumstances, this line will read 1.

Line 21b: .ENH File Name. Enter the name of the **`*.enh`** file containing specifications for enhancement.

Line 22: Number of CNR Fisheries (required). Enter the number of fisheries that have chinook non retention (CNR) regulations to be evaluated. If the number of CNR fisheries is > 0, then include the following line in the **`*.opt`** file:

Line 22a: .CNR File Name. Enter the name of the **`*.cnr`** file containing specifications for CNR fisheries.

Line 23: Number of Fisheries With Size Limit Changes (required). Enter the number of fisheries that have size limit changes. If this number > 0, then include the following:

Line 23a: enter one line for each fishery which has size limit changes.

Line 24: Fishery Policy File Name. Enter the name of the **`*.fp`** (fishery policy) file name containing stock, year, and fishery scalars that are to be applied to base period harvest rates. The **`*.fp`** file is a random access file created with the program **`creatfp3.bas`**. These scalars are used to model harvest rate management strategies and shaping options that disproportionately impact different stocks.

Line 25: Minimum Age for Terminal Run Stats. This line specifies the minimum ocean age of fish to be included in terminal run statistics. This line usually reads 3 (adults) as opposed to 2 (jacks).

Line 26: Ceiling Strategies. Enter "Y" or "N" to indicate whether or not catch ceilings are to be evaluated. If "Y", then add the following line to the **`*.opt`** file:

Line 26a: File Name for Ceiling Strategy. Enter the name of the file that contains the specifications for catch ceilings. Section 2.2.2 describes the format of the **`*.cei`** file.

Note: The following are options for running CRiSP Harvest. The PSC Chinook Model does not support the options described below. Leave the following lines blank when running the PSC Chinook (QuickBasic) model.

Line 27: First simulation year (FirstSimYr). This year is used to deactivate sliders during the calibration period. EV Scalars are deactivated for 1979 through FirstSimYr -3; harvest rate, PNV, and catch ceiling sliders are deactivated for 1979 through FirstSimYr - 1.

Line 28: Monte Carlo configuration specifications. Enter "Y" or "N" to indicate whether or not Monte Carlo runs are to be conducted. If "Y", then add the following line to the **`*.opt`** file:

Line 28a: File Name for the **`*.monte`** file. Enter the name of the file that contains the specifications for the Monte Carlo setup.

Line 29: SLCMc Statistics. Enter "Y" or "N" to indicate whether or not SLCMc statistics are to be saved. These statistics track catches of individual cohorts for selected stocks to simulate CWT recovery data. These data can then be used to estimate parameters required by the SLCMc model. See Section 2.6 for more details. [**NOTE: CRiSP Harvest does not support this option. Always enter N for CRiSP Harvest runs.**] If "Y", then add the following line to the **`*.opt`** file:

Line 29a: File Name for SLCMc statistics. Enter the name of the file that contains the specifications for SLCMc output.

Line 30: In-River Management. Enter "Y" or "N" to indicate whether or not in-river management strategies are to be included. These strategies include fixed escapement goals using strong, weak, or combined stock management and fixed combined harvest rate goals. If "Y", then add the following line to the **`*.opt`** file:

Line 30a: File Name for **`*.riv`** file. Enter the name of the file that contains the specifications for in-river management.

Files of type **`*.bse`**

The **`*.bse`** file (Fig. 2.2.) contains basic information regarding the numbers and names of stocks and fisheries and essential parameters from the calibration. The same **`*.bse`** file is normally used for all simulations once a model is calibrated. You enter only the name of this file. The file is prepared

automatically when the model is calibrated and there should be no further need to modify it.

```
30                                              Number of stocks
 5                                              Maximum ocean age
 25                                             Number of fisheries
 1979                                           Initial year (fixed at 1979)
 4                                              Age when net catches are assumed mature
Alaska
***
                                                Fishery Names

Col R S
0.59680 0.69110 0.03260 0.00860                 Proportion non-vulnerable
***                                                 Rows are fisheries
                                                    Columns are ages (2,3,4,5)
0.59680 0.69110 0.03260 0.00860
0.5 0.4 0.3 0.2 0.1                             Natural mortality by age (1,2,3,4,5)
0.3 0.9 0.3                                     Incidental mortality rates (troll, net, sport)
0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0   1 denotes ocean net fishery
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
***                                             1 denotes terminal fishery
                                                    rows are stocks
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 1
Alaska South SE , 1.400 7400 1.00 0 1 ,AKS ,2.02448
***
```

Age 2 to 1 conversion factor

Stock abbreviation

MSH escapement flag
    1 truncates at maximum
    0 truncates at optimum

Flag for hatchery stocks

IDLs for calibration runs only

Estimate of MSY escapement

Production parameter A
    Ricker A value for natural stocks
    Productivity for hatchery stocks

Stock name

Fig. 2.2 Sample **`*.bse`** file.

Files of type `*.stk`

The `*.stk` file contains data for individual stocks (Fig. 2.3). This file is generally the same for all simulations after calibration. The elements of the `*.stk` file are shown in Fig. 2.2. A line-by-line description follows.

```
Line
1       AKS
2       0.16082775E+05 0.88410469E+04 0.42651133E+04 0.72223273E+03
3       0.53398825E-01 0.14530915E+00 0.69034618E+00 0.10000001E+01
4       0.58872306E+00 0.80788922E+00 0.96903467E+00 0.10000001E+01
5a      0.00000000E+00 0.41631317E+00 0.24833483E+00 0.25773025E+00
        ***


5y      0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
        *** Repeat For Each Stock ***
```

Fig. 2.3 Sample `*.stk` file.

Line 1: Stock designator.

Line 2: Initial cohort abundance (age 2, 3, 4, and 5)

Line 3: Maturation rates (age 2, 3, 4, and 5)

Line 4: Adult equivalent factors (age 2, 3, 4, and 5)

Lines 5+: Fishery exploitation rates. Columns are ages (2, 3, 4, and 5) and rows are fisheries. These are the values that are viewed in the Base Period Harvest Rates dialog box.

Files of type `*.msc`

This file must be specified for simulation runs. Results of annual exploitation rate analyses indicate that maturation schedules can vary substantially from year to year. This information can be incorporated into CRiSP Harvest through the use of an **`*.msc`** file (Fig. 2.4). The **`*.msc`** file identifies stocks with annual estimates of year-specific maturation schedules and provides the name of the file that actually contains the maturation data (.MAT). The **`*.mat`**, **`*.bse`**, and **`*.stk`** files must correspond to a particular Model calibration; you must insure that the same maturation schedules are used for both calibration and model runs so that results will be compatible. You should enter "NONE" if the model was calibrated with no annual variation in maturation schedules.

```
hanford.mat , Name of maturation data file
AKS, Alaska Spring
BON, Bonneville
CWF, Cowlitz Fall
GSH, Georgia Strait Hatchery
LRW, Lewis River Wild
ORC, Oregon Coastal
RBH, Robertson Creek Hatchery
RBT, WCVI Wild
SPR, Spring Creek
URB, Columbia River Upriver Bright
WSH, Willamette Spring
```

Fig. 2.4 Sample **`*.msc`** file.

Line 1: Name of file containing annual maturity schedules, Descriptor

Lines 2,3,4,...: One line for each stock

  Item 1: Stock abbreviation (see Introduction for list)

  Item 2: Descriptor

Files of type `*.mat`

The **`*.mat`** file is used in conjunction with the **`*.msc`** file. See "**`*.msc`** File Structure" above. The information appears in blocks in the file (Fig. 2.5). Each block corresponds to a year and begins with the year in the first column followed by rows corresponding to each stock. Subsequent values on each row are the maturation rates and adult equivalents for the stock.

```
1979
  AKS,   0.0534 0.1453 0.6903 0.5887 0.8079 0.9690
  BON,   0.0000 0.2404 0.9877 0.5626 0.8418 0.9988
  CWF,   0.0011 0.1295 0.8170 0.5665 0.8132 0.9817
  GSH,   0.0340 0.3559 0.9533 0.6032 0.8690 0.9953
  LRW,   0.0515 0.1139 0.6604 0.5799 0.7987 0.9660
  ORC,   0.2627 0.1792 0.4807 0.6819 0.8017 0.9481
  RBH,   0.0914 0.1444 0.6035 0.5999 0.8096 0.9604
  RBT,   0.0914 0.1444 0.6035 0.5999 0.8096 0.9604
  SPR,   0.0171 0.4362 0.9635 0.6567 0.8845 0.9963
  URB,   0.0376 0.0508 0.4887 0.5886 0.7670 0.9489
  WSH,   0.0081 0.6895 0.9351 0.6395 0.9308 0.9935
1980
etc. for remaining years
```

Fig. 2.5 Sample ***.mat** file.

Col 1: Stock abbreviation.

Cols 2, 4, 6:Maturation rates (ages 2, 3, and 4)

Cols 3, 5, 7:Adult equivalent factors (ages 2, 3, and 4).

Files of type `*.evo`

The `*.evo` files (Fig. 2.6) contain estimates of stock and brood specific productivity scalars (EV scalars) up through the last year of available data and then uses averages for all subsequent years. You can modify the EV's for years following the last estimated year using the dialog boxes (see "Dialog Boxes" on page 2.31) opened from the drop-down menus (see "Drop-Down Menus" on page 2.24) or by modifying the `*.evo` file with a text editor.

EV values are approximately log-normally distributed and future versions of the model will incorporate this feature which will be useful for running the model in Monte Carlo mode when the model has to select a value for the EV for each stock for each year. The standard method is to "Bootstrap" the value from the historical values.

```
Line
  1 1979 ───────────────────────── First brood year of stock scalars
  2 2005 ───────────────────────── Last brood year of stock scalars
  3 1 0.1172331E+01  0.1514850E+01  0.5180302E00...
                     * * *


 29 0.19503513E-01 0.58093452E+00 0.24624143E0.
```

Scalar for 1981 brood

Scalar for 1980 brood

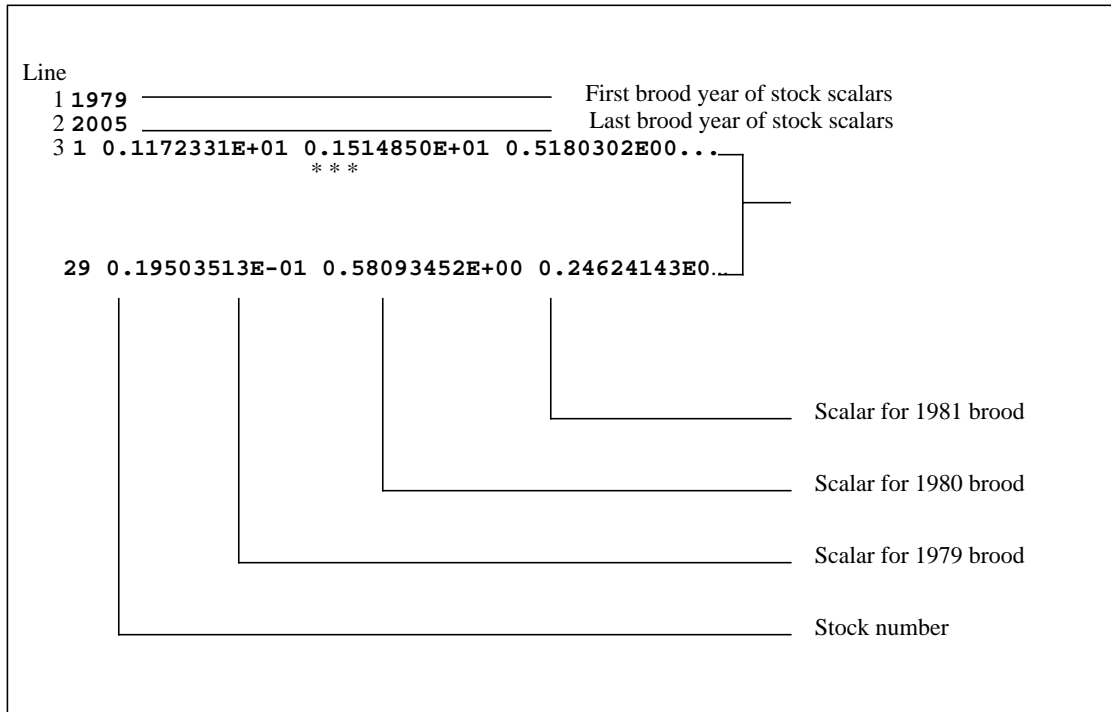Scalar for 1979 brood

Stock number

Fig. 2.6 Sample `*.evo` file.

Line 1: First brood year for EV scalars

Line 2: Last brood year for EV scalars

Line 3: EV scalars

    Item 1: Stock number

    Item 2,3,4,...: EV scalars (one for each year)

Files of type `*.idl`

Effects of post-fishery, pre-spawning mortality can be examined through use of `*.idl` files. Currently, this file (see Fig. 2.7) only includes estimates of inter-dam loss for Columbia River stocks. Since most inter-dam loss occurs after all fisheries, inter-dam loss is essentially treated as escapement when calculating ocean and terminal area harvest rates. Changes in estimates of inter-dam loss rates can be assessed by modifying this file. It should be noted, however, that the numbers in the `*.idl` files are actually estimates of total adult *survival* past all Columbia River dams. Estimated IDL values are used through the present year, then an average of all estimated values is used for future years.

```
3
URB
1973
1994
0.993,1.036,0.613,1.194,1.279,0.930,0.923,0.535,0.475,0.501,0.804,0.8
79,0.943,0.952,0.867,0.922,0.856,0.790,0.733,0.874,0.815,0.809
SPR
1973
1994
0.550,0.550,0.743,0.362,0.488,0.402,0.518,0.859,0.626,1.002,0.666,0.5
45,0.355,1.003,1.020,1.026,0.981,0.975,0.636,0.655,0.853,0.969
LYF
1973
1994
0.519,0.545,0.202,0.286,0.702,1.419,0.626,0.319,0.222,0.286,0.390,0.9
10,0.507,0.308,0.331,0.273,0.336,0.339,0.209,0.466,0.603,0.750
```

Fig. 2.7 Sample `*.idl` file.

Line 1: Number of stocks with IDL factor.

For each stock, sets of 4 data lines:

Line 2: Three character identifier for stock (defined in `*.bse` file)

Line 3: First year for start of IDL scalars

Line 4: Last year for IDL scalars

Line 5: Post-fishery, prespawning survival, one entry per year

Files of type `*.enh`

The `*.enh` file (see Fig. 2.8) has information on changes in enhancement schedules for hatchery and natural supplementation programs. Modifications of the `*.enh` file can be made either: (1) to incorporate actual changes in the enhancement schedule; (2) to assess possible changes in enhancement. All

enhancement changes are relative to average levels during the 1979-1981 base period.
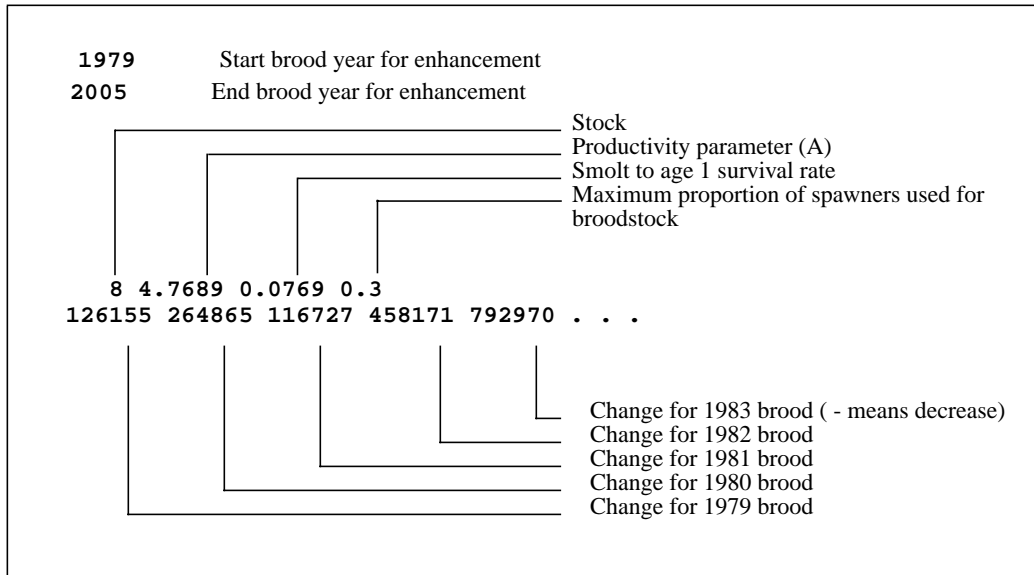
Fig. 2.8 Sample `*.enh` file

Line 1: First year for enhancement changes, Descriptor

Line 2: Last year for enhancement changes, Descriptor

Line 3: For each stock with enhancement changes, include 2-line sets of data

>   Item 1: Stock number
>
>   Item 2: 'A' value for enhancement productivity, simulated using exponential function (e^a)
>
>   Item 3: Smolt to age 1 survival
>
>   Item 4: Maximum proportion of spawners that can be used for broodstock (used for supplementation).

Line 4: This line must contain one data element for each year in the period indicated by lines 1 and 2. Data entry values represent smolt production changes from the base period by brood year (measured as yearly releases minus average base period releases).

Files of type `*.cnr`

Management agencies have implemented non-retention restrictions to prevent the catch in a fishery from exceeding an established ceiling. These chinook non-retention (CNR) fisheries result in incidental mortality losses of

adults and juveniles. The format of the ***.cnr** file (see Fig. 2.9) is described below.

```
Line
1  1979 , Start year
2  2005 , end year
3  1 , Fishery index
4  0.34     ,          1, Legal Sublegal Selectivity
5a 0        ,          NO CNR encounters / year = 1979
5b 0        ,          NO CNR encounters / year = 1980
5c 1        ,          2, 18225, 18578, 248800 ... = 1981
 ...
3  2 , Fishery Index
4  0.2 , 1, Legal Sublegal Selectivity
5a ...
```

Fig. 2.9 Sample ***.cnr** file

Line 1: First year for CNR data, Descriptor

Line 2: Last year for CNR data, Descriptor

      Sets of data for each CNR fishery

Line 3: Number of fishery with CNR regulations, Descriptor

Line 4: Legal selectivity scalar, Sublegal selectivity scalar, Descriptor

Selectivity scalars are used to compensate for changes in fleet behavior during CNR restrictions. Scalar values are all relative to 1.0 (no change). Values in the example above indicate a 66% reduction in impacts on legal-sized chinook retention.

Line 5: Specifications for CNR fisheries, one for each year

Currently, there are three different methods that can be used to calculate CNR mortality. Each method requires different types of data. The section that follows details how to describe this data in the ***.cnr** files.

Methods for determining CNR mortality

Method 0 ("RT Method") estimates CNR mortality through ratio (RT) factors generated by the Model. RT factors represent the ratio between harvest rates associated with a catch ceiling and base period rates. Consequently, RTs can be considered as surrogate indicators for season length. If the RT method is selected, the Model estimates CNR mortality of legals and sublegals by multiplying mortalities associated with the catch ceiling by the selectivity scalars and mortality rates appropriate for the gear involved. This method is generally applied when no other data are available or when projecting regimes into the future. If this method is used, Line 5 will have the following format:

      Item 1: Flag for CNR fishery (0 = no CNR fishery; 1 = CNR fishery)

Item 2: CNR method (0 = RT method; 1 = Season length; 2 = encounters)

Item 3: Descriptor

e.g.   `1, 0, CNR RT 1990`

Different CNR mortality methods can be used to determine how mortalities are calculated during the calibration period. during the simulation period, however, the current version of CRiSP Harvest uses the "RT Method" exclusively.

Method 1 ("Season Length Method") can be used to model past seasons when only information about season length is available. This method uses the ratio of regular season length to the CNR season length.

Item 1: Flag for CNR fishery (0 = no CNR fishery; 1 = CNR fishery)

Item 2: CNR method (0 = RT method; 1 = Season length; 2 = encounters)

Item 3: Season length (days)

Item 4: CNR Season length (days)

Item 5: Descriptor

e.g.   `1, 1, 60, 9, Season length/legal season/ CNR days for 1990`

Method 2 ("Encounter Rate Method") is used when specific data on encounter rates are available. To use this method, you must enter the following data.

Item 1: Flag for CNR fishery (0 = no CNR fishery; 1 = CNR fishery)

Item 2: CNR method (0 = RT method; 1 = Season length; 2 = encounters)

Item 3: Encounters of legal sized fish during CNR fishery

Item 4: Encounters of sublegal sized fish during CNR fishery

Item 5: Total landed catch in fishery

Item 6: Descriptor

e.g.   `1, 2, 18225, 18578, 248000, Enc./Est of CNR enc/year = 1990`

Files of type `*.pnv`

A separate `*.pnv` file (see Fig. 2.10) is created for each fishery in which one or more changes in the minimum size limit have occurred since the base period. The proportions in a `*.pnv` file replace those proportions in the `*.bse` file for each fishery specified by a `*.pnv` file.

```
     24    Fishery
   1982    First year for change in proportion non-vulnerable
   2005    Last year of data
 0.8101 0.8101 0.8101 0.8101 0.8101 0.8101 ─┐ ...
 0.0098 0.0098 0.0098 0.0098 0.0098 0.0098 ─┤ ...
 0.0014 0.0014 0.0014 0.0014 0.0014 0.0014 ─┤ ...
 0.0102 0.0102 0.0102 0.0102 0.0102 0.0102 ─┘ ...

                                              ┌─ Age 2 PNV
                                              ├─ Age 3 PNV
                                              ├─ Age 4 PNV
     One column per year (first year through last year)  └─ Age 5 PNV
```

Fig. 2.10 Sample ***.pnv** file

Files of type ***.fp**

The ***.fp** files are used for detailed Fishery Policy (Harvest Rate) scalars that alter the impact of a given fishery on the stocks on a year-by-year basis. The format is to place all of the FP values in a block for a year. Each year has a separate block. Within each block the 30 rows are for the 30 stocks and each of the 25 columns is one of the fisheries. There are no other flags, values or tokens in this file.

Files of type ***.cei**

The ***.cei** files (see Fig. 2.11) is used to set catch ceilings which are the primary means selected by the PSC to reduce stock exploitation rates. The ***.cei** file is used: (1) to specify fisheries with ceilings; (2) to set ceiling levels (catch levels); and (3) to allow you to force Model catches to equal the ceiling.

```
1979        ,          Start of base period
1984        ,          End of base period
1985        ,          First year of ceiling management
1998        ,          Last year for ceiling management
11          ,          Number of fisheries with ceilings
7           ,          Number of ceiling level changes
1986 1987 1988 1990 1991 1992 , years to change ceilings
.................. S.E. Alaska Troll (excluding hatchery add-ON)......
1           ,          1st Fishery Number
         338000    ,1979,catch
                   ... continue for each year
         230712    ,1990,catch
         162995    ,1992, THROUGH LAST YEAR OF CLG MGMT
         8         ,Number of years to force ceilings
         1985 1986 1987 1988 1989 1990 1991 1992 , years to force
.................. (etc for remaining Fisheries)
```

Fig. 2.11 Sample ***.cei** file.

Line 1: Start of base period. The Model computes average catches during a user-specified based period and then compares subsequent ceiling levels with these averages.

Line 2: End of base period.

Line 3: First year for ceiling management to be applied.

Line 4: Last year for ceiling management to be applied. After the last year, the Model will use RT factors associated with the last ceiling level to constrain fishery exploitation/harvest rates.

Line 5: Number of fisheries with ceilings.

Line 6: Number of changes in ceiling levels.

Line 7: Years in which ceiling levels are changed.

Lines 8a through 8r: One set per ceilinged fishery.

Line 8a: Header to improve readability. Contents are ignored by the Model.

Line 8b: Number of Ceilinged Fishery, descriptor.

Lines 8c-8p: Ceiling level (Catches), year, descriptor.

Line 8q: Number of years to treat ceilings as quotas ("forcing"). When a ceiling is not treated as a quota, the harvest rate in a fishery will be held at or below base period levels as modified by the **`*.fp`** file. Under conditions of low abundance, catches will be less than the ceiling level if base period harvest rates are maintained. If the ceiling is forced, then the harvest rate in the fishery is allowed to increase so that the ceiling is reached. In most circumstances, all ceilings are forced all years.

Line 8r: Years to treat ceiling as quotas, followed by descriptor.

Files of type **`*.monte`**

The **`*.monte`** file (see Fig. 2.12) uses a token based structure and hence the specific keywords are expected by the file parser. The **`*.monte`** file is used to configure the model for Monte Carlo simulations. See "Running the model in Monte Carlo mode" on page 2.39.

```
monte Log Normal Indep
  seed 14297
  games 250
  start_year 1993
  track escapement
  output_config_file log.config
end monte
```

Fig. 2.12 Sample *.MONTE file.

Line 1: Keyword "monte" followed by a second keyword ("Bootstrap" or "Log Normal Indep.") describing the type of sampling method to use for EV scalars.

   If the "Bootstrap" method is used, then for each year during the simulation period (i.e., future years) this method randomly selects a year from the calibration period (e.g. 1979-1991), with each calibration year having equal probability of being selected. For each stock, the program then sets the EV Scalar for the simulation year equal to the EV Scalar value for that stock in the selected calibration year. For example, if the simulation year is 2002 and the calibration period is 1979-1991, the program randomly selects a year between 1979 and 1991, say 1983. For each stock, the program then sets the EV Scalar in year 2002 to the same value used in year 1983. The basic idea of this method is to allow for correlations between stocks. Instead of letting the EV Scalars vary independently, this methods says "lets make future year 2002 look just like year 1983 for all stocks."

   If the "Log Normal Indep." method is used, then for each year during the simulation period (i.e., future years), the model randomly selects EV Scalars for each stock from a log normal distribution unique to that stock. The two parameters defining each stock's log normal distribution are included in the `*.evo` file and typically are estimated from the calibration period EV Scalars computed during the calibration process. This method allows the EV Scalars for each stock to vary independently.

Line 2: Keyword "seed" followed by a random number seed value (an integer)

Line 3: Keyword "games" followed by the number of "games" or simulations to be "played" (run).

Line 4: Keyword "start_year" followed by the first year in which the random EV scalars are to be used. The EV Scalars (brood year survival rates) can only be estimated after all the age classes from a given brood year have returned to the spawning grounds (five year lag). For example, once the data for 1996 have been gathered it is possible to estimate the EV Scalars for the brood year 1991, but not for brood years 1992-1995. In this example, the "start_year" should be set to 1992.

Line 5: Keyword "track" followed by the type of output to be tracked. Currently, only "escapement" can be tracked during monte carlo runs so this line must read "track escapement".

Line 6: Keyword "output_config_file" followed by a filename in which the data will be stored.

Line 7: Keyword "end monte".

Files of type `*.config`

The `*.config` file (see Fig. 2.13) is used to configure output from Monte Carlo runs.

```
config
 output escapement
 stocks 1 LYF
 years 2 1998 2017
 end output
 output escapement_quantiles
 stocks 1 LYF
 end output
end config
```

Fig. 2.13 Sample *.CONFIG file.

Line 1: Keyword "config".

Line 2: Keyword "output" followed by keyword "escapement". This tells the program to store the escapement data for all games for the stocks and years given in lines 3 and 4 below.

Line 3: Keyword "stocks" followed by the number of stocks to store outputs for and a list of the stock abbreviations (e.g., LYF, URB). The stock abbreviations must be the same as the ones used in the *.BSE file.

Line 4: Keyword "years" followed by the number of years to store outputs for and a list of the years.

Line 5: Keywords "end output".

Line 6: Keyword "output" followed by keyword "escapement_quantiles". This tells the program to compute and store the median and 75th and 95th quantiles of the escapements from all games for the stocks listed in line 7 below.

Line 7: Keyword "stocks" followed by the number of stocks to store outputs for and a list of the stock abbreviations (e.g., LYF, URB). The stock abbreviations must be the same as the ones used in the `*.bse` file.

Line 8: Keywords "end output".

Line 9: Keywords "end config".

Files of type `*.riv`

The `*.riv` file (see Fig. 2.14, Fig. 2.15 and Fig. 2.16) uses a token based structure and hence the specific keywords are expected by the file parser. The `*.riv` files are used to specify the management parameters controlling in-river harvest.

Fixed Escapements, Weak Stock Management

```
policy fixed_escapement
 river Columbia

        fishery Col R N
        mgmt_type weak
        mgmt_years 1995 1996 1997 1998 1999
        forced_years 1995 1996 1997 1998 1999
        stock URB
         mgmt_idls 0.815 0.815 0.815 0.815 0.815
          escapements 45000 45000 45000 45000 45000
        end (stock)
        stock LYF
         mgmt_idls 0.815 0.815 0.815 0.815 0.815
          escapements 1500 1500 1500 1500 1500
        end (stock)

 end (river)
end (policy)
```

Fig. 2.14 Sample `*.riv` file for fixed escapement, weak stock management.

Fixed Escapements, Combined Stock Management

```
policy fixed_escapement
 river Columbia

         fishery Col R N
         mgmt_type combined
         mgmt_years 1995 1996 1997 1998 1999
         forced_years 1995 1996 1997 1998 1999
         escapements 45000 45000 45000 45000 45000
         stock URB
          mgmt_idls 0.815 0.815 0.815 0.815 0.815
         end (stock)
         stock LYF
          mgmt_idls 0.815 0.815 0.815 0.815 0.815
         end (stock)

 end (river)
end (policy)
```

Fig. 2.15 Sample ***.riv** file for fixed escapement, combined stock management.

Fixed Escapements, Fixed Harvest Rate Management

```
policy combined_harvest_rate
 river Columbia
         fishery Col R N
         mgmt_years 1995 1996 1997 1998 1999
         forced_years 1995 1996 1997 1998 1999
         harvest_rates 0.15 0.15 0.15 0.15 0.15
         stock URB
          mgmt_idls 0.815 0.815 0.815 0.815 0.815
         end (stock)
         stock LYF
          mgmt_idls 0.603 0.603 0.603 0.603 0.603
         end (stock)
 end (river)
end (policy)
```

Fig. 2.16 Sample ***.riv** file using combined fixed harvest rate management.

Appendix: 2.2 - CRiSP Harvest Output Files

Depending on the configuration of the model as specified by the ***.opt** file. One or more of the following files may be produced.

*prefix***???.prn**	Stock specific mortality by year (rows) and fishery (columns)
*prefix***abd.prn**	Abundance indices in blocks for each fishery by years for the fisheries specified for abundance generation in the ***.opt** file (lines 9i+)
*prefix***cat.prn**	Catch by year (rows) and fishery (columns)
*prefix***coh.prn**	Abundance indices in blocks for the fisheries specified for abundance generation in the ***.opt** file (lines 9i+) by year (rows) and stock (columns).
*prefix***esc.prn**	Spawning escapement by year (rows) and stock (columns)
*prefix***lim.prn**	Incidental mortality estimates of legal sized chinook by year (rows) and fishery (columns).
*prefix***ohr.prn**	Adult equivalent total exploitation rates by year (rows) and stock (columns). Notes: this does not include shaker losses. The values in this file are affected by the selection of method in line 9f of the ***.opt** file.
*prefix***sim.prn**	Incidental mortality estimates for sub-legal sized chinook by year (rows) and fishery (columns).
*prefix***thr.prn**	Adult equivalent total exploitation rates by stock and year. See notes for *prefix***ohr.prn**.
*prefix***tim.prn**	Total incidental mortalities by year (rows) and fishery (column)
*prefix***trm.prn**	Terminal run by year (row) and stock (column) This is affected by the choice of "minimum age for terminal run stats" in the ***.opt** file.

Appendix: 2.3 - Editing CRiSP Harvest Files

It is important to retain the file extensions for the CRiSP Harvest parameter files. The extensions identify the type of file to the executable. Unfortunately, Windows NT and Windows 95 try to associate an application with each type of file. The best editor for looking at and editing these ASCII files is called WordPad but it is not the default application for any of the files. Currently, the filename extensions used for various CRiSP Harvest files help identify the type of file and allow cross-platform compatibility between PC and Unix versions of the model.

To use WordPad to look at or edit the CRiSP Harvest ASCII files you do one of the following:

Launch WordPad and then open the file

1. From the Windows Start menu select "Programs".
2. Select "Accessories".
3. Select "WordPad".
4. Open CRiSP Harvest ASCII files using the Open command on the File menu.

Attempt to associate individual file types with an application

Note: not all files with various extensions used by CRiSP Harvest can be mapped to a specific application. Some of these extensions are reserved.

1. Highlight the file from an Explorer window.
2. Select "Options..." from the "View" menu.
3. Select the "File Types" tab.
4. Click "New Type..."
5. Follow dialog box instructions.
6. Be sure to add "Open" to the Actions list and choose "`c:\program files\accessories\wordpad.exe`" as the application.

Appendix: 2.4 - Glossary

Table 2.4 Some terms used in CRiSP Harvest.

Term	Definition
Abundance Index	The expected catch given the current year size limits and cohort sizes but the base period (1979-1981) harvest rates.
Adult Equivalence Factors	Used to adjust fishery catches to a common impact on the spawning stock. For example, on average a three year old fish harvested by an ocean fishery has less impact on the spawning stock than a five year old fish harvested by a river fishery, because some three year old fish would normally die of natural causes before they had an opportunity to spawn. Thus, one three year old fish eliminated from the ocean catch will result in less than one additional fish in the spawning stock, whereas one five year old fish eliminated from the river catch will result in one additional fish in the spawning stock.
Adult Escapement	Terminal Run fish that survive the terminal fisheries and pre-spawning mortality. Age two fish returning to the river are not considered reproductively viable and are not included in the adult escapement for each stock.
Base Period Harvest Rate	Average stock, age, and fishery specific harvest rate between 1979-1982. Harvest Rate scalars are relative to this rate.
Brood Year	The year in which a fish was propogated or spawned (i.e., the year in which the eggs were fertilized). Chinook salmon typically migrate downstream the following year (most Fall chinook), or the year after (most Spring chinook).
Catch Ceilings	Maximum catch (numbers of fish) for a fishery or group of fisheries for a specified time period. These are not established for specific stocks. This is the Pacific Salmon Commission's primary management tool.
Chinook Non-Retention Mortalities	Mortalities of legal and sub-legal chinook that are caught and brought up to the boat in coho fisheries at times when it is not legal to land and sell any chinook.
CNR (mortalities)	See Chinook Non-Retention Mortalities.

Table 2.4 Some terms used in CRiSP Harvest.

Term	Definition
Coded-Wire-Tag (CWT)	Tiny wire tags (1.0 x 0.25 mm) inserted in the nose cartilage of salmon fingerlings or fry, typically in the hatchery, to identify the origin of an individual fish. Each tagged fish has the adipose fin clipped to indicate that it has a CWT in its snout. Scientists use CWT recoveries to estimate harvest rates and migration patterns.
Cohort	A group of fish that have the same demographic characteristics, such as belonging to the same age class of a given stock.
Cohort Analysis	Same as Virtual Population Analysis.
Enhancement	Production of fish at facilities such as hatcheries.
Escapement	Fish that are not caught by any fisheries (i.e, they "escape" the fisheries).
EV Scalar	Scalars used to adjust the average production of age one fish by a spawning stock to account for inter-annual Environmental Variability (EV).
Gillnet	A harvest method in which fish are trapped in a net stretched across their migration path. The net may either be set from a drifting boat (drift gillnetting) or from a fixed position (set gillnetting). The fish become entangled by their gill plates or jaws, and can neither back out nor move forward.
Harvest Rate Scalars	Scalars used to adjust the harvest rate during a given year compared to the Base Period.
IDL (rate)	See Inter-Dam Loss rate.
Inter-Dam Loss rate	These are actually *survival* rates between the last fishery and the spawning grounds. Also called the Pre-spawning mortality. IDLs are stock specific, but are not age (or size) specific. This mortality is applied to Columbia River stocks that spawn upriver from dams and is assessed after fishing mortality to account for losses between dams.
Legal (size)	Above a certain size criteria.

Table 2.4 Some terms used in CRiSP Harvest.

Term	Definition
Maturation Rates	The proportion of a stock that is mature and ready to return to the spawning ground. These are age and stock specific and can vary across years as well. However the model does not allow for age 6 fish so the MR for age 5 fish should always be 1. The stock that is mature is considered the terminal run.
Natural Ocean Mortality	Non-fishing mortality assessed at the beginning of each year in the model. This mortality is age specific, but not stock specific.
Net Fisheries	In CRiSP Harvest, this refers to fisheries using gillnet and purse seine gears.
Pacific Salmon Commission	International regulatory agency created by the 1985 Pacific Salmon Treaty between the United States and Canada with responsibility for management of North American salmon stocks and fisheries.
Percent Non-Vulnerable	Fraction of a cohort that is below the legal size limit. PNVs vary by year, age, and fishery, but not by stock.
PNV	See Percent Non-Vulnerable.
Pre-Spawning Mortality	See Inter-Dam Loss.
Preterminal (catch)	Catch that occurs before the mature segment of a cohort begins migrating back to the spawning grounds. Thus, preterminal catches are primarily ocean catches.
PSC	See Pacific Salmon Commission.
Purse Seine	A commercial fishing system in which a school of fish are encircled by a vertically hanging net and then are trapped by closing the bottom of the net (pursing).
Recruitment	Fish from a given stock that become available (i.e., recruit) to a fishery.
Recruitment Age	The age at which fish from a given stock become available to a fishery.
Ricker Function	A popular type of Spawner/Recruit Relationship (named after Dr. William Ricker) in which the number of recruits per spawner declines exponentially. The resulting curve has a desending right hand limb (i.e., too many spawners produce fewer recruits).

Table 2.4 Some terms used in CRiSP Harvest.

Term	Definition
Shakers	Sublegal chinook that are caught (i.e., hooked and brought up to the boat) and released (i.e., "shaken" off the gear) during directed chinook fisheries.
Spawner/Recruit Relationship	A mathematical relationship between the number of spawners in a given year and the resulting number of progeny that become available (i.e., recruit) to the fisheries in some future year. Usually estimated from historical data and used in simulation models to predict future recruitment from a given spawning stock.
Sub-legal (size)	Below a certain size criteria.
Supplementation	Artificial propogation intended to reestablish or increase the abundance of natural populations.
Terminal Catch	Catch of the mature segment of a cohort as it migrates back to the spawning grounds. Some ocean net catches that occur in nearshore waters are considered terminal catches.
Terminal Run	Mature fish leaving the open ocean and returning to the spawning grounds. Compare to True Terminal Run.
Total Catch	Sum of the Preterminal and Terminal catches.
Troll	A commercial harvest method for chinook and coho salmon, usually in the open ocean, that captures individual fish on lures or baited hooks being slowly pulled through the water.
True Terminal Run	The Terminal Run minus nearshore ocean net catches. Thus, it is the number of fish entering the natal river (as opposed to the number of mature fish leaving the ocean feeding areas). Compare to Terminal Run.
Virtual Population Analysis	A technique (sometime referred to as VPA) for reconstructing the history of a cohort of fish. By counting the number of spawners and the catches and making estimates of the natural mortalities it is possible to reconstruct the history of a cohort.

Appendix: 2.5 - Stock Abbreviations

The stocks are listed alphabetically by their three letter code and cross-referenced to their number and name. The numbers are used in place of the abbreviations in some of the parameter files. The stocks appear in numerical order in the drop-down menu of stocks on the CRiSP Harvest toolbar.

Abbreviation	Number	Stock Name
AKS	1	Alaska South SE
BON	21	Lower Bonneville Hatchery
CWF	22	Fall Cowlitz Hatchery
CWS	25	Spring Cowlitz Hatchery
FRE	3	Fraser Early
FRL	4	Fraser Late
GSH	9	Upper Straight of Georgia Hatchery
GSQ	7	Upper Straight of Georgia
GST	8	Upper Straight of Georgia Natural
LRW	23	Lewis River Wild
LYF	29	Lyons Ferry
MCB	30	Mid-Columbia River Brights
NKF	10	Nooksack Fall
NKS	14	Nooksack Spring
NTH	2	North/ Central BC
ORC	27	Oregon Coast
PSF	11	Puget Sound Fingerling
PSN	12	Puget Sound Natural F.
PSY	13	Puget Sound Yearling
RBH	5	West Coast Vancouver Island (WCVI) Hatchery
RBT	6	West Coast Vancouver Island (WCVI) Natural
SKG	15	Skagit Wild

Abbreviation	Number	Stock Name
SNO	17	Snohomish Wild
SPR	20	Spring Creek Hatchery
STL	16	Stillaguamish Wild
SUM	26	Columbia River Summers
URB	19	Columbia Upriver Brights
WCH	18	Washington Coastal Hatchery
WCN	28	Washington Coastal Wild
WSH	24	Willamette River

Chapter 3. Sample Lessons

Table of Contents

3.1 - Introduction

Sample Lessons

This chapter contains a few sample lessons, or tutorials, to learn more about the model behavior. Each sample lesson includes four sections: **Motivating Question**, **Analysis Approach**, **How To Do It**, and **Discussion Questions**. More lessons will be posted on the Columbia Basin Research web site:

http://www.cqs.washington.edu/crisp/model.html.

3.2 - Who Catches Who?

Motivating Question

Salmon are known for extensive migrations. What stocks are harvested by each fishery?

Analysis Approach

Use the Map Icons to determine which stocks are harvested by each fishery.

How To Do It

1. Launch and run the model.
2. Make sure the Fishery Circles and Stock Circles buttons on the tool bar are activated.
3. Click on a Fishery Icon. This will draw circles around all stocks harvested by that fishery (the name of the fishery will be displayed in the lower left corner of the map). The relative size of the circle indicates the approximate relative harvest rates on each stock.
4. Repeat step 3 for other fisheries of interest.
5. Click on the map background to clear the circles.
6. Click on a Stock Icon. This will draw circles around all fisheries that harvest that stock (the name of the stock will be displayed in the lower left corner of the map). Again, the relative size of the circle indicates the approximate relative harvest rates in each fishery.
7. Repeat step 6 for other stocks of interest.

Discussion Questions

1. Do you see any trends in the number of stocks harvested by different fisheries?
2. Which fisheries harvest the greatest number of stocks?
3. Which fisheries harvest the fewest number of stocks?
4. What American stocks are harvested in Canadian fisheries?
5. What Canadian stocks are harvested in American fisheries?

3.3 - Status Quo Catch Analysis

Motivating Question

The default long-term management strategy is to make some catch reductions during 1995-1997 and then beyond 1998 keep catches and harvest rates at about the average 1991-1994 level. How will this strategy impact fishery catches?

Analysis Approach

Run the model under the default long-term management strategy and record the catch trends for each fishery.

How To Do It

1. Create a table with three columns for recording the data. Column one is for the fishery name, column two is for the trend (increasing, decreasing, stable), and column three is for the approximate value in year 2017.
2. Launch and run the model.
3. Click the Fishery Menu.
4. Click Fishery Graphs.
5. Click Catches.
6. Click Total.
7. Resize the resulting Total Catch Graph so it fits in the upper right portion of the screen and lets you see the map icons.
8. Click the "wand" button at the top of the graph.
9. Move the mouse pointer over a fishery icon (boat icon) to show the catch trend for that fishery (the fishery name will be at the top of the graph window).
10. Record the trend of the catch during the simulation period.
11. Move the mouse pointer onto the graph window (be careful not to move the pointer over another fishery icon or it will change the graph) and determine the approximate catch in year 2017. Record the catch in the table.
12. Repeat steps 9-11 until data for all fisheries has been recorded.

Discussion Questions

1. How many fisheries have increasing, decreasing, or stable catch trends?
2. Is there any correlation between catch trends and fishery type (troll, net, sport)?
3. Why do some catch ceiling fisheries have perfectly stable catches while other ceiling fisheries have increasing or decreasing catches?

3.4 - Status Quo Escapement Analysis

Motivating Question

The default long-term management strategy is to make some catch reductions during 1995-1997 and then beyond 1998 keep catches and harvest rates at about the average 1991-1994 level. How will this strategy impact spawning escapements? (The term "escapement" refers to the fish that "escape" all fisheries and return to the spawning grounds.)

Analysis Approach

Run the model under the default long-term management strategy and record the escapement trends for each stock.

How To Do It

1. Create a table with three columns for recording the data. Column one is for the stock name, column two is for the trend (increasing, decreasing, stable), and column three is for the approximate value in year 2017.
2. Launch and run the model.
3. Click the Stock Menu.
4. Click Stock Graphs.
5. Click Escapements.
6. Resize the resulting Total Escapement Graph so it fits in the upper right portion of the screen and lets you see the map icons.
7. Click the "wand" button at the top of the graph.
8. Move the mouse pointer over a stock icon (fish icon) to show the escapement trend for that stock (the stock name will be at the top of the graph window).
9. Record the trend of the escapement during the simulation period.
10. Move the mouse pointer onto the graph window (be careful not to move the pointer over another fishery icon or it will change the graph) and determine the approximate escapement in year 2017. Record the escapement in the table.
11. Repeat steps 9-11 until data for all stocks has been recorded.

Discussion Questions

1. How many stocks have increasing, decreasing, or stable escapement trends?
2. What factors not in the model might affect escapement trends?

3.5 - Environmental Effects --Deterministic Mode

Motivating Question

Fishery biologists know that salmon survival during the first year of life is highly variable from year to year. This is called the "brood year survival rate" and is represented in model by the EV (Environmental Variability) Scalars. What happens to the model predictions if future survival rates don't match what the scientists predict?

Analysis Approach

Select a stock of interest and run the model in deterministic mode using different values for the future EV Scalars for each run of the model. In this case we will choose the Snake River Fall Chinook stock because it is listed under the Endangered Species Act.

How To Do It

1. Launch and run the model.
2. Set the Default Stock to Lyons Ferry.
3. Click the Stock Menu.
4. Click Stock Graphs.
5. Click Escapements.
6. Record the trend and value in year 2017.
7. Close the Escapement Graph.
8. Click the Stock/EV Scalars button.
9. Click the tab with year 2000.
10. Record the EV Scalar value used during the simulation period.
11. Click the "Y Box" at the top of the EV Scalar window.
12. Set the EV Scalar for year 2000 to 3.0 (note that this changes all the simulation years to 3.0, also).
13. Click apply and OK.
14. Close the EV Scalar window.
15. Click the run button on the tool bar.
16. Repeat steps 3 through 16 using EV Scalar values of 1.0 through 6.0.

Discussion Questions:

1. What EV Scalar value for the Lyons Ferry stock gives a stable escapement trend?
2. What do you think would happen if the EV Scalar value changed every year instead of remaining constant?

3.6 - Environmental Effects -- Stochastic Mode

Motivating Question

Fishery biologists know that salmon survival during the first year of life is highly variable from year to year. This is called the "brood year survival rate" and is represented in model by the EV (Environmental Variability) Scalars. What happens to the model predictions if future survival rates don't match what the scientists predict?

Analysis Approach

Select a stock of interest and run the model in stochastic mode, allowing the EV Scalars to vary randomly from year to year during a given run of the model.

How To Do It

1. Launch and run the model.
2. Click the Run Menu.
3. Click Monte Carlo.
4. Set the number of games to 1.
5. Click Run Monte. When the run is completed, an escapement graph for the selected default fishery appears.
6. Click the Stock Menu.
7. Click Stock Graphs.
8. Click Escapements and notice that the escapement for the selected stock varies considerably from year to year.
9. Resize and move the Escapement Graph so the map icons are visible.
10. Click the Stock/EV Scalars button.
11. Click the tabs for years beyond 1995 to examine the EV Scalar values that were used during this Monte Carlo run.
12. Pick out the year with the highest EV Scalar value and notice that the resulting high escapement occurs several years later when the fish are mature.
13. Close the EV Scalar window.
14. Click the Wand button at the upper left of the Escapement Graph window.
15. Move the mouse pointer over other stock icons to produce Escapement Graphs for other stocks and observe their variable escapement.
16. Examine EV Scalars for other stocks also.

Discussion Questions

1. What fresh water environmental factors affect brood year survival rates?
2. What marine environmental factors affect brood year survival rates?
3. What types of human activities affect brood year survival rates?

3.7 - Shut down the fisheries!

Motivating Question

How quickly will weak stocks recover if all harvesting is stopped?

Analysis Approach

Use the meta-slider function to set all Harvest Rate Scalars (for each stock, fishery, year combination) to near zero (setting these scalars to zero might cause a program crash because it may create a "divide by zero" error). This will effectively eliminate all harvests.

How To Do It

1. Launch and run the model.
2. Click the Harvest Menu.
3. Click Harvest Rate Scalars.
4. Click the tab including year 2000.
5. Click the "Y Box", the "F Box", and the "S Box" at the top of the slider window.
6. For the year 2000, type in a Harvest Rate Scalar of 0.05 (do not use the sliders; they don't work properly). You may have to wait up to a minute for all the parameters to be changed.
7. Click apply and OK.
8. Click the Run button on the tool bar.
9. When the run is complete, set the Default Stock to Lyons Ferry (or another stock that had a declining escapement trend under the default management strategy).
10. Click the Stocks Menu.
11. Click Stock Graphs.
12. Click Escapements and observe the escapement trend.
13. Resize and move the Escapement Graph so the map icons are visible.
14. Click the Wand button at the upper left portion of the graph window.
15. Move the mouse pointer over other stock icons to observe escapement trends for other stocks.

Discussion Questions

1. How many stocks reach an equilibrium condition (i.e., a constant escapement trend) by year 2017?
2. Are there any stocks that do not increase when all fishing is eliminated?
3. How many years of a "no fishing" strategy would be needed to bring all stocks up to an acceptable escapement level?
4. How much lost revenue would the fishing fleets suffer under a "no fishing" strategy?

3.8 - Improve upstream survival around dams.

Motivating Question

Returning adult salmon on the Columbia River must pass over several large hydroelectric dams on their way to the spawning grounds. Even though all dams have fish ladders to help salmon over the dams, some mortalities still occur. How much does improving upstream survival of adults increase spawning escapements?

Analysis Approach

Prespawning mortalities are simulated in CRiSP Harvest by the IDL (inter-dam loss) parameters. The analysis approach is to record escapements for the Lyons Ferry stock under the default management strategy, change the future Lyons Ferry IDL parameters to simulate improved survival, re-run the model, and record the new escapement trend.

How To Do It

1. Launch and run the model.
2. Set the Default Stock to Lyons Ferry.
3. Click the Stocks Menu.
4. Click Stocks Graph.
5. Click Escapements.
6. Record the trend and value in year 2017 (or print the graph).
7. Close the Escapement Graph.
8. Click the Stock/Inter Dam Loss button.
9. Select the tab with year 2000.
10. Click the "Y Box" at the top of the window.
11. Set the IDL value for year 2000 to .900. This will increase the prespawning survival rate for the Lyons Ferry stock to 90% for all simulation years.
12. Click apply and OK.
13. Click the Run button on the tool bar.
14. Repeat steps 3 through 6 to observe the new escapements.

Discussion Questions

1. Do you think it is more effective to improve survival near the end of a fishes life (e.g., prespawning survival rates) or at the beginning (e.g., brood year survival rates)?

3.9 - Reducing ocean troll fisheries.

Motivating Question

Ocean fisheries are generally the least selective fisheries. That is, they tend to harvest the greatest number of stocks. How much will reducing ocean troll fisheries improve escapements of weak stocks?

Analysis Approach

We will drastically reduce the Alaska and West Coast of Vancouver Island troll fisheries and observe the effect on the Lyons Ferry stock and the Columbia River Net fishery.

How To Do It

1. Launch and run the model.
2. Set the Default Stock to Lyons Ferry.
3. Click the Stocks Menu.
4. Click Stocks Graph.
5. Click Escapements.
6. Record the Lyons Ferry Escapement in year 1998.
7. Close the Escapement Graph.
8. Repeat steps 2 through 7 to record the Upriver Brights escapement in year 1998.
9. Set the Default Fishery to Alaska Troll.
10. Click the Fishery Menu.
11. Click Fishery Graphs/Catches/Total.
12. Record the Alaska Troll catch for year 1998.
13. Close the catch graphs.
14. Repeat steps 9 through 13 to record the catches for the WCVI Troll and Columbia River Net fisheries in 1998.
15. Click Fishery/Catch Ceilings.
16. Select the Alaska Troll fishery.
17. Click the tab that contains year 1998.
18. Set the 1998 Alaska Troll Catch Ceiling to 50,000 and click apply.
19. Repeat steps 16 through 18 to set the 1998 WCVI Catch Ceiling at 50,000.
20. Click run the model.
21. Repeat steps 2 through 14 to record the 1998 escapements for the Lyons Ferry stock and the 1998 catches in the Alaska Troll, WCVI Troll, and the Columbia River Net fisheries.

Discussion Questions

1. How much did the Lyons Ferry escapement go up in 1998?
2. What happened to the Columbia River Net fishery catch in 1998? Why?

Chapter 4. Theory

Table of Contents

4.1 - Introduction

Computation Flow

Life cycle computations in CRiSP Harvest are performed on an annual basis. The sequence of computations reverses the procedures employed in the cohort analysis used to generate the stock-specific input data. The annual computational sequence is illustrated in Fig. 4.1 and outlined below:

- Population ageing
- Natural ocean mortality
- Preterminal (ocean) fishing mortality
    - Legal harvest
    - Incidental mortality (shakers and CNRs)
- Maturation
- Terminal fishing mortality
    - Legal harvest
    - Incidental mortality (shakers and CNRs)
- Adult escapement (ages 3, 4, and 5)
- Pre-spawning mortality (inter-dam losses) for some stocks
- Spawning escapement
- Production of progeny in the next year.

Incidental fishing mortalities include "shakers" (sub-legal sized fish caught and released during chinook fisheries) and "CNRs" (legal and sub-legal sized fish caught and released during "chinook non-retention" fisheries directed at other species (e.g., coho).

The remaining five sections of this chapter describe the functional relationships of the model. Natural survival processes are described first, followed by production processes, fishing processes, catch ceiling management, and in-river management.

Although many of the parameters are year specific, year indices have been deleted to make the equations easier to interpret. Brief descriptions of all variables follow each equation.
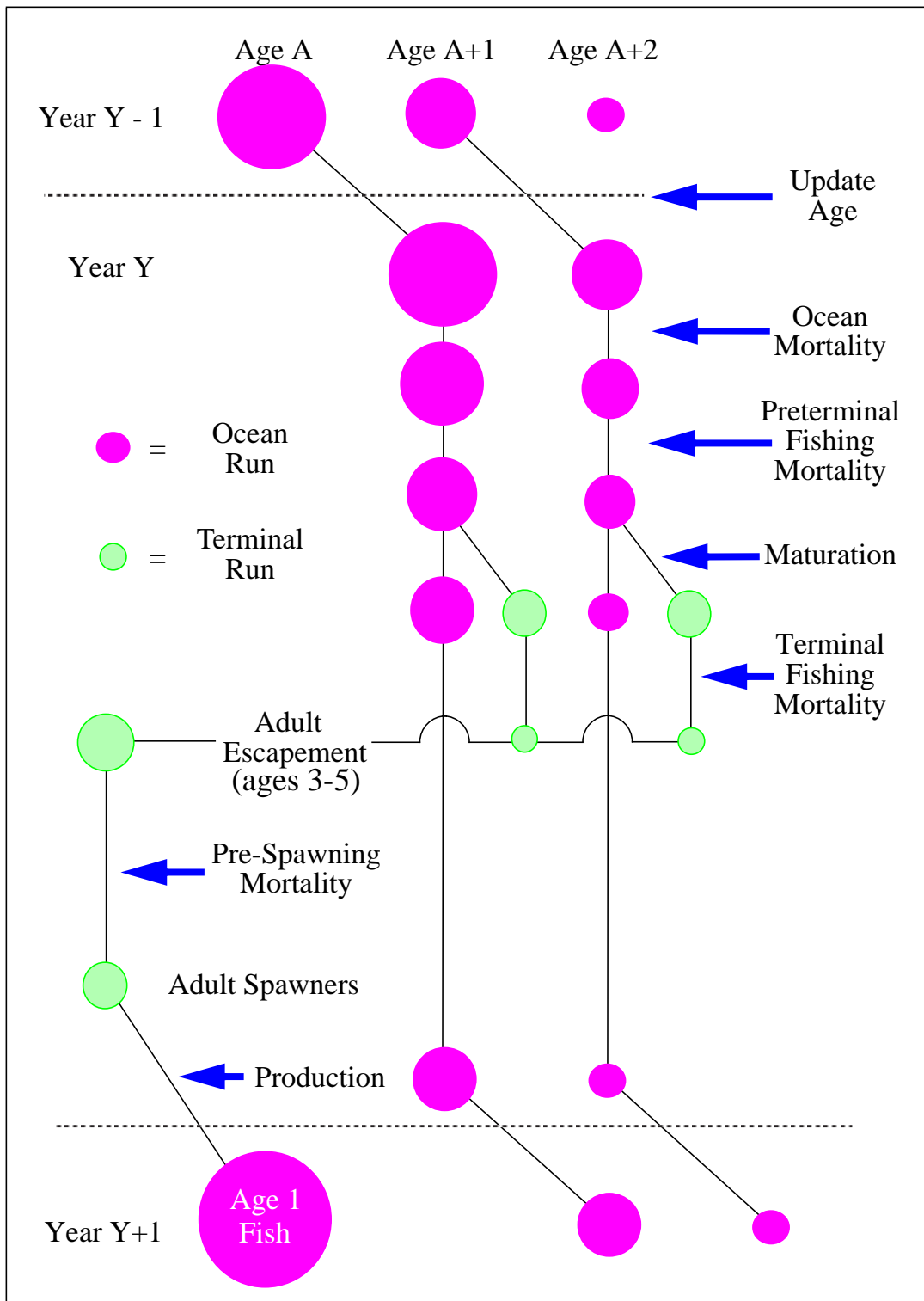
Fig. 4.1 Illustration of the annual computation cycle in CRiSP Harvest.

4.2 - Biological Processes

Natural Ocean Mortality

Non-fishing and fishing mortalities occur independently and at different times of the year. For most stocks, non-fishing mortality is composed entirely of natural ocean mortality and is assessed at the beginning of each year. For Columbia River stocks that spawn upriver from dams, additional non-fishing mortality (called pre-spawning mortality or inter-dam losses) is assessed after fishing mortality to account for losses between dams (Fig. 4.2).
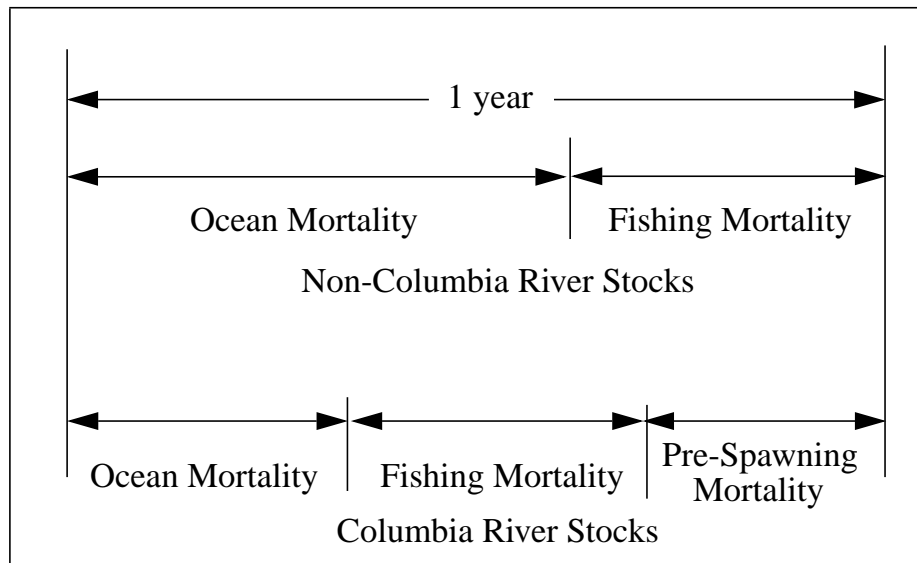
Fig. 4.2 Assessment of mortalities during one year.

Natural ocean mortalities are age specific, but not stock specific. For example, age two fish from all stocks have the same natural ocean mortality, or survival, rate. Thus, at the start of each year, ocean run sizes for each cohort are updated as follows:

$$OcnRun(s, a) \ = \ Cohort(s, a)OcnSurvRt(a) \qquad (4.1)$$

where

- *OcnRun(s,a)* = ocean run size of stock *s*, age *a*
- *Cohort(s,a)* = cohort size of stock *s*, age *a* at the start of the year
- *OcnSurvRt(a)* = natural ocean survival rate for age *a*.

The following description of natural mortality estimation procedures is taken from CTC (1988). Direct estimates of natural (non-catch) mortality for chinook salmon are lacking. The numbers used in the cohort analysis were chosen to conform to the numbers used in the Georgia strait virtual population

analysis (Argue et al., 1982--spreadsheet version). Specifically, the argue paper used a natural mortality of 1.5% per month for ages three to five and 3% per month for age two. These values calculate to 31% and 17% per year for age two and ages three through five, respectively.

In 1982, when these cohort analysis procedures were begun (undocumented), it was decided to use stepped values of mortality by age. The values chosen are given in Table 4.1 The mean of the values used for ages three through five is 20% (similar to the 17% used in the Argue paper). The 40% continues the stepped progression.

Table 4.1 Natural ocean mortality and survival rates for ages 1-5.

Age (*a*)	*OcnMortRt(a)*	*OcnSurvRt(a)*
1	.5	.5
2	.4	.6
3	.3	.7
4	.2	.8
5	.1	.9

Maturation

Stocks mature at ages two through five and begin their return migration to the spawning grounds. Maturation rates are stock and age specific. The mature fish in each cohort are called the terminal run.

$$TermRun(s, a) = (OcnRun(s, a) - PreTermMort(s, a))MatRt(s, a) \qquad (4.2)$$

where

- *TermRun(s,a)* = terminal run for stock *s*, age *a*
- *PreTermMort(s,a)* = preterminal fishing mortalities for stock *s*, age *a* (over all fisheries)
- *MatRt(s,a)* = maturation rate for stock *s*, age *a*.

Recent analyses indicate that age specific maturation rates can vary substantially from year to year for some stocks. When annual maturation rate estimates are available, they are allowed to vary each year in the model.

Adult Escapement

Terminal run fish must pass two obstacles before reaching the spawning grounds: (1) terminal fisheries; and (2) river obstructions, such as dams. Fish passing all terminal fisheries are called the adult escapement. The age two fish returning to the river are not considered reproductively viable, and are not included in the adult escapement for each stock.

$$AdltEsc(s) = \sum_{a=3}^{5} (TermRun(s, a) - TermMort(s, a)) \qquad (4.3)$$

where

- *AdltEsc(s)* = adult escapement for stock *s*
- *TermMort(s,a)* = terminal fishing mortalities for stock *s*, age *a* (over all fisheries).

Pre-Spawning Mortality

Three stocks, all from the Columbia River system (Upriver Brights, Spring Creek, and Lyons Ferry), are assessed pre-spawning mortality (also called "Inter-Dam Losses"). All other stocks have 100% survival between the terminal fishing area and the spawning grounds. Pre-spawning mortality is applied to the total adult escapement as follows:

$$Spawners(s) = AdltEsc(s)PreSpSurvRt(s) \qquad (4.4)$$

where

- *Spawners(s)* = number of spawners for stock *s*
- *PreSpSurvRt(s)* = pre-spawner survival rate for stock *s*.

Note that all age classes in the adult escapement are assessed the same mortality rate. Thus, the model assumes that age and size have no influence on the upstream survival rate.

4.3 - Production Processes

Overview

For each stock, the relationship between *Spawners* in year *y* and progeny (termed *AgeOneFish*) in year *y* + 1 is perhaps the most critical component of the model. It is through this relationship that time dynamics are incorporated into the analysis of alternative stock rebuilding strategies.

Stocks in the PSC Chinook Model are divided into two categories based on their production type: hatchery or natural. In general, hatchery production is modeled as a simple linear relationship between *Spawners* and *AgeOneFish* while natural production is modeled by a truncated Ricker curve relating spawners to adult recruitment, which is then corrected to *AgeOneFish* through a procedure outlined in detail later.

For both types of stocks, *AgeOneFish* are adjusted to make allowances for recruitment variability by incorporating "Environmental Variability" (EV) scalars. EV scalars can be thought of as pre-recruitment (i.e., prior to age one) survival scalars that compensate for both environmental variation and any bias in the original production parameter estimates. EV scalars for the calibration period are determined during calibration, while EV scalars for the simulation period are specified by the user. Model results are known to be very sensitive to the choice of EV scalars during the simulation period.

Hatchery Production

A simple linear model is used to relate hatchery spawners in year *y* to *AgeOneFish* in year *y* + 1. When the number of spawners does not exceed hatchery capacity, we have

$$AgeOneFish(s, y + 1) \ = \ Spawners(s, y) \cdot e^{HatchProd(s)} \qquad (4.5)$$

where

- *AgeOneFish(s,y+1)* = number of progeny for stock *s* in year *y* + 1.
- *Spawners(s,y)* = number of spawners for stock *s* in year *y*.
- *HatchProd(s)* = base period hatchery production efficiency for stock *s*.

The *HatchProd(s)* parameter is given in exponential form because the analogous productivity term in the Ricker function for natural stocks is represented in exponential form. If *Spawners(s,y)* > S_{opt} (= average hatchery

production during the base period 1979-1981), the excess spawners are transferred into terminal catch.

The model assumes that hatchery production is maintained at the average 1979-1981 level unless instructed otherwise. In such cases, the first step in modeling changes in enhancement activities (which are input as changes in smolt production) is to compute the increased (or decreased) number of spawners required to meet the new smolt production goal:

$$EnhSpawners(s) = \frac{Smolts(s) \cdot SmoltSurvRt(s)}{e^{EnhProd(s)}} \qquad (4.6)$$

where

- *Smolts(s)* = change in smolt production for stock *s*
- *EnhSpawners(s)* = number of required to produce *Smolts(s)*
- *SmoltSurvRt(s)* = smolt to age on survival rate for stock *s*
- *EnhProd(s)* = enhancement production efficiency for stock *s*.

EnhProd(s) is generally smaller than *HatchProd(s)*, reflecting the decrease in efficiency when producing more smolts.

If production is decreased, eq (4.5) is used to compute *AgeOneFish,* but the hatchery spawning goal is reduced to S_{opt} - *EnhSpawners*. Again, excess spawners are transferred to terminal catch.

If production is increased, additional *AgeOneFish* are computed using eq (4.5), with *EnhProd* replacing *HatchProd* to reflect the lower production efficiency. If the number of spawners exceeds the number required for both base and enhanced production, the excess spawners are added to the terminal catch, with the exception of one stock --Georgia Strait Hatchery (GSH). In this case, the additional spawners (up to a maximum of 5,000) are assumed to be returned to the river and are modeled as natural spawners using the truncated Ricker curve (described in the next section). Additional excess spawners are transferred to terminal catch. Fig. 4.3 illustrates all hatchery production functions.
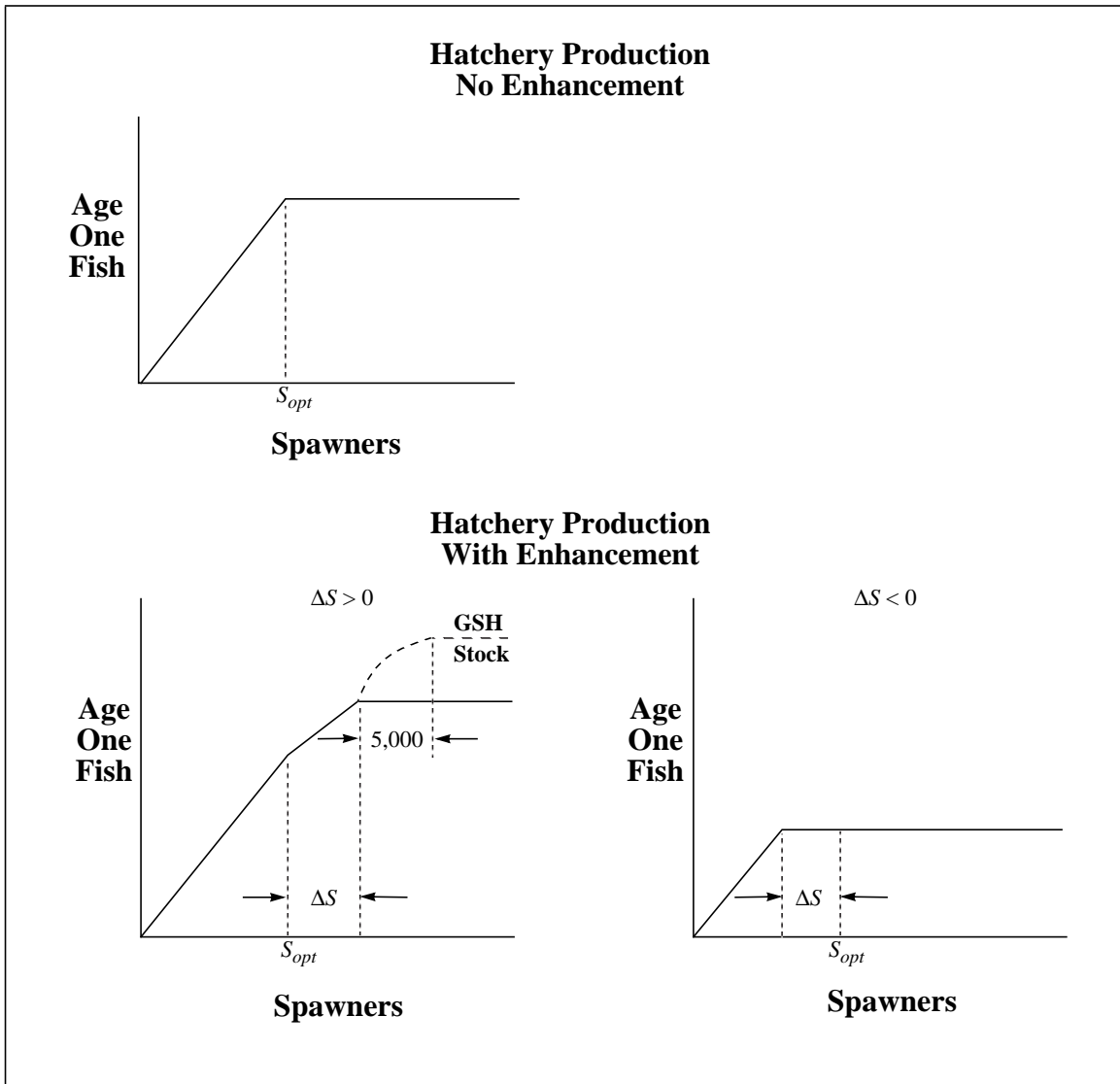
Fig. 4.3 Hatchery production functions, with and without enhancement. The term ΔS equals *EnhSpawners* (i.e., the change in the number of spawners required to meet the changed smolt production goal).

Natural Stocks

All natural stocks incorporate a truncated Ricker Spawner/Recruit Relationship (SRR) relating spawners to adult equivalent recruitment. The general form of the Ricker SRR is:

$$Recruits = (Spawners)e^{\alpha\left(1 - \frac{Spawners}{\beta}\right)} \qquad (4.7)$$

where

- *Spawners* = number of adult spawners on the spawning grounds
- *Recruits* = number of adults recruiting to the fishery
- α = productivity parameter
- β = capacity parameter.

The general form of the Ricker SRR is illustrated in Fig. 4.4. The slope of the curve at the origin is e^α and β is the spawning level at the point where the SRR intersects the exact replacement line (in most cases, this is equivalent to the equilibrium condition in the absence of harvesting).
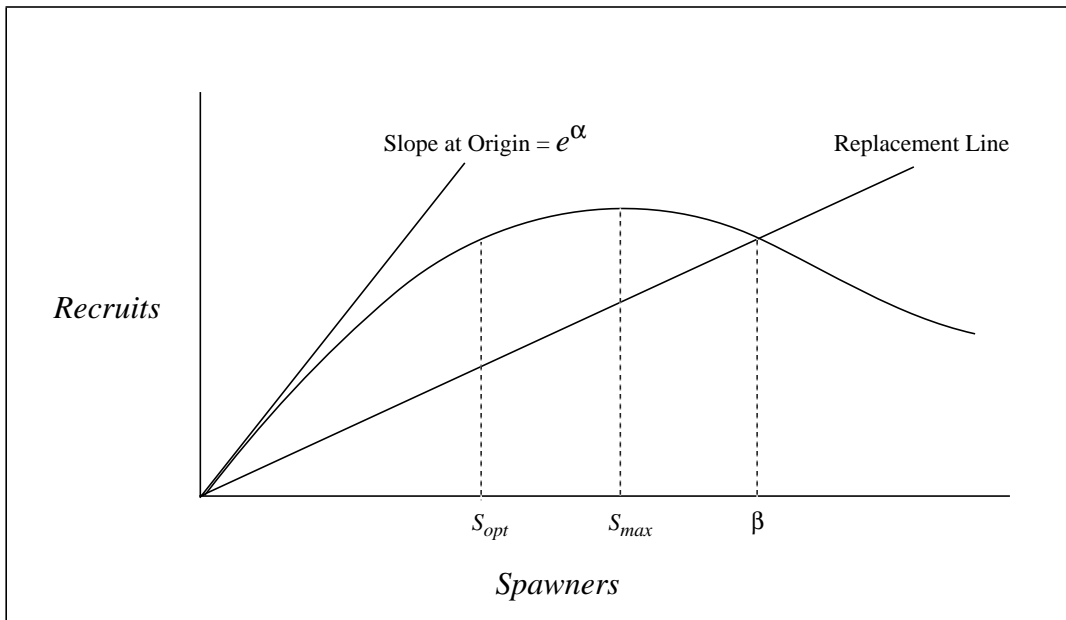
Fig. 4.4 Typical Ricker spawner-recruit relationship. S_{opt} is the spawning level that produces maximum sustainable harvest (i.e., maximum difference between recruitment and exact replacement line), S_{max} produces the maximum number of recruits, and β is the equilibrium spawning level in the absence of harvest.

For each stock, the input data files provide α, but not β. Instead the model inputs the estimated optimum number of spawners (S_{opt}), as determined from historical data and field observations. The Ricker β parameter is then computed from S_{opt} and α using the approximation given by Hilborn (1985):

$$\beta = \frac{S_{opt}}{0.5 - 0.07\alpha} \tag{4.8}$$

Maximum production (S_{max}) is given by

$$S_{max} = \frac{\beta}{\alpha} \qquad (4.9)$$

Note that *Recruits* in eq (4.7) includes ages two through five. For modeling purposes, it is necessary to simulate the production of *AgeOneFish*, not the mature fish recruiting to the fishery. For chinook salmon stocks, several year classes may contribute to the spawning stock. In the equilibrium condition with no fishing, the age distribution is stationary and there is a constant linear relationship between adult recruitment and *AgeOneFish* (Fig. 4.5).
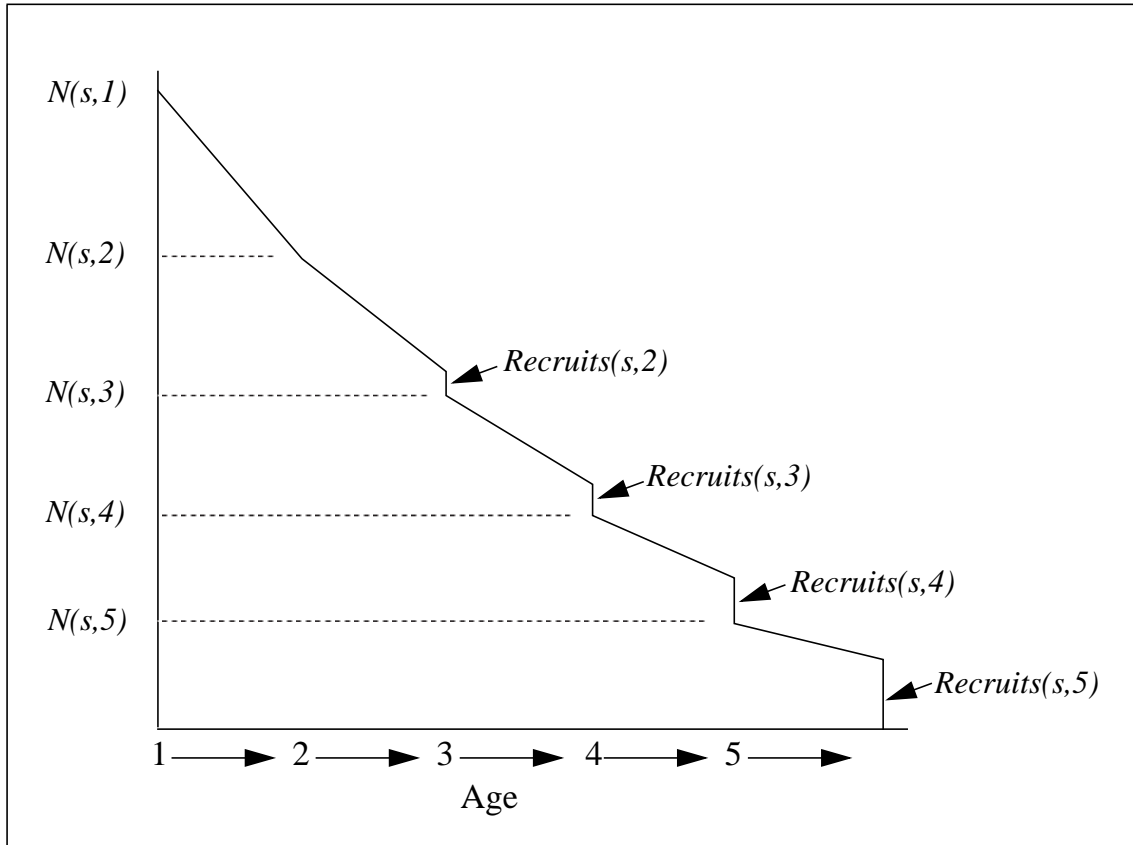
Fig. 4.5 Illustration of abundance and recruitment when there is no fishing mortality and the age distribution is stationary.

For ages three, four and five, the abundance at the start of each year and the number of mature fish returning to spawn are given by

$$N(s, a) = N(s, a-1)SurvRt(s, a-1)(1 - MatRt(s, a-1)) \qquad (4.10)$$

$$Recruits(s, a) = N(s, a)SurvRt(s, a)MatRt(s, a) \qquad (4.11)$$

The model relates spawners to *AgeOneFish* by computing a constant scaling factor called *RecAtAge1*. This value is computed by setting *N(s,1)* equal to one

and recursively computing $N(s,a)$ using eq (4.10) and summing $Recruits(s,a)$ for ages two through five:

$$RectAtAge1(s) = \sum_{a=2}^{5} Recruits(s, a) \tag{4.12}$$

When maturation rates are permitted to vary by year, new *RectAtAge1* parameters are computed each year. The number of AgeOneFish is computed by:

$$AgeOneFish(s) = \frac{Recruits(s, a)}{RectAtAge1(s)} \tag{4.13}$$

For natural stocks without supplementation, the Ricker SRR is truncated at either S_{opt} or S_{max} (Fig. 4.6).

Fig. 4.6 Truncated Ricker curves used for natural production with no enhancement.

Supplementation

The model allows for enhancement of natural stocks (also called supplementation) in which a portion of the natural spawners are removed for hatchery production. The number of spawners removed may not exceed a maximum allowable percentage of the adult spawners.
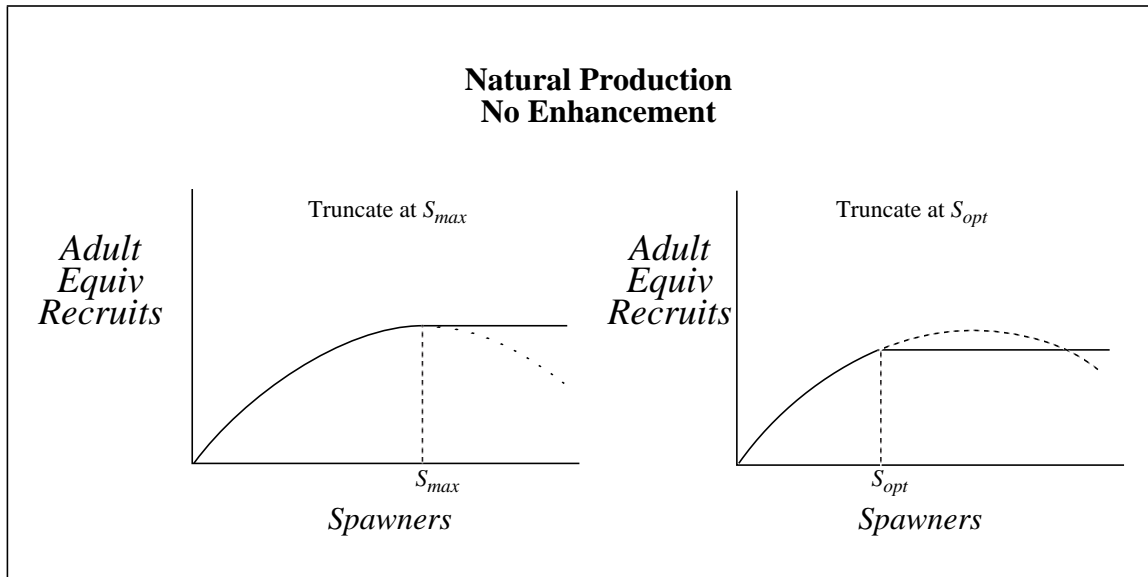
$$MaxBrood(s) = EnhProp(s) \cdot Spawners(s) \tag{4.14}$$

where

- *MaxBrood(s)* = maximum number of spawners that can be removed for supplementation for stock *s*.
- *EnhProp(s)* = maximum enhancement proportion for stock *s*.

Smolts from hatchery production are returned back to the river of origin, and therefore may compete with the naturally produced smolts. This competition may be modeled as either density dependent or density independent. In either case, the number of spawners required to meet the smolt production goal (*EnhSpawners*) is computed using eq (4.6), just as for hatchery stocks, truncating to *MaxBrood*, if necessary.

When density independence is assumed, natural and hatchery production are computed independently and added together. The naturally produced portion of *AgeOneFish* is computed from the remaining natural spawners (i.e., *Spawners(s) - EnhSpawn(s)*) using the appropriate truncated Ricker curve (Fig. 4.6). Hatchery produced portion of *AgeOneFish* is computed as follows:

$$AgeOneFish(s, y+1) = EnhSpawners(s, y) \cdot e^{EnhProd(s)} \qquad (4.15)$$

When density dependence is assumed, *AgeOneFish* is computed using a truncated Ricker curve (Fig. 4.6), but the "effective" size of the spawning stock is increased to reflect the fact that eggs from some of the spawners are reared in a hatchery. The enhancement efficiency of the hatchery is given by

$$EnhEff(s) = \frac{e^{HatchProd(s)}}{e^{\alpha(s)}} \qquad (4.16)$$

In general, *HatchProd(s)* is greater than $\alpha(s)$ so *EnhEff(s)* is usually greater than one. The effective number of spawners is given by

$$EffSpawners = EnhSpawn\frac{EnhEff}{\alpha} + (AdltEsc - EnhSpawn) \qquad (4.17)$$

**Natural Production
With Enhancement**

Density Dependent

Density Independent

Recruits

Recruits

*Hatchery
Production*

*Hatchery
Production*

*Natural
Production*

*Natural
Production*

S

S

*Natural
Spawners*

*Natural
Spawners*

*Effective Hatchery
Spawners*

*Spawners Removed
To Hatchery*

*Spawners Removed
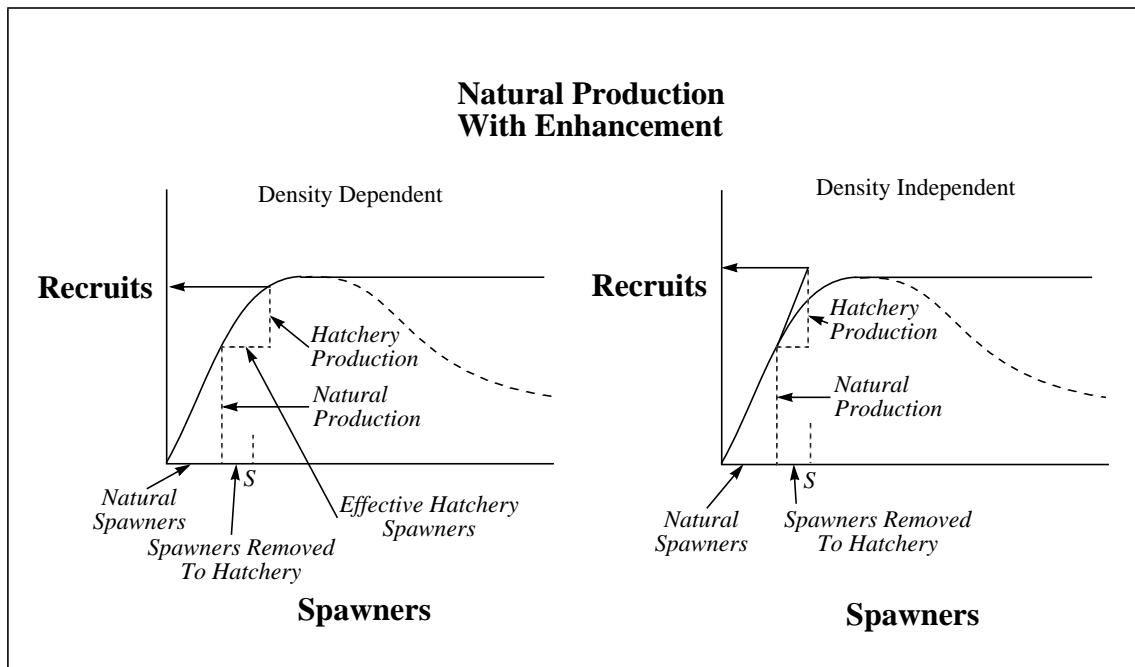To Hatchery*

Spawners

Spawners

Fig. 4.7 Production functions for natural stocks with enhancement. Ricker curves truncated at S_{max} are shown. Other stocks may have the Ricker curve truncated at S_{opt}.

4.4 - Fishing Mortality

Three types of fisheries are modeled in CRiSP Harvest: troll, net, and sport. Troll and net fisheries are commercial fisheries. The net category includes both purse seine and gillnet fisheries.

Fishing mortality rates are estimated using cohort analysis based on coded-wire-tag (CWT) recoveries and are stock, age, and fishery specific. The estimation procedure is explained in more detail in the next section.

Two types of fishing mortality rates are distinguished. "Exploitation Rates" are expressed in terms of total coastwide abundances, not regional abundances. Thus, an exploitation rate of 0.10 for a given stock, age, and fishery means that 10% of the coastwide abundance of that stock/age cohort is harvested in the given fishery. "Harvest Rates" refer to fishing mortality rates in terminal areas where the regional abundance (i.e., true terminal run) of the stock is known.

Mortalities associated with fishing activities are assessed in two phases—preterminal and terminal—corresponding to the two primary life history phases of each cohort—immature and mature. Within each phase there are legal harvests and incidental mortalities. Incidental mortalities are caused by (1) the inadvertent capture of sublegal sized fish during fisheries targeting on chinook salmon (called shaker mortalities) and (2) the inadvertent capture of sublegal- and legal-sized chinook salmon during fisheries targeting on other salmon species (called chinook non-retention, or CNR, mortalities).

Estimating Fishing Mortality Rates

Parameters are estimated by a technique known as "cohort analysis" or "virtual population analysis". A cohort, in this context, is the total production which results from the escapement of a single year class from a particular group of fish. This type of analysis involves the reconstruction of an annual series of abundance estimates using the following data:

- Catch at age data from fisheries of interest
- Assumptions regarding incidental mortality rates and losses associated with these catches
- Escapements at age data
- Expansion of escapements to account for straying and pre-spawning mortality rates for some stocks
- Assumed rates of natural mortality
- Assumptions regarding the maturity of fish in the catch (i.e., differentiating between terminal and preterminal fisheries).

Data from CWT experiments are employed to produce a profile of harvest and escapement for the entire production of a stock. Data are analyzed through a backwards-stepping procedure, beginning with the oldest age class (assumed to be age five). Escapement, an estimate of pre-spawning mortality (when appropriate) and the terminal catch (including associated incidental mortality) are added to produce a mature run size for that age class. The ocean catches of that age class, associated incidental mortalities, and the cohort size of the next older age class are added to compute the size of the population immediately prior to fishing. This sum is then divided by the survival rate (1 - natural mortality) to give the cohort size for that age class. These calculations are summarized in Fig. 4.8.

Escapement (*a*)
    + Pre-Spawning Mortality (*a*)
    + Terminal Catch (*a*)
    + Incidental Terminal Mortality (*a*)
= Mature Run Size (*a*)
    + Preterminal Catch (*a*)
    + Incidental Preterminal Mortality (*a*)
    + Cohort Abundance (*a* + 1)
= Abundance of age *a* fish immediately prior to ocean fishery

Fig. 4.8 Calculations used in cohort analysis.

Once each cohort has been reconstructed, the following parameters can be estimated:

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

At this stage of development, CRiSP Harvest is a forecasting model and does not estimate parameters. It relies completely on parameters estimated by the PSC Chinook Technical Committee.

Preterminal vs Terminal Fishing Mortalities

All fishing mortalities are computed at the stock/age/fishery level, and thus the model must keep track of which stock/age/fishery mortalities are to be considered preterminal and which terminal. The preterminal/terminal designations are determined by three variables entered at startup and do not change throughout the simulation time period.

Fisheries that harvest only mature individuals from certain stocks are designated "terminal" for those stocks. For example, the Columbia River net fishery is considered terminal for all ages of all stocks of Columbia River origin. Some fisheries are terminal for some stocks and preterminal for others. For example, the Columbia River sport fishery is considered terminal for Columbia River stocks, but preterminal for the Oregon coastal stocks, which it also harvests.

On startup, the model reads in a two dimensional array of boolean characters, called *TermPt(s,f)* for "Terminal Pointer", to identify stock/fishery combinations for which all ages are to be considered terminal. Terminal fisheries and the stocks they harvest by geographic region are listed in Table 4.2.

All troll fisheries are considered preterminal for all ages of all stocks they harvest. Net fisheries are more complicated. Some ocean net fisheries harvest both immature and mature ages from the same stock. For example, the nearshore ocean waters where some net fisheries operate are habitat for immature ages and for mature ages returning to spawn. At startup, the model sets the age at which all harvests by net fisheries are to be considered mature. The variable is called the *TermNetAge* and is usually set at age four.

In summary, the model uses three variables to determine whether a stock/age/fishery harvest is preterminal or terminal: *TermPt*, *OcnNetFlg*, and *TermNetAge*. Table 4.3 summarizes the relationship between these variables for a given stock/fishery combination.

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Table 4.2 Stock/fishery interactions considered terminal for all ages.

Region	Terminal Fisheries	Stocks
Fraser River	Fraser Net	Fraser River Early Fraser River Late
West Coast Vancouver Island	WCVI Net WCVI Sport	WCVI Hatchery WCVI Natural
Puget Sound	Puget Sound North Net Puget Sound South Net	Nooksack Fall Puget Sound Fingerling Puget Sound Natural Puget Sound Yearling Nooksack Spring Skagit Wild Stillaguamish Wild Snohomish Wild
Washington Coast	Washington Coast Net	Wash Coastal Hatchery Wash Coastal Wild
Columbia River	Columbia River Net Columbia River Sport	Upriver Brights Spring Creek Hatchery Lower Bonneville Hatchery Fall Cowlitz Hatchery Lewis River Wild Willamette River Spring Cowlitz Hatchery Columbia River Spring Lyons Ferry

Table 4.3 Preterminal/terminal harvest criteria.

	OcnNetFlg = **FALSE**	*OcnNetFlg* = **TRUE**
TermPT = FALSE (Preterminal)	All ages preterminal	Ages < *TermNetAge* are preterminal Ages >= *TermNetAge* are terminal
TermPT = TRUE (Terminal)	All ages terminal	All ages terminal

Legal Harvests

Harvests of legal sized fish are computed as follows:

$$MDLCohortCat(s, a, f) \ = \ Run(s, a)HR(s, a, f)FP(s, f)PV(a, f) \quad (4.18)$$

where

- *MDLCohortCat(s,a,f)* = preterminal or terminal catch of stock *s*, age *a*, in fishery *f*
- *Run(s,a)* = coastwide ocean abundance, *OcnRun(s,a)*, or coastwide terminal run, *TermRun(s,a)*, for stock *s*, age *a*
- *HR(s,a,f)* = harvest rate for stock *s*, age *a*, in fishery *f*
- *FP(s,f)* = fishery policy scalar for stock *s* in fishery *f*
- *PV(a,f)* = proportion vulnerable for age *a* in fishery *f* (i.e., proportion of age *a* fish that are recruited to the gear and are above the legal size limit in fishery *f*).

Note that when preterminal harvests are computed, the stock/age/fishery specific exploitation rates are applied to the coastwide ocean abundance of the cohort, not the regional abundance. When terminal harvests are computed, the stock/age/fishery specific harvest rates are applied to the coastwide terminal run of the cohort. Terminal runs are computed by subtracting preterminal legal catches and incidental mortalities from the coastwide ocean abundance and then multiplying times the maturation rate.

Note that the *PV*s are age and fishery specific, but not stock specific. The *FP*s are fishery policy scalars and are unique to each stock, fishery, and year. They are used to simulate the effects of changes in fishery policies that disproportionately impact different stocks relative to the base period (e.g., changing the timing of the fishing period may impact stocks differently). For example, a value of *FP(2,3)* = 0.5 indicates that the harvest rates for all ages of stock 2 in fishery 3 are 50% of the corresponding base period harvest rates. Other stocks harvested by fishery 3 may be impacted differently.

Estimating Proportion Vulnerable

The following description is taken from CTC (1988).

The calculation of incidental mortalities associated with size limit restrictions depends critically upon the estimation of the proportion of each stock that is vulnerable (PV) in a particular fishery by age. Available data are not sufficient to permit estimation of stock-specific PVs. Therefore, age-size distributions for large fishing areas were calculated from available data. CWT recoveries turned out to be the best source of this type of age-length data. This is because these data belong to a large (and easily available) data set that can be identified accurately as to age and catch location. A description of the procedure used to estimate the proportion vulnerable by age follows.

Due to the absence of sufficient, direct observational data on the size distribution of fish encountered by a particular fishery, age-length data from

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CWT tag recoveries were examined from troll and seine fisheries from Canada and some U.S. fisheries. Seine data were preferred because they are potentially the least size-selective of the fisheries. Troll CWT data were also examined. Canadian sport recoveries were not useful since most returns are from voluntary sources without sampling and consistent measuring procedures. Year-to-year variability seemed to be less than area-to-area variability; data across years were combined as well as some minor areas to produce specific age-size distributions. Seine data from Canadian fisheries appeared to lacking representative fish in the larger size classes while the troll data lacked fish in the smaller size classes (due to size limits). The two data sets were pooled to give large combined data sets for each region (e.g., West Coast Vancouver Island). Only the Alaska seine data were used to estimate the size distribution of chinook salmon encountered by the alaska troll fishery.

The estimated PVs were then adjusted using the PSC Chinook Model to estimate the encounter rates (non-retained/retained) for particular fisheries. These were then compared to field data collected in those fisheries (where available). The PVs were adjusted iteratively until they corresponded as closely as possible to the observed data.

The estimated PVs from the PSC model (by fishery) were then sorted by calendar year (and age) and became input data into the cohort analysis procedure. Size limit changes are represented by changes in the proportion vulnerable at age in the appropriate year.

Shaker Mortality

Many chinook salmon fisheries have size limits. Any captured chinook salmon whose length is below the size limit must be released, or "shaken" off the gear, hence the term "shakers." Some of the shakers survive, but others die due to the stress of being captured and released. The shaker mortality rate (i.e., the fraction of shakers that die) is gear dependent. Troll and sport gears cause relatively low shaker mortality, since the fish are captured individually and in many cases can be released without serious injury. Net fisheries cause higher shaker mortalities, because the capture process is more stressful.

Modeling stock/age/fishery specific shaker mortalities involves two estimation problems: (1) estimating the number fish from each stock/age cohort that are shaken in a given fishery, and (2) estimating the mortality rate for shaken fish. Since there are no landing records for shaken fish, both problems are difficult.

There are no estimates for age specific shaker mortality rates for chinook salmon, although the subject is currently being studied. Until improved estimates become available, the model sets the shaker mortality rates for troll and sport fisheries at 0.30 and for net fisheries at 0.90. These values are in the

range of accepted values agreed to by the full Chinook Technical Committee in 1986. Note that these rates are not age specific, and thus affect all ages equally.

Shaker Calculations

Calculating shaker mortalities consists of six steps. The procedure is identical for calculating both preterminal and terminal shaker mortalities. The steps are outlined below and further illustrated in Table 4.4.

Step 1

Compute the relative contribution of each stock in each fishery, called *StkWgt(s,f)*, as follows:

$$StkWgt(s, f) = \frac{FP(s, f) \sum_a MDLCohortCat(s, a, f)}{\sum_s FP(s, f) \sum_a MDLCohortCat(s, a, f)} \quad . \tag{4.19}$$

Note that the numerator is the catch of stock *s* by fishery *f* and the denominator is the total catch by fishery *f*. Note also that if all catches by fishery *f* are multiplied by a common scaling factor, call it *R*, the *StkWgt(s,f)* term is unchanged. This fact is useful in examining catch ceiling and fixed escapement management algorithms which require adjusting all catches by a fishery to meet management objectives.

Step 2

Compute *TotPNV(f)* and *TotPV(f)* for each fishery, as follows:

$$TotPNV(f) = \sum_s \sum_a N(s, a)PNV(a, f)StkWgt(s, f) \tag{4.20}$$

$$TotPV(f) = \sum_s \sum_a N(s, a)PV(a, f)StkWgt(s, f) \tag{4.21}$$

Note that these variables represent the total number of sublegal *(TotPNV(f))* and legal *(TotPV(f))* fish recruited to the gear in fishery *f*.

Step 3

Compute the encounter rate *EncRte(f)* for each fishery.

$$EncRte(f) = \frac{TotPNV(f)}{TotPV(f)} \tag{4.22}$$

Step 4

Compute *FracNV(s,a,f)* for each stock, age, and fishery.

$$FracNV(s, a, f) = \frac{StkWgt(s, f)N(s, a)PNV(a, f)}{TotPNV(f)} \tag{4.23}$$

Step 5

Compute the total shakers *TotShak(f)* for each fishery. Total shakers in fishery *f* is the product of the total catch by fishery *f* (the summation terms in the equation below) times the encounter rate times the shaker mortality rate.

TotShak(f) =

$$ShakMortRte(f)EncRte(f)\sum_{s}FP(s, f)\sum_{a}MDLCohortCat(s, a, f) \tag{4.24}$$

Note that if all the catches in a given fishery are multiplied by a common scaling factor, *TotShak(f)* is also multiplied by that factor.

Step 6

Compute shaker mortalities *Shakers(s,a,f)* for all stocks, ages, and fisheries by distributing total shakers across all cohorts.

$$Shakers(s, a, f) = FracNV(s, a, f)TotShak(f) \tag{4.25}$$

Table 4.4 Spreadsheet illustration of sample shaker calculations for a hypothetical fishery harvesting three stocks.

Stk	Age	Run	HR	PNV	Catch	StkWgt *Run	TotPV	TotPNV	FracNV	Shakers
1	2	20000	0.01	0.95	10	6233	312	5921	0.371	584
1	3	10000	0.06	0.50	300	3116	1558	1558	0.098	154
1	4	5000	0.10	0.10	450	1558	1402	156	0.010	15
1	5	1000	0.20	0.00	200	312	312	0	0.000	0
				Total	960					
		StkWgt(1) = 960/3081 =		0.312						
2	2	12000	0.10	0.95	60	4784	239	4544	0.284	448
2	3	8000	0.05	0.50	200	3189	1595	1595	0.100	157
2	4	4000	0.13	0.10	468	1595	1435	159	0.010	16
2	5	2000	0.25	0.00	500	797	797	0	0.000	0
				Total	1228					
		StkWgt(2) = 1228/3081 =		0.399						
3	2	5000	0.15	0.95	38	1449	72	1376	0.086	136
3	3	4000	0.12	0.50	240	1159	579	579	0.036	57
3	4	3000	0.15	0.10	405	869	782	87	0.005	9
3	5	1000	0.21	0.00	210	290	290	0	0.000	0
				Total	893					
		StkWgt(3) = 893/3081 =		0.290						
		Total over all stocks			3081		9374	15976	1.000	1575

Encounter Rate = 15976/9374 = 1.70

Sample FracNV(1,2) = 5921/15976 = 0.371

Total Encounters = 3081*1.70 = 5250

Total Shakers = 5250*0.30 = 1575

Sample Shakers(1,2) = 1575*0.371 = 584

Chinook Non-Retention Mortality

Several of the model fisheries that are subject to chinook catch ceilings, or quotas, also catch other species of salmon (coho, sockeye, pink, and chum). As chinook abundances increase or catch ceilings are reduced, the time required to catch the ceiling would be expected to be shortened. In order to provide continued access to other species, it is assumed that managers would permit the fishery to continue, but retention of chinook salmon would be prohibited. Such

fisheries are called chinook non-retention, or CNR, fisheries, and are listed below:

- Alaska troll
- Northern BC troll
- Central BC troll
- West Coast Vancouver Island troll
- Strait of Georgia troll
- Alaska net
- Strait of Georgia sport.

In each CNR fishery, the selectivity of the fishing gear for legal and sublegal size chinook salmon may decrease in response to changes in fleet behavior. These selectivities never approach zero however, and some of the chinook salmon caught and released would die, resulting in CNR mortalities. The model assumes that the shaker mortality rate in the legal fishery also applies to the CNR fishery. Note that since chinook of all sizes must be released in CNR fisheries, there are both legal and sublegal CNR mortalities. Thus, an important model assumption is that within each CNR fishery, all chinook have the same shaker mortality rate, regardless of size.

The model provides three alternative methods of computing CNR mortalities. The following sections describes the computations in detail.

CNR Mortality Computation Overview

The amount of fishing time during which chinook retention is prohibited depends on the abundance of other species. At this time, the model does not incorporate abundances and management regimes for other salmon species. However, it does use data from CNR fisheries to estimate CNR mortalities when available.

During the calibration period, the model estimates CNR mortalities by using either (1) direct observations of legal and sublegal chinook encounter rates in CNR fisheries or (2) season lengths for directed and CNR fisheries. When forecasting beyond the calibration period, the model uses relative harvest rates compared to base period harvest rates (during which there were no, or relatively few, CNR mortalities) to estimate CNR mortalities.

Although there are some observations on chinook encounters in CNR fisheries, there are no data on how those encounters are distributed among stock/age cohorts. In the absence of such data, each CNR method assumes that the ratios between the CNR mortalities (legal and sublegal) and mortalities in the legal fisheries (legal and sublegal) are equal for all stock/age cohorts in a fishery, as follows:

$$\frac{CNRSublegalCat(s, a, f)}{Shakers(s, a, f)} = CNRSublegalRatio(f) \qquad (4.26)$$

$$\frac{CNRLegalCat(s, a, f)}{MDLCohortCat(s, a, f)} = CNRLegalRatio(f) \qquad (4.27)$$

where

- *CNRSublegalCat(s,a,f)* = sublegal CNR mortalities for stock *s*, age *a*, in fishery *f*
- *Shakers(s,a,f)* = shaker mortalities for stock *s*, age *a*, in fishery *f* computed by the model
- *CNRLegalCat(s,a,f)* = legal CNR mortalities for stock *s*, age *a*, in fishery *f*
- *MDLCohortCat(s,a,f)* = legal preterminal or terminal catch of stock *s*, age *a*, in fishery *f* computed by the model, depending on whether preterminal or terminal CNR mortalities are being computed.

Once the ratios are determined, the sublegal ratio is multiplied by the shakers to get the sublegal CNR mortalities and the legal ratio is multiplied by the legal catch and the shaker mortality rate to get the legal CNR mortalities (remember, the *Shakers()*s already have the shaker mortality rate applied whereas the *MDLCohortCat()*s do not). Again, note the assumption that the shaker mortality rate applies to all sizes. Rearranging terms, we have:

$$CNRSublegalCat(s, a, f) =$$

$$CNRSublegalRatio(f)Shakers(s, a, f) \qquad (4.28)$$

$$CNRLegalCat(s, a, f) =$$

$$CNRLegalRatio(f)MDLCohortCat(s, a, f)ShakMortRte(f) \qquad (4.29)$$

Each method uses a different technique for computing the legal and sublegal ratios. Fig. 4.9 illustrates the types of data used by each CNR computation method.

The *RelHR*s in Fig. 4.9 are generated by the model, as described in the Ceiling Management section. They are the ratios that adjust the catches in ceilinged fisheries to match the specified catch ceilings (remember that all CNR fisheries are ceilinged fisheries).

Equations (4.30) and (4.31) show the assumed relationships on which the actual calculations are based.

$$\frac{1 - RelHR}{RelHR} = \frac{LegalSeasonLen}{CNRSeasonLen} = \frac{RPTSublegalEnc}{(EncRte)(RptCatch)} \qquad (4.30)$$

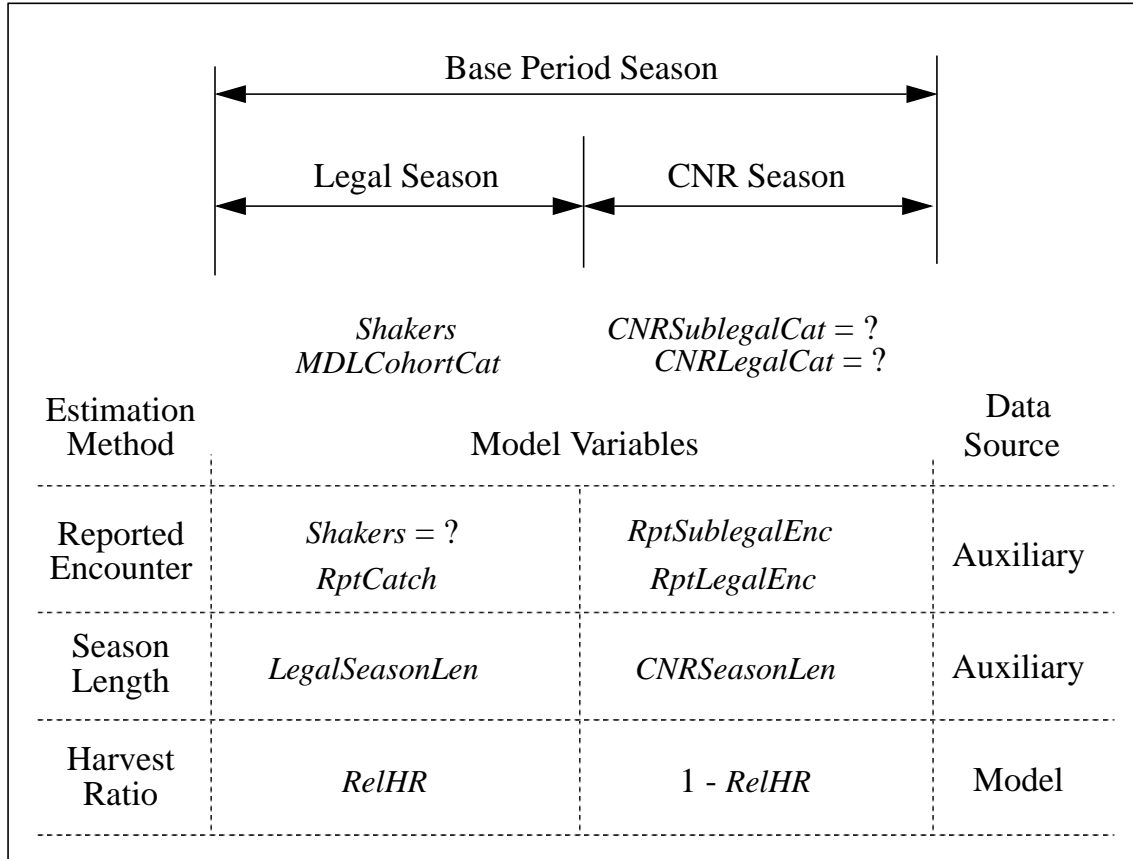$$\frac{1 - RelHR}{RelHR} = \frac{LegalSeasonLen}{CNRSeasonLen} = \frac{RPTLegalEnc}{RptCatch} \qquad (4.31)$$

Base Period Season

Legal Season | CNR Season

Shakers
MDLCohortCat

CNRSublegalCat = ?
CNRLegalCat = ?

Estimation Method	Model Variables		Data Source
Reported Encounter	*Shakers = ?* *RptCatch*	*RptSublegalEnc* *RptLegalEnc*	Auxiliary
Season Length	*LegalSeasonLen*	*CNRSeasonLen*	Auxiliary
Harvest Ratio	*RelHR*	*1 - RelHR*	Model

Fig. 4.9 Variables and data sources used in calculating CNR mortalities.

Harvest Ratio Method

This method estimates CNR mortality through *RelHR(f)* factors generated by the model for each ceilinged fishery *f*. These factors represent the ratio between harvest rates associated with a catch ceiling and base period rates. Consequently, *RelHR(f)*s can be considered as surrogate indicators for season length in fishery *f*. If the harvest ratio method is selected, the model estimates CNR mortality of legals and sublegals by multiplying mortalities associated with the catch ceiling by the selectivity scalars and mortality rates appropriate for the gear involved. This method is generally applied when no other data are available or when projecting regimes into the future. Ratios are calculated as follows:

$$CNRSublegalRatio(f) \,=\, CNRSublegalSel(f)\frac{1-RelHR(f)}{RelHR(f)} \qquad (4.32)$$

$$CNRLegalRatio(f) \,=\, CNRLegalSel(f)\frac{1-RelHR(f)}{RelHR(f)} \qquad (4.33)$$

The *CNRSublegalSel(f)*s and *CNRLegalSel(f)*s are selectivity scalars used to compensate for changes in fleet behavior during CNR restrictions. Scalar values are all relative to 1.0 (no change). For example, setting *CNRLegalSel(f)* = 0.34 indicates a 66% reduction in impacts on legal-sized chinook during CNR fisheries compared to fisheries allowing chinook retention.

Season Length Method

This method uses the ratio of the regular season length to the CNR season length to estimate CNR mortalities.

$$CNRSublegalRatio(f) \,=\, CNRSublegalSel(f)\frac{CNRSeasonLen(f)}{LegalSeasonLen(f)} \qquad (4.34)$$

$$CNRLegalRatio(f) \,=\, CNRLegalSel(f)\frac{CNRSeasonLen(f)}{LegalSeasonLen(f)} \qquad (4.35)$$

where

- *CNRSeasonLen(f)* = length of the CNR fishery season (in days) for fishery *f*
- *LegalSeasonLen(f)* = length of the legal fishery season (in days) for fishery *f*.

Reported Encounter Method

This method requires direct observations of encounters of legal and sublegal (shaker) chinook during CNR fisheries and knowledge of the chinook catch during the directed fishery. From these observations one can compute the ratios of legal chinook encountered during CNR fisheries to the catch during the directed fishery. Same for the sublegal ratio. The predicted directed chinook catch from the model is then multiplied by these ratios to get predicted legal and sublegal CNR mortalities.

$$CNRSublegalRatio(f) \,=\, \frac{RptSublegalEnc(f)}{EncRte(f)RptCatch(f)} \qquad (4.36)$$

$$CNRLegalRatio(f) = \frac{RptLegalEnc(f)}{RptCatch(f)} \qquad (4.37)$$

where

- *RptSublegalEnc(f)* = reported encounters of sublegal-sized chinook (numbers of fish) in fishery *f* when it is illegal to retain chinook
- *RptLegalEnc(f)* = reported encounters of legal-sized chinook (numbers of fish) in fishery *f* when it is illegal to retain chinook.

4.5 - Catch Ceiling Management

Overview

The primary management tool of the Pacific Salmon Commission is the use of catch ceilings. A catch ceiling consists of an upper limit on the numerical catch for a fishery, or group of fisheries, for a specified time period. For example, the 1991 catch ceiling (upper limit) for the combined Southeast Alaska troll, net, and sport fisheries was 273,000 chinook. Note the following:

- catch ceilings are not established for individual stocks
- catch ceilings may include fisheries that are considered preterminal for some stocks but terminal for other stocks.

The PSC Chinook Model only allows catch ceilings to be applied to individual fisheries. Fisheries that have ceiling management are identified during data input (Table 4.5).

Table 4.5 Fisheries with ceiling management.

Fishery	Harvest Types
Alaska Troll	Preterminal
Northern B.C. Troll	Preterminal
Central B.C. Troll	Preterminal
WCVI Troll	Preterminal
Washington/Oregon Troll	Preterminal
Strait of Georgia Troll	Preterminal
Alaska Net	Preterminal and Terminal
Northern B.C. Net	Preterminal and Terminal
Central B.C. Net	Preterminal and Terminal
Alaska Sport	Preterminal
North/Central B.C. Sport	Preterminal
Washington Ocean Sport	Preterminal
Strait of Georgia Sport	Preterminal

For each ceilinged fishery, ceilings are specified for each year of the simulation. During each simulation year, if the sum of the computed individual stock catches using input harvest rates (as modified by any fishery policy

factors) does not exceed the ceiling amount, the ceiling has no effect (i.e., the stock abundance is such that the ceiling will not be reached given the specified stock exploitation rates). The model also allows ceilings to be "forced," or modeled as a fixed catch. A forced ceiling is called a "quota" and is taken every year regardless of the stock abundance. Most catch ceilings are modeled as quotas.

CRiSP Harvest uses a slightly different algorithm from the PSC model, but the net effect is the same. The CRiSP Harvest algorithm is described here, with significant differences from the PSC version noted.

Setting Catch Ceilings

For catch ceiling management, the simulation period is divided into two time segments. The base period includes the years 1979 to 1984 (i.e., years prior to enactment of the PST). The simulation period includes year 1985 and beyond.

Catch ceilings are established in two steps. During data entry, base period (1979-1984) catches for each fishery (from the *.CEI file) are summed and averaged. Catches for the remaining years are divided by the average to get scalar values relating observed catches to average base period catches. During model execution, preterminal and terminal catches for each fishery are summed and averaged. At the end of the base period, the scalars computed during data entry are multiplied by the average preterminal and terminal model catches to get the catch ceilings for the remainder of the simulation period. Thus, the model catches during the ceiling management period are not equal to the catches given in the *.CEI file, but have the same relative value compared to the base period catches. Table 4.6 illustrates how the catch ceilings are computed.

Table 4.6 Computation of catch ceilings. For example, in 1985 the ceiling scalar = 212,827/272,500; the model preterm ceiling = 216,667*.781; the model terminal ceiling = 64,833*.781.

Year	Observed Catch (*.CEI file)		Model PreTerm Catch	Model Terminal Catch	Model Total Catch
1979	338,000		250,000	75,000	325,000
1980	300,000		235,000	70,000	305,000
1981	248,000		198,000	65,000	263,000
1982	242,000		202,000	64,000	266,000

Table 4.6 Computation of catch ceilings. For example, in 1985 the ceiling scalar = 212,827/272,500; the model preterm ceiling = 216,667*.781; the model terminal ceiling = 64,833*.781.

Year	Observed Catch (*.CEI file)		Model PreTerm Catch	Model Terminal Catch	Model Total Catch
1983	271,000		235,000	55,000	290,000
1984	236,000		180,000	60,000	240,000
Average Base Period	272,500		216,667	64,833	281,500
Year	Observed Catch	Ceiling Scalars	Model PreTerm Ceiling	Model Terminal Ceiling	Model Total Ceiling
1985	212,827	.781	169,217	50,635	219,852
1986	229,980	.844	182,867	54,719	237,586
1987	230,901	.847	183,517	54,915	238,432
1988	216,427	.794	172,034	51,477	223,511
1989	220,966	.811	175,717	52,580	228,297

The algorithm used to keep model catches for each fishery below ceilings (or equal to quotas, if forcing is specified) depends on whether or not any ceilinged fisheries have both preterminal and terminal harvests. If a fishery has only preterminal harvests, the model simulates the effects of ceiling management policies by calculating catches in two passes. The first pass calculates catch as if no ceiling were present. The ratio of the ceiling divided by the total catch of all stocks in the fishery is then calculated. This ratio is the basis for adjustment during the second pass. If the ratio is less than one (i.e., the ceiling is less than the computed catch), the catch is reduced by multiplying the age-specific catch of each stock by the ratio. If the ratio is greater than one and the user specifies quota management, the catch is increased to meet the quota; if the ratio is greater than one and ceiling management is specified, no adjustment to catch is made.

Fisheries that are "terminal" for one or more stocks must use an iterative procedure to compute the appropriate adjustment ratios. This is because

preterminal catches are computed prior to the calculation of mature run sizes and terminal catches. For each fishery, the procedure is as follows:

- Compute ocean catches and mature run sizes
- Compute terminal catches by age and stock, using any specified fishery policies
- Compute a cumulative ratio as the previous ratio (= 1 on the first iteration) multiplied by the ratio between the ceiling and the total catch for all stocks
- Process the ceiling according to the same procedure described for ocean fisheries
- Repeat the procedure until the computed catch using the cumulative ratio factor is within .999 of the specified ceiling level.

In instances where a fishery is (1) terminal for a particular stock and (2) the terminal run size after fishing exceeds the specified spawning escapement goal, any catch ceilings specified for that fishery will not include the harvest of fish in excess of the spawning escapement goal.

4.6 - In-River Management

As described in the previous section, the primary management tool of the Pacific Salmon Commission is the establishment of catch ceilings for fisheries harvesting stocks originating from both the US and Canada. These fisheries are mostly preterminal fisheries, and thus are first in line in the long gauntlet of fisheries harvesting each stock. The total harvest on a stock is fine-tuned via in-river management of the last fisheries to harvest each stock.

The most common strategy for in-river management is fixed escapement. An escapement goal is established for one or more stocks and catches are adjusted to meet the escapement goal. The original PSC Chinook Model did not include this type of management option. It was added to the CRiSP Harvest model to better simulate management of Columbia River fisheries which are governed by the court ordered Columbia River Fish Management Plan (*US vs Oregon*).

For fall chinook salmon, the Columbia River Fish Management Plan (FMP) established the following spawning escapement goals: "40,000 naturally spawning Columbia River upriver bright (URB) adults above McNary Dam. The goal for the developing Snake River fall chinook program shall be addressed in the Snake River (mainstem) Subbasin plan. Bonneville Pool hatchery (BPH) brood stock necessary to meet hatchery program production requirements." The present goal is a combined escapement of 45,000 fall chinook salmon above McNary dam.

The PSC Chinook Model has two fisheries that target Columbia River stocks—Col R Sport and Col R Net. The Col R Sport fishery operates primarily at the river mouth and harvests significant numbers of fish from stocks outside the Columbia River, including Georgia Strait stocks. The Col R Net fishery harvests no fish that spawn outside the Columbia River basin. Both fisheries were originally modeled as fixed harvest rate fisheries in which stock/age/fishery specific harvest rates are fixed within each year, but can be modified from year to year by changing the stock/fishery specific fishery policy (FP) scalars. Under this method, escapements vary from year to year. The problem with this approach is that there is no dynamic mechanism for adjusting harvest rates to meet a fixed escapement goal.

A more realistic modeling approach would establish escapement goals for each year and adjust catches to meet those goals. The net affect is that the harvest rates on each stock will change dynamically from year to year as relative stock abundances change. This is especially important for analyzing recovery options for the listed Snake River Fall Chinook stock, as simulated by the LYF stock. Both the Col R Sport and Net fisheries harvest both the URB and LYF stocks. Thus, if the URB stock increases over time and a fixed escapement policy is implemented, the harvest rate on the weaker LYF stock will increase

over time. This type of dynamic behavior cannot be modeled with a stock/fishery specific fixed harvest rate policy.

A second type of in-river management is combined fixed harvest rate strategy. Under this type of policy, a constant fraction of the combined cohorts (from one or more stocks) entering the river are harvested each year. Under this type of policy, the harvest rate on each cohort changes each year as the relative abundance of the cohorts changes. In terms of the computation algorithms, this type of policy is nearly identical to that of fixed escapement. Once one knows the total number of fish available for in-river harvest and the desired combined harvest rate, one also knows the desired combined fixed escapement level.

In CRiSP Harvest, fisheries managed under a fixed escapement and fixed harvest rate policies are treated as a special type of terminal fishery called a river fishery. A control statement in the *.OPT file indicates if any fisheries are to be designated river fisheries and provides the name of a *.RIV file that gives specific information about the desired policies.

Nonlinear Harvesting Formula

Our overall goal was to modify the original PSC Chinook Model such that during the simulation period, the harvest rates in the Columbia River Sport and Net fisheries were adjusted dynamically to meet an escapement goal at McNary Dam. We also wanted to preserve the concept that in-river harvest rates would be applied to the terminal runs, just as other terminal catches are. That is, we did not want the harvest rates to be applied to the "true terminal run" returning just to the river (i.e., terminal run minus ocean terminal catches). And to the extent possible, we wanted to maintain the shaping options defined by the harvest rates, FP scalars, and the PNVs contained in the input files.

These goals proved to be impossible because scaling all river catches (by stock, age, and fishery) up or down by an equal factor often resulted in catches exceeding the fish available. For example, a strong terminal run (i.e., much larger than the escapement goal) might require a two- or three-fold increase in the input harvest rate to meet the escapement goal. Such a large increase in the catch of a weak stock often resulted in a harvest rate greater than 1.0, which is impossible. Thus, we were forced to use a non-linear harvesting function that prevented harvests from exceeding the available fish.

Recall that in non-river fisheries the preterminal and terminal legal harvests are computed as follows:

$$Catch_{s, a, f} = Run_{s, a} \cdot HR_{s, a, f} \cdot FP_{s, f} \cdot PV_{a, f} \tag{4.38}$$

where

- $Catch_{s,a,f}$ = preterminal or terminal catch of stock s, age a, in fishery f

- $Run_{s,a}$ = coastwide ocean abundance or coastwide terminal run for stock *s*, age *a*
- $HR_{s,a,f}$ = harvest rate for stock *s*, age *a*, in fishery *f*
- $FP_{s,f}$ = fishery policy scalar for stock *s* in fishery *f*
- $PV_{a,f}$ = proportion vulnerable for age *a* in fishery *f* (i.e., proportion of age *a* fish that are recruited to the gear and are above the legal size limit in fishery *f*).

Note that this type of catch equation is a simple linear relationship of the form:

$$Catch \ = \ Run \cdot P \tag{4.39}$$

where P is the proportion of the run that is harvested.

A more realistic type of catch equation is the following:

$$Catch \ = \ Run \cdot (1 - e^{-q \cdot E}) \tag{4.40}$$

where *q* is called the "Poisson Catchability Coefficient" and *E* is the amount of fishing effort (Robson and Skalski 1993). In this formulation, catch can never exceed the run size. Note that if we have an estimate of *P* for some level of effort (e.g., input values for *HR*, *FP*, and *PV*), we can solve for the product *qE*.

$$q \cdot E \ = \ -\ln(1 - P) \tag{4.41}$$

If we want to simulate the effects of adjusting effort, we simply replace *qE* with *qERatio*, where *Ratio* is the relative increase or decrease in effort.

Fig. 4.10 illustrates the differences between eq (4.39) and eq (4.40). For low harvest rates and relative efforts less than one, the equations are very similar. However, for larger harvest rates and as relative effort is increased, the non-linear representation provides a more realistic simulation of increased harvesting because it does not permit the entire stock to be harvested.
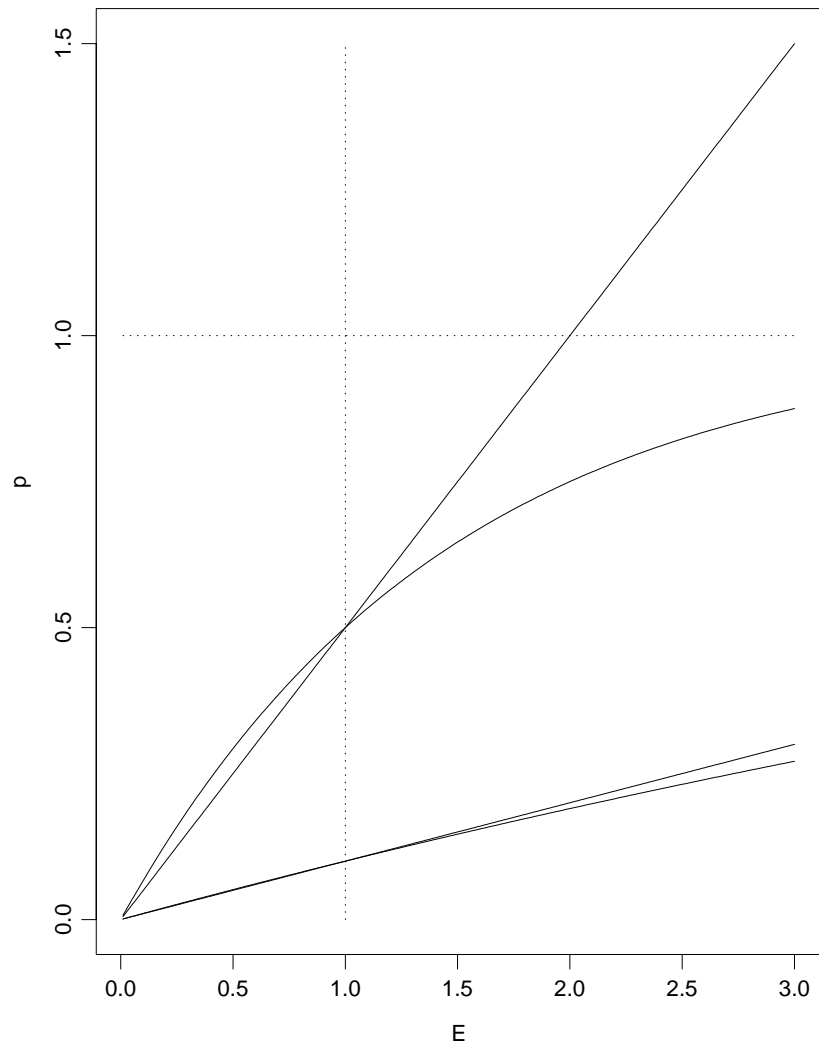
Fig. 4.10 Illustration of the relationship between relative fishing effort level compared to the base period (E) and the fraction of the stock harvested (p) for two cohorts with base period harvest rates of 10% and 50%. Straight and curved lines represent harvesting using eq (4.39) and eq (4.40), respectively. Note that when the effort level is increased more than two-fold, the linear harvesting equation results in a harvest fraction greater than one for one stock.

Before the fixed escapement and fixed harvest rate algorithms are implemented, a four step procedure is utilized to translate the harvesting equations into non-linear form by computing the input Poisson catchability coefficients.

First, we compute the maximum fraction of the terminal run for each cohort that can be taken by the river fisheries. The fish available for the river fisheries is just the terminal run minus the terminal mortalities (legal harvests plus

incidental mortalities) in non-river fisheries, sometimes called the true terminal run. Thus, the maximum fraction that can be harvested is:

$$MaxP_{s,a} = \frac{TrueTermRun_{s,a}}{TermRun_{s,a}} \qquad (4.42)$$

where

$$TrueTermRun_{s,a} = TermRun_{s,a} - \sum_{f \neq riv} TermMort_{s,a,f} \qquad (4.43)$$

If either $TrueTermRun_{s,a} < 0$ or $TermRun_{s,a} < 0$, then we set $MaxP_{s,a} = 0$. Note that in eq (4.42) s indexes all stocks that are harvested by the fisheries managed under in-river management but f indexes fisheries not included in in-river management.

Second, we compute the total in-river harvest fraction from input data (HRs, FPs, and PVs):

$$TotP_{s,a} = \sum_{f = riv} P_{s,a,f} \qquad (4.44)$$

where

$$P_{s,a,f} = HR_{s,a,f} \cdot FP_{s,f} \cdot PV_{a,f} \qquad (4.45)$$

Here, s and f index stocks and fisheries that are harvested and managed under in-river management, respectively

Third, we create a new variable call $PScal_{s,a}$ to adjust the input variables if they are unreasonable. If $TotP_{s,a}$ is less that $MaxP_{s,a}$, then the input values are within reasonable limits, no adjustments are necessary, and we set $PScal_{s,a} = 1$. However, if $TotP_{s,a}$ is greater than $MaxP_{s,a}$, then the input values are too large and must be scaled down by:

$$PScal_{s,a} = \frac{MaxP_{s,a}}{TotP_{s,a}} \qquad (4.46)$$

If $TotP_{s,a} = 0$, then we set $PScal_{s,a} = 0$.

Finally, for each stock, age, and fishery specific river harvest, we compute the Poisson catchability coefficient as

$$q_{s,a,f} = -\ln(1 - (P_{s,a,f} \cdot PScal_{s,a})) \qquad (4.47)$$

We set the maximum fraction of a cohort that can be harvested to be about 99% by setting a maximum limit on $q_{s,a,f}$ to be 5.0.

Note that we now have catchability coefficients that will not generate catches that are greater than the true terminal run. However, this does not guarantee that the river catches plus the river shakers will be less than the true terminal run. We account for that possibility later.

Fixed Escapement Algorithm

The computation algorithm is similar to that for multi-phase ceiling management in that catches are computed by an iterative procedure. The fixed escapement algorithm is implemented after all initial terminal catches are taken but before final escapements are computed. If multiple stocks in the same river are being managed via fixed escapements, three types of policies may be implemented: (1) strong stock management in which the river is managed to meet the strongest stock's escapement goal; (2) weak stock management in which the river is managed to meet the weakest stock's escapement goal; or (3) combined stock management in which the escapement goal is based on the sum of all stocks.

Step 1.

Compute the river catches using the formula:

$$RivCatch_{s,a,f} = TermRun_{s,a} \cdot (1 - e^{-(q_{s,a,f} \cdot Ratio)}) \qquad (4.48)$$

where *Ratio* is the relative increase or decrease in the river fishing effort required to adjust the river catch to meet the escapement goal. Note that *Ratio* = 1 on the first iteration.

We also compute the river shaker mortalities for each stock, age, and fishery in the usual manner. Note that for each cohort it is possible for the catch plus the shakers to exceed the true terminal run. This is accounted for in Step 3.

Step 2.

We create a new variable for the total river mortalities, called *RivMorts*, which can not exceed the available fish. This is a temporary variable and is only used within this algorithm. For each stock and age we compute

$$RivMorts_{s,a} = min(RivCatch_{s,a} + RivShakers_{s,a}, TrueTermRun_{s,a}) \qquad (4.49)$$

where $RivCatch_{s,a}$ and $RivShakers_{s,a}$ are summed over all river fisheries. Thus, $RivMorts_{s,a}$ cannot exceed the total available fish.

Step 3.

Compute another temporary variable called *TempNewScale*. If strong or weak stock management is being implemented, the algorithm computes separate adjustment values for each stock using the following formula:

$$TempNewScal_s = \frac{TrueTermRun_s - \dfrac{EscGoal_s}{MgtIdl_s}}{\displaystyle\sum_{a=3}^{5}\sum_{f=riv} RivMort_{s,a,f}} \tag{4.50}$$

where

$$TrueTermRun_s = \sum_{a=3}^{5} TrueTermRun_{s,a} \tag{4.51}$$

$RivMort_{s,a,f}$ =River catches plus incidental mortalities for stock *s*, age *a*, in river fishery *f*.

$EscGoal_s$ = Escapement goal for stock *s*;

$MgtIdl_s$ = Interdam survival rate for stock *s* after all harvesting mortalities to the point where the escapement goal is measured.

For strong or weak stock management, the largest or smallest *TempNewScal* is used to compute the adjustment ratio to be applied to all catches by the river fisheries, respectively.

If combined stock management is used, *TempNewScale* is computed as follows:

$$TempNewScal = \frac{\left[\displaystyle\sum_{s} MgtIdl_s \cdot TrueTermRun_s\right] - EscGoal}{\displaystyle\sum_{s}\left(MgtIdl_s \sum_{a=3}^{5}\sum_{f=riv} RivMort_{s,a,f}\right)} \tag{4.52}$$

Step 4. Compute NewScal

We compute *NewScal* as follows:

$$NewScal = \frac{\ln(1 - (TempNewScal \cdot WgtAvgP))}{\ln(1 - WgtAvgP)} \tag{4.53}$$

where the *WgtAvgP* terms are the weighted average of the adjusted harvest rates (i.e., *P*PScal* values). The weights are the terminal run sizes divided by the total terminal run for the managed stocks. Thus, if weak or strong stock management is being used, the weights are simply the fraction each age cohort contributes to the strong or weak stock. If combined stock management is being used, the weights are the fraction each stock/age cohort contributes to the total terminal run (ages 3, 4, and 5) for the river managed stocks.

Step 5. Update the adjustment ratio

The final step is to multiply *Ratio* by *NewScal* to get a new ratio. Then go to *Step 1* and repeat until *NewScal* is close to one.

$$Ratio \ = \ Ratio \cdot NewScal \tag{4.54}$$

Fixed Combined Harvest Rate Algorithm

For any given stock, if one knows the total number of fish available for in-river harvest and the desired harvest rate, one also knows the desired escapement level. Setting TempNewScal = 1 and rearranging terms in eq (4.54) gives

$$EscGoal_s \ = \ MgtIdl_s \cdot (TrueTermRun_s - RivMort_s) \tag{4.55}$$

Thus, we first compute the combined true terminal run (i.e., the number of fish that actually enter the river) for the stocks under in-river management:

$$TrueTermRun \ = \ \sum_s TrueTermRun_s \tag{4.56}$$

where *s* indexes stocks under in-river management.

Next we compute the escapement goal that will produce the desired harvest rate goal:

$$EscGoal \ = \ TrueTermRun \cdot MgtIDL \cdot (1 - HRGoal) \tag{4.57}$$

Note that the MgtIDL is assumed constant for all stocks being managed under the fixed harvest rate policy in the river. Once the combined escapement goal is determined, the combined fixed escapement algorithm is implemented to determine in-river catches. Note that the harvest rate goal includes both legal catches and associated incidental mortalities.