SALMOD

A Population Model
For Salmonids

USER'S MANUAL

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By

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INTRODUCTION

SALMOD is a computer model that simulates the dynamics of freshwater salmonid populations, both anadromous and resident. The model's premise is that egg and fish mortality are directly related to spatially and temporally variable micro- and macrohabitat limitations, which themselves are related to the timing and amount of streamflow. Habitat quality and capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which we use as spatial "computation units" in the model. The model tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of local water temperature. Individual cohorts either remain in the computational unit in which they emerged or move, in whole or in part, to nearby units. Model processes include spawning (with redd superimposition), growth (including egg maturation), mortality, and movement (freshet-induced, habitat-induced, and seasonal). Model processes are implemented such that the user (modeler) has the ability to more-or-less "program" the model on the fly to create the dynamics thought to animate the population.

In this document, we outline the essential features of the model using examples derived from a Trinity River, California, chinook salmon (*Oncorhynchus tshawytscha*) population. Selected examples from resident trout models are also included. For a more complete understanding of the conceptual basis for SALMOD, and examples from applications, please see the References section at the end of this document.

MODEL DESCRIPTION

Model Resolution

SALMOD is best explained by describing its fundamental structure in terms of temporal, spatial, and biological resolution. These three components are not independent; the size of any computational unit (spatial resolution) has a direct bearing on the distance a fish of a given size (biological resolution) might need to move within one time step (temporal resolution). The scale of resolution also affects the way model processes are envisioned and implemented, their assumptions, and their limitations.

Temporal Resolution. We employ a weekly time step for one or more biological years. Biological years typically (but not mandatorily) start with the first week of spawning. All rate parameters (e.g., growth, mortality) are weekly values unless otherwise stated. Physical state variables (e.g., streamflow, water temperature) are represented by weekly averages.

Spatial Resolution. Spatial resolution is consistent with the mesohabitat inventory approach, in which the study area is classified and mapped as discrete mesohabitat types, intermediate between micro- and macrohabitat, that tend to behave similarly in response to discharge fluctuations. Classification is based primarily on channel structure and slope, modified by the general distribution of microhabitat, including cover.

Streamflow, water temperature, and habitat type are the physical state variables included in this model. The stream can be divided into flow and temperature segments either by distance or by computational unit numbers. Flow and temperature data are organized by river segments and by time step for each segment. Habitat is defined by a flow versus habitat relationship for each habitat type.

Currently, SALMOD only "sees" a linear stream, with no tributaries or branches possible. However, various options control what happens to fish moving out of the collection of computational units defining the study area, either upstream or down.

Biological Resolution. The biological resolution is fairly standard in the sense that we employ a typical categorization of fish life history related to morphology and reproductive potential (see Figure 1). Fish in the simulated population are tracked by cohorts within computational units. Each cohort is classified by life stages, and class within life stages (Table 1). Life stages 1-4 are adult life stages, defined and ordered as: Male Adult, Male Spawner, Female Adult, and Female Spawner. Adult life stages cannot be further divided. Juvenile life stages can be divided into classes. Life stage 5 is reserved for egg life stages, and is classified by percent development (deposition to emergence). Life stages six through twelve are non-adult life stages classified by size (Table 1). The number of size classes and their definition can vary, but at least 1 size class must be used to describe each non-adult life stage. As a cohort grows, its life stage and size class attributes are modified when it graduates (or matures) to the next size class or life stage.

The various rate parameters (e.g., growth, mortality) can depend on life stage and class. Non-adult cohorts are tracked individually within a computational unit, but any given cohort's identity may be lost when part or all of the cohort moves into a different computational unit.

Several variables are tracked for each cohort throughout the model, including:

> Number of eggs or fish
> Average weight and length of fish
> Percent egg development (deposition to emergence)
> Number of redds composing an egg cohort
> Number of *in vivo* eggs per ripe spawning female
> Life stage and class of the cohort

Variables are defined only for appropriate cohorts (e.g., the *in vivo* eggs variable only applies to spawning females). Individual measurements such as weight, length, and number of *in vivo* eggs represent the average value for the cohort. Fish growth is computed in weight; length is determined from a weight:length relationship, with the exception that a loss in weight does not result in a loss of length. Fish must regain lost weight prior to new growth in length. Biomass of each cohort is defined for non-egg cohorts as the number in the cohort times the average weight of individuals in the cohort. Biomass of each life stage is the sum over all cohorts in that life stage.

SALMOD is a unique simulation model in that it is integer based, i.e., only whole animals are ever born, die, or even exist. This integer formulation was chosen for three reasons. First, so that small numbers of fish could be modeled realistically, second, so that the computations would be as fast as possible, and third, so that people quit asking why the model is dealing with 0.4 animals! One consequence of the integer decision is that a low mortality rate, such as the base mortality rate of 0.001 per time step on adults, in combination with low numbers of animals in each cohort pose a unique problem. If you simply multiply the mortality rate (0.001) times anything less than 1000 animals, nobody would ever die, if the rule were to only kill whole animals. So, SALMOD takes a probabilistic approach whenever there are fewer than 5 animals per cohort. SALMOD essentially draws a uniform random number out of the hat, and if that number is less than the mortality rate, it kills an animal. One consequence of this technique is that a degree of randomness can slightly skew results if you have a large number of cohorts with fewer than five fish and low mortality rates. Since

the focus of SALMOD is early life history when one generally expects 1000's of fish per cohort, generally this is not a problem.

Table 1. Example life stage and class structure definition of an anadromous salmonid population along with the model's order of calculation. Classes are defined by percent development (deposition to emergence) for egg stage and by length (mm) for fry to yearling.

Life stage name	Calculation order	Class	Class definition		
Spawner	1	sf	Spawning Female		
	3	sm	Non-Spawners		
Adult	2	af	Female		
	4	am	Male		
Egg/Alevin	5	1	0.0%	to	33.3%
		2	33.3%	to	66.7%
		3	66.6%	to	100.0%
Fry	6	f1	34 mm	to	38 mm
		f2	38 mm	to	50 mm
Pre-smolt	7	p1	50 mm	to	60 mm
		p2	60 mm	to	70 mm
		p3	70 mm	to	80 mm
Immature-smolt	8	i1	80 mm	to	90 mm
		i2	90 mm	to	110 mm

Holding/Spawning Adults by river segment → Post-spawning mortality

Base mortality
Water temperature-related mortality
Habitat → Density-related mortality

Natality
Timing of spawning ◄— Water temperature
Number and sex ratio of adults
Fecundity (by size group)
Spawning habitat capacity

Pre-spawning adult mortality
In vivo egg mortality
"Lost" eggs

Water temperature → Maturation rate → Eggs and alevins in gravel

Base mortality
Water temperature-related mortality
Habitat capacity-effective incubation
Habitat capcity-redd superimposition

Eggs and alevins in-gravel mortality

Water temperature → Growth rate → Fry by size group ◄ In-movement from upstream ◄ Movement mortality

Base mortality
Water temperature-related mortality
Habitat → Density-related mortality

Freshet-induced movement
Habitat-induced movement

Fry mortality by size group

Out reach movers allocated to downstream reaches

Hatchery supplementation

Water temperature → Growth rate → Pre-smolts by size group ◄ In-movement from upstream ◄ Movement mortality

Base mortality
Water temperature-related mortality
Habitat → Density-related mortality

Freshet-induced movement
Habitat-induced movement
Season-induced movement

Pre-smolt mortality by size group

Out reach movers allocated to downstream reaches

Hatchery supplementation

Water temperature → Growth rate → Imm. smolt by size group ◄ In-movement from upstream ◄ Movement mortality

Base mortality
Water temperature-related mortality
Habitat → Density-related mortality

Freshet-induced movement
Habitat-induced movement
Season-induced movement

Imm. smolt mortality by size group

Out reach movers allocated to downstream (and upstream) reaches

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Model Processes

SALMOD represents the freshwater population dynamics of two life history variants: (1) an anadromous fish species that returns to the stream as an adult to spawn or (2) a resident population of salmonids. The focus is on biological processes that affect the early lifestages of the species. The model simulates (1) spawning, (2) egg development and growth, (3) movement, induced by freshets, time of year, or living space constraints, and (4) various types of mortality. In the *anadromous* variant, adults die after spawning and smolts do not graduate to the adult stage; they exit the study area. Thus the population is re-initialized each biological year. Life history patterns where the juveniles spend more than one year in freshwater have not yet been attempted with SALMOD. In the *resident* variant, adults do not die after spawning and a juvenile lifestage (e.g., yearlings) may mature to adults capable of spawning.

Each computational process is applied sequentially to each individual cohort for all spatial computational units for a single time step. The simulation processes and how they function are defined by the model, but the user has a great deal of flexibility over those processes including the order of execution, specification of control parameters, and simulation options such that a range of applications and hypothesis testing may be flexibly incorporated. Note, however, that the order of calculations is not always benign. For example, having adult females move before adult males can influence the effective mortality rates slightly. This fact, combined with a few processes that make mortality a stochastic process when numbers of fish in a cohort are small, mean that mortalities between the sexes may not always be exactly as expected. Differences should, however, be small.

MODEL IMPLEMENTATION

The SALMOD computer program is implemented in FORTRAN 90 with some extensions in an IBM-PC microcomputer environment. The model is almost 100% data-driven, giving the client thorough control over the definition of the life history descriptors and the linking of the life history to the model processes. Data input has been designed to be very flexible using a "free format" approach to input data arrays, thus facilitating data import from a wide variety of data base management and spreadsheet software. Data output consists of a variety of graphs and tables that are created through post-processors. Like the input data formats, output data are arranged to expedite and encourage transfer to other postprocessing software for subsequent analysis or display.

Memory and Hardware Requirements

The executable files associated with SALMOD require approximately 1.5 megabytes of disk space. Significantly more disk space is required for data and output files. We recommend that the user allot 10 megabytes of disk space for SALMOD and associated files. A 80386 or higher processor and 1 megabyte of available XMS memory are required to run SALMOD (use the DOS MEM command to check for available memory). A math co-processor, a smart drive for hard disk caching (or the Windows 95 environment which takes care of all of this), and the fastest machine available are all recommended to decrease the run time and make your use of SALMOD more enjoyable and efficient.

Installing SALMOD

To install SALMOD, create a directory for the SALMOD programs, and copy files from the diskettes into the new directory. Edit the AUTOEXEC.BAT file, and add the SALMOD directory to the PATH. If run under a DOS window in Windows 95, no additional set up is necessary, and is the recommended method of running SALMOD.

If, however, you are running solely on a DOS-based machine, the file DOSXMSF.EXE must be in a directory listed in the DOS PATH. DOSXMSF.EXE is a DOS memory extender. If you want to run SALMOD under Microsoft Windows 3.x, the file DOSXNT.386 must be included in your Windows directory and be referenced in the [386Enh] section of the SYSTEM.INI file as:
        device=dosxnt.386
DOSXNT.386 is a DPMI device driver that allows SALMOD to run as a 32-bit DOS-extended program in a Windows MS-DOS session.

Running SALMOD

   Several options are available when running the SALMOD program, including a pre-process run that lists the input data, a standard run that creates the statistics for plotting results, and a run that creates summary statistics only. Select options based on the type and detail of information needed.

Option	Description
-i0 (or -I)	complete data pre-process run
-i1	data pre-process run *without* UA vs. flow relationships and related warnings
-t	creates a binary output (**T**ransactions) file in a format for PLOTMORT. Note: file can be large.
-f<filename>	standard run, with user specified name for FILES.DAT
-s	creates a binary output (**S**tatistics) file in a format for PLOTSTAT. Note: file can be large.
-o<filename>	user specified output file; default is SALMOD.OUT
-b	brief annual summary output (spreadsheet importable)
-b1	brief weekly summary output (spreadsheet importable)
-h	help display on command line switches

The format for the SALMOD command is:

SALMOD <-option<filename>> <-option<filename>> <-option<filename>>
The command to run the SALMOD program might look like:

        C> SALMOD -s -f*files.dat* -o*run.out*

where -s indicates a standard statistics run, -f indicates that filenames are found in the named file [*files.dat*], and -o indicates that output is written to the named file [*run.out*]. (Note that a / may be

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used interchangeably with the -.) SALMOD will look for an input file called FILES.DAT automatically; therefore, the -f switch is unnecessary if that is the input file name. Likewise, if the -o switch is not used, output will be written to a file named SALMOD.OUT.

The following table lists the files that make up the SALMOD fish population model and data. Each file is described in a section below under its generic name, even though all names may be user defined. Those files listed as data files contain data that the programs use. These files need to be created or modified by the user for the particular application. The internal files are temporary files created by SALMOD and may be directed to a RAM disk in FILES.DAT. SALMOD creates four output files that contain simulation results. These files are designated in the list below by the *.OUT extension. Three internal scratch files are also created and used by the main program.

Program Files	SALMOD.EXE	Main simulation program file.
	PLOTSTAT.EXE	Plots data in the output statistics file.
	PLOTMORT.EXE	Plots data in the output transactions file.
	SALOPT.EXE	Flow file optimization program.

Note: The PLOT, PLOTINP, and 3DPRINT programs, previously released with SALMOD are no longer supported.

Data Files	CONTROL.DAT	Specifies simulation and data parameters.
	FILES.DAT	Assigns input file numbers to data files.
	FLOW.DAT	Stream flow data for each time step and river segment.
	RELATION.DAT	Movement, mortality, and growth relationships.
	SPAWN.DAT	Spawning parameters and timing.
	SPECIES.DAT	Names species, lifestages, and classes, and gives their length limits.
	STREAM.DAT	Defines the stream computational units, defines flow and temperature segmentation, and controls tally of outmigrants.
	SUPLMENT.DAT	Timing and location of fish to be added to the stream.
	TEMP.DAT	Stream temperature data by time step and river segment.
	WUA.DAT	Flow vs. (weighted) usable area functions for all lifestages and habitat types.

Internal Files	SV.DAT	State Variable Storage.

HAB.DAT	UA vs. Flow relationships.	
MOVE.DAT	Virtual stream for movers.	

Output Files   SALMOD.OUT   Standard output is written to this file unless the user overrides the filename with the -o command line switch.

STATS.OUT   Population statistics used by PLOTSTAT. The actual filename is specified in FILES.DAT.

SINK.OUT   Statistics on population exiting the study reach. Used by PLOTSTAT, the actual filename is specified in FILES.DAT.

SUMMARY.OUT   An abbreviated summary of the normal SALMOD.OUT file. The actual filename is specified in FILES.DAT.

SALMOD.ERR   A small file that contains an error message useful only if SALMOD is run as a child process for another umbrella program, e.g., SIAM.

Note: If SALMOD is aborted for any reason, the output and temporary files listed above may left behind and generally will be empty. These files can be deleted. In addition, if the abort is due to a power failure, soft boot, or hard boot, there may be temporary DOS files that were not deleted. Some of these files may appear as zero length files in the root directory. The filenames will be an MS-DOS-devised collection of letters. Users should also run CHKDSK/F after an aborted run to remove any temporary DOS system files left behind. See your DOS manual for instructions on using CHKDSK.

Data Files

   Data input for SALMOD includes stream statistics, habitat classifications, and fish population parameters. The input data have been split into several ASCII files. Each file contains a single type of information described in the following sections. The DOS filenames can be changed by editing the FILES.DAT file read by SALMOD to assign filenames.

   Input of species, stage, and/or class names is limited to 30 characters, and line length is limited to 80 characters. Note that while the order information is presented in the file is very specific, data lines are almost completely free-format, which means: (1) fields (input values) on a line can be separated by a comma or one or more blanks and do not have to be in specific columns, and (2) comments at the end of a line can be included after a semicolon following all fields on a line. **NOTE**, however, that no tabs may be included in the files. The input files are described below by describing each field and giving the file format that shows fields aligned on lines in the file. If several fields are shown on one line, it is possible to enter them on separate lines in the file; however, if this is done, comments can only be placed after the last field. If the fields are shown on separate lines, they cannot be collapsed into a single line. Indentation with spaces can be used to help structure the input, as in the examples below. Repetitions of a particular line for an input list are indicated by indexing the fields

(i.e., (n) being the subscript). For example, input shown as below indicates that there are two fields per line for 10 lines.

        FIELDA(1), FIELDB(1)
          .
          .
          .
        FIELDA(10), FIELDB(10)

   Measurement units for data in the SALMOD set of programs and all of its files are listed in the table below. **NOTE** that usable area is in units different from typical PHABSIM output.

Flow	cfs
Usable Area	ft^2/ft
Length of fish	millimeters
Weight	grams
Temperature	^{o}C
Density	$grams/meter^2$
Area	$meters^2$
Distance (stream lengths)	meters

FILES.DAT

   This file contains the names of the data files, output files, and temporary files. All filenames must be valid DOS filenames and can be up to 30 characters long, including a path (drive, directory, and subdirectory if necessary) specification. Temporary files can be assigned to a RAM drive to speed up the operation of SALMOD (e.g., E:SV.DAT, where E: is a designated RAM drive).

Note: Filenames must be entered in the order listed below and the title line must be included.

<u>Format</u>

Title Line
Flow Filename
Stream Filename
Spawning Filename
Species Filename
Relation Filename
Temperature Filename
Weighted Usable Area Filename
Supplement Filename
Control Filename
Sink File Output Filename
Statistics Output Filename
Transactions Output Filename
Summary Output Filename
Habitat Temporary Filename
Movement Temporary Filename
SV - State Variable Temporary Filename

<u>Example</u>

```
Full Trinity River Model
c:\data95\Flow.dat
c:\data\Stream.dat
c:\data\Spawn.dat
c:\data\Species.dat
c:\data\Relation.dat
c:\data95\Temp.dat
c:\data\Wua.dat
c:\data95\Suplment.dat
c:\data\Control.dat
c:\output\Sink.out
c:\output\Stats.out
c:\output\Trans.out
c:\output\Summary.out
E:Hab.tmp
E:Move.tmp
E:SV.tmp
```

STREAM.DAT

   This file describes the river's habitat types. In STREAM.DAT, the stream is divided into computational units. The length (in meters) and habitat type of each computational unit are supplied by the user. A remark, up to 30 characters at the end of each line defining a computational unit, can be used to label that unit. Data for computational units must be entered in a downstream order (i.e., the computational unit farthest upstream is entered first.) It would be unwise to have a computation unit <u>longer</u> than the shortest distance any class could move in any movement process. Though we have not tested SALMOD under these circumstances, it seems likely that fish might get "stuck" in such a long CU. Simply break them up into smaller units of identical habitat types.

After the lines providing information for each computational unit, flow and temperature segments are defined. Separate sets of data are required for each flow or temperature segment. For example, if data from only one stream gage are available for the study reach, then one flow segment will be defined for the reach. Temperature and flow segments can be defined in terms of either distance or computational units. If segment boundaries are defined in distances, a real variable is used (indicated by a decimal in the number). Integer values are used to define segment boundaries by computational units.

The final two lines in the STREAM.DAT file contain the "gate" definitions for the study area. These gates control the movement of fish into and out of the study area. Each line must contain the gate ID and the gate type. Gate IDs are 'Gate1' for the upstream gate and 'Gate2' for the downstream gate. Gate types define the direction that fish can move through the gates. These can be "downstream" (indicating downstream movement only), "upstream" (indicating upstream movement only), or "bidirectional" (allowing movement in both directions).

During model execution, the gate types will determine the extent of movement of fish into and out of the study area. Gates that allow movement out of the study area (upstream and bidirectional for Gate1, and downstream and bidirectional for Gate2) will have that movement tabulated in the "sink" file. Gates that allow movement into the study area permit those fish leaving through the opposite gate to reenter. For example, fish that exit the study area through the downstream gate would reenter through the upstream gate to attempt to simulate an unbounded, representative section of stream. Several examples of how gates can be used follow.

In each example, consider the following diagram:

Gate 1   Gate 2

```
 ┌─────────────────────────────────────────────┐
 │  Flow ➔                                      │
 └─────────────────────────────────────────────┘
```

Downstream Gate   --->
Upstream Gate   <---
Bidirectional Gate   <-->

Gate 1   Gate 2

--->   --->   In this example, only downstream movement is allowed through both gates. Those fish exiting the study area through Gate2 would be tabulated and would reenter through the upstream gate. This situation would be reversed if both gates were upstream gates. Either situation results in no net migration.

<---   --->   In this example, fish would be allowed to leave the study area and would be tabulated, but no fish would reenter. The gates are set to allow movement out only.

<-->   --->   This situation allows fish to exit the study area through either end; however, fish exiting the downstream gate would reenter the study area upstream. Fish exiting the upstream gate would be tabulated only.

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--->	<---	No fish can exit the study area in this situation.
<-->	<-->	In this example, fish are allowed freedom of movement in both directions through both gates. Fish exiting the downstream gate would reenter through the upstream gate and vice-versa; therefore, exiters would be tabulated, but there would be no net migration.

Note: Title lines and full line comments are not valid in STREAM.DAT.

<u>Format</u>

Number Of Computational Units (n)
Computational Unit Length (1), Habitat type Code (1) ;Label (up to 30 chars. optional)
  . . .
   . . .
  . . .
Computational Unit Length (n), Habitat type Code (n)
Number Of Flow Segments (m)
Beginning Of Flow Segment (1), End Of Flow Segment (1)
  . . .
   . . .
Beginning Of Flow Segment (m), End Of Flow Segment (m)
Number Of Temperature Segments (q)
Beginning Of Temperature Segment (1), End Of Temperature Segment (1)
  . . .
   . . .
Beginning Of Temperature Segment (q), End Of Temperature Segment (q)
Gate ID, Gate Type
Gate ID, Gate Type

```
  6           ; Number of Computational Units
  100   C1    ; First CU  is 100 m  (Two habitat types, C1 and C2 are
defined)
  200   C2    ; Second CU is 200 m long
  400   C1    ; Third CU  is 400 m
  800   C2    ;            ...
 1000   C1
 2000   C2    ; (entire stream is 4500 m long)
   2          ; number of flow segments
    1   3      ; flow segment 1 definition (includes CU's 1-3, note
integer values)
    4   6     ; flow segment 2 (includes CU's 4-6)
   2          ; number of temperature segments
   0.0 3000. ; temp segment 1 definition (includes first 3000 m of
stream, note decimal points)
  3000.  4500.; temp segment 2 is the rest of the stream
Gate1  Upstream     ;  Upstream gate
Gate2  Bidirectional;  Downstream gate
```

SPECIES.DAT

The species, stage, and class definitions are provided in the SPECIES.DAT file. The number of species to be modeled (maximum of two) is designated along with species, life stage, and class names. The percent maturation classes for eggs, and length classes for the next sub-adult stages (e.g.,fry, fingerlings, and juveniles) are also identified. The number of classes and class definitions can vary among species, but must always be at least one class per stage.

Note: Names of species, life stages, and classes may use the slash (/) character, but if so, the name must be enclosed in single quotes (') when used as a range parameter in the CONTROL.DAT file (see below).

Field definitions
Number of Life Stages	: 12 maximum
Life Stage Name	: 1 - 30 character name
Number Of Species	: 2 species maximum
Species Name	: 1 - 30 character name
Number Of Classes	: 1 - 5 classes
Class Name	: 1 - 30 character class name
Class Lower Limit[*]	: Percent developed or size class lower limit
Class Upper Limit[*]	: Percent developed or size class upper limit

   * class lower limit must be less than upper limit and contiguous size class limits must align
      within a stage and between stages of a species.

Note: Title lines and full line comments are not valid in SPECIES.DAT.

Format

```
Number Of Life Stages (m)
Life Stage Name 1 for adult females
Life Stage Name 2 for spawning females
Life Stage Name 3 for adult males
Life Stage Name 4 for spawning males
Life Stage Name 5 for eggs/alevins
Life Stage Name 6 for first juvenile class, e.g., fry
Life Stage Name 7 for second juvenile class, e.g., fingerlings
Life State Name . . . for next juvenile class, e.g., pre-smolts
Life Stage Name 12 for last juvenile class, e.g., smolts
Number Of Species (ns)
Species Name (1)
  Number Of Classes for stage 5 (n)
    Class Name (1)
    Class Lower Limit (1), Class Upper Limit (1)
    Class Name (2)                          Repeat      Repeat
    Class Lower Limit (2), Class Upper Limit (2)     for    for
       . . .                                 stages     each
       . . .                                 6 - m      species
       . . .
    Class Name (n)
    Class Lower Limit (n), Class Upper Limit (n)
```

Example

```
8                       ; -- number of life stages
Adult Females           ; -- names of life stages
Spawning Females
Adult Males
Spawning Males
Eggs/Alevins            ;  (classes are not listed here)
Fry
Pre-Smolts
Immature Smolts
1                       ; -- number of species
Chinook Salmon          ; -- species name
        3               ; -- number of egg classes   (first 4 stages do
not
    Prop. Mature        ; -- egg class 1 name          have classes)
        0   .33         ; -- class 1 limits (0-33% maturation)
    Prop. Mature        ; -- class 2 name
      .33  .67          ; -- class 2 limits (33-67% maturation)
    Prop. Mature        ; -- class 3 name
      .67 1.00
        2               ; -- number of fry classes
    F1                  ; -- fry class 1
       34    38         ; -- class 1 limits (32-38 mm length)
    F2                  ; -- fry class 2
       38    50
        3               ; -- number of pre-smolt classes
    P1                  ; -- pre-smolt class 1
       50    55         ; -- class 1 length (50-60 mm length)
    P2                  ; -- pre-smolt class 2
       55    65
    P3                  ; -- pre smolt class 3
       65    80
        3               ; -- number of immature smolt classes
    S1                  ; -- immature smolt class 1
       80    90
    S2                  ; -- immature smolt class 2
       90   110
    S3
      110   200
```

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CONTROL.DAT

The CONTROL.DAT file defines the simulation control parameters and is arguably the most complicated file to understand and use effectively. Two types of information are specified in CONTROL.DAT, simulation *options* and simulation *processes*. Simulation options specify certain general rules for the model operation. There are really two kinds of processes: those that may be viewed as principally biological in nature and those that are more computational, though the boundary may be fuzzy for some. A brief description of options and processes follows.

Simulation Options

Capacity - The CAPACITY format indicated, either *Numbers* or *Biomass*, must correspond with the habitat capacity data provided in RELATION.DAT. The system default is *Biomass*.

Date - The DATE option specifies a beginning date for the simulation and associates a specific calendar date with the time steps. The system uses the beginning date to determine weekly dates for the output tables. This option must be specified or a runtime error will occur.

Population - The POPULATION option determines whether the current fish population remains in the river at the end of the year. When POPULATION = *Anadromous* each year in a multi year run will begin with a new stock of spawners, and spawners die after spawning. When POPULATION = *Resident*, spawners do not die after spawning and the MATURE process should be included to allow juveniles to mature into adults.

Summarize - The SUMMARIZE option creates a report of summary population statistics in the output file. If SUMMARIZE=*Time*, the population status, mortality, and movement statistics during each time step and cumulative statistics at each time step are reported. If SUMMARIZE=*Units*, the same information is provided for each computational unit at each time step. This option can use the */Time=* switch (see discussion of switches below) to limit the time steps in which the summary will be printed. Note that this option will produce a large output file if allowed to run for all time steps. Compared with the DETAILS process switch (described below), the SUMMARIZE option is much easier to read.

Timestep - The TIMESTEP option allows the user to specify the length of the simulation run in weeks. This option must be specified, or the system will default to zero and nothing will happen.

Biological Process Descriptions

Carry - The CARRY process determines when adult females carry eggs. This process calculates the number of eggs for females in a cohort based on their weight and then tracks the number of eggs with them to estimate the in vivo egg mortality due to the exposure temperature of the adult female environment.

Freshet Movement - The FRESHET process is used to determine if a freshet (an abrupt change in flow volume) has occurred during the current time step, and if so, moves the specified stages/classes according to the user-specified parameters governing proportion of fish moved per time period, the distance downstream., and any associated mortality There are currently three options for defining a freshet (see below) based on either the rate of change in weekly streamflow, or simply user specified.

Growth - Cohort growth is a function solely of water temperature in the computational unit and is based on a percent growth per day versus temperature relation. The GROWTH process is typically invoked for each relevant cohort during each time step. **Note** that fish can lose weight through negative growth rates at extreme temperatures. If they do lose weight, they do not lose length. They gain length only after they regain the lost weight. The user may choose to let some cohorts grow and some not if, for example, it is hypothesized that fish moving for a specific reason do not grow. See the Control file later in this document for an example.

Habitat Movement - Habitat-induced movement occurs if the number (or biomass) of fish exceeds the habitat capacity of a computational unit for a given lifestage. Movement to alleviate the capacity constraint necessitates mortality in a manner controlled by the user. Habitat capacity is governed by a flow versus habitat relationship specified for each lifestage. Habitat-induced movement may be upstream or downstream, or both. Note that one can impose further guidance on HABITAT MOVEMENT through proper use of the size class switches. For example, if you believe that smaller fish are forced to move first if a given computational unit is over capacity, you can order the processes accordingly. See Example 1 below.

Mature - When the *resident* variant of the model is used, the MATURE process turns the selected stage/class into adult fish capable of spawning with the sex ratio preset to 50:50. This process is unnecessary if the *anadromous* variant is being used because the SUPPLEMENT process is typically used to introduce adults into the population at a user-specified sex ratio.

Mortality - All mortality not explicitly handled with one of the other processes is computed by the MORTALITY process. This includes temperature, density, in vivo egg, incubation, and superimposition losses. In addition, a base mortality for all causes not related to any other process is also computed here. Most of the mortality causes are straightforward functional relations contained in the RELATION file, such as for temperature or density. Superimposition is explained in conjunction with the SPAWN process. The odd man out is incubation mortality which is complicated because it depends so heavily on antecedent conditions.

Imagine that on time step five, there were 100 square meters of spawning habitat available (computed from the flow:habitat area function in the WUA data file) and each redd pocket consumed two square meters (from the SPAWN data file). Imagine also that there were a sufficient number of female spawners to completely fill the spawning habitat with redds—obviously 50 females— and remember that no superimposition occurs in a computation unit for spawners that spawn <u>within</u> a single time step. Now, at the beginning of time step six, the flow in the computation unit changes and now there are 75 square meters of spawning habitat, but only 90 square meters of incubation habitat (also from the WUA data file). Ten square meters of redds constructed during time step five no longer are viable and die, with all (or a fractional part) of the redds within that area, and the cohort of eggs they represent, dying as well. Suppose further that in time step seven incubation habitat increased to 95 square meters, no problem for redds. However, during time step eight, incubation habitat declined to 80 square meters. In this case, 10 additional square meters of redds (90-80) are lost. And so on through time, all further complicated by other factors such as superimposition of the redds during each spawning time step, but in reality only simple bookkeeping. The important points are that spawning and incubation habitat are independently tracked through time on a computation unit basis. This is the mesohabitat equivalent to PHABSIM's cell-by-cell effective spawning calculation routine. As such, it is analogous to effective spawning except that a continuous time series of flows is potentially important and disruptive to a continuous time series of incubating eggs within a computation unit, each cohort of which potentially originated in a different time step and under different spawning conditions. In contrast, PHABSIM deals only with a single pair of flow conditions as representative of the most extreme cases and does not track multiple dates of redd

deposition or superimposition. Thus, SALMOD has to some degree traded spatial resolution for temporal resolution.

Seasonal Movement - Seasonal movement is similar to the FRESHET process, except it is invoked solely based on time of year. Unlike freshet movement, fish moving in response to the season may move up or downstream.

Spawn - As its name implies, SPAWN calculates the appropriate fraction of adults that should spawn in the current time step, and then generates from those adult females redd cohorts containing eggs from user supplied parameters detailing acceptable spawning temperatures, area per redd, and number of eggs per female. Several options control the calculation of how many pre-existing redds may be superimposed by newly constructed redds. SPAWN also calculates mortality of some eggs that are never successfully deposited. For the condition in which there are too many spawners for the available spawning habitat at the time of spawning, it is assumed that these eggs are shed ("lost"), and die with mortality reported as "habitat loss". If spawners fail to spawn by the duration of the spawn process, those eggs are assumed to die with the adult in the anadromous model and be resorbed in the resident model. In none of these cases do eggs get tallied as being successfully deposited.

Using the */Time* switch on the SPAWN process is especially meaningful. The appropriate fraction of adults of both sexes will be treated as spawners for the entire time step during which the SPAWN process is active as specified in the CONTROL.DAT file. This means that adult fish will be subjected to 1) mortality, movement, and growth rates appropriate for spawners as contained in RELATION.DAT, and 2) use the usable area appropriate for spawners as contained in WUA.DAT, all assuming that processes in CONTROL.DAT are specified in that way. As mentioned elsewhere, after spawning, spawners will die in the *Anadromous* variant of the model and revert to adults in the *Resident* variant. There is a special case in the *Anadromous* variant in which a few adult males may be left in the stream post-spawning. This occurs if they were in a computation unit that had, for whatever reason, no spawning females. If you find that this number of adult males is anything other than a trivial number, you probably have something wrong in your process list or timing switches.

Should spawning be delayed due to temperature, spawners remain as spawners awaiting the next possible spawning opportunity, as controlled by the */Time* switch and the temporal limits implied in SPAWN.DAT. Note, however, that all remaining spawners will be returned to the adult life stages at the beginning of the first time step after spawning has completed. It is advised that one double check the output at the end of a biological year to see if either spawners or adults are still in the system when they should not be. As a general guideline, the times of spawning indicated in SPAWN.DAT should be a subset of the */Time* range of the SPAWN process. In the *Resident* model for example, adults may begin to seek (move to) appropriate spawning habitat a week prior to actual egg deposition. In this case, the */Time* switch should initiate the SPAWN process a week earlier than that given in the SPAWN.DAT file. This would allow movement to spawning habitat a week earlier than egg deposition. See the example CONTROL file for the *Resident* variant later in the manual.

Notes: SPAWN must precede MORTALITY. This version of SALMOD does not make any check to see that the sex ratio within any computation unit is or is not appropriate for spawning to be successful.

Supplement - The SUPPLEMENT process is the way to initialize the stream with adults for spawning in the *anadromous* variant of the model, or to "seed" the stream with pre-existing fish for the *resident* variant; in fact, there is a special */Time=0* option which may be used to force seeding prior to any other process which can be a valuable thing to do. It may also be used to "supplement" the stream with hatchery fish at specific geographic locations, or to add fish migrating from a tributary. The

SUPPLEMENT process introduces fish into the study area in proportion to the habitat available for the given life stage at the time of introduction. Adults are apportioned to spawning habitat in the *anadromous* variant and proportioned to adult habitat in the *resident* variant of the model. If no habitat for the life stage exists, fish are introduced in proportion to the computation unit lengths. In the *anadromous* variant, SUPPLEMENT forces spawners to be created at the beginning of any time step during which spawning occurs.

Computational Process Descriptions

Biomass - The BIOMASS process computes the biomass of each computational unit for each life stage. This process logically precedes both mortality processes dealing with either numbers (or biomass) and habitat capacity, i.e., HABITAT MOVEMENT and density mortality.

Catastrophe - Quite often, a relatively rare event disrupts "normal" population processes. Severe floods or droughts generate abiotic conditions outside the realm of the functional relationships that compose the model. If the user wishes to attempt to mimic unusual mortality events, the CATASTROPHE process allows removal of a given percentage of any class of fish.

Collapse - Large numbers of computational units and a growing number of cohorts due to splits during movement can generate an exponential number of cohorts to track. Earlier version of SALMOD ran into computer memory limitations that severely degraded simulation times. The COLLAPSE process was a way to reduce the number of cohorts by combining cohorts in the same computational unit and class. A weighted average of the combined cohorts attributes (length, weight, etc.) was used. Newer compilers and faster computers have reduced, or perhaps eliminated, the need for this process, but the user is free to experiment with it should processing times be a major factor. **Note** that the adult life stages always exist in only one cohort per computation unit, and therefore have no need to be collapsed. Also, SALMOD has a built-in limit of 25 cohorts of a given class that can be in a single computation unit; if this limit is exceeded, an automatic COLLAPSE is performed to alleviate the constraint.

Details - It is not uncommon for a user to be perplexed at the output from a simulation, in effect wondering if he or she is responsible for a given result from a data input error or whether SALMOD has produced a computational error. As the name implies, the DETAILS process triggers SALMOD to print the gory details of the next process in the list to the standard output file (typically SALMOD.OUT) so that details of the computations may be checked. Warning: output may be terse, voluminous, and arcane, but at least it is there. For processes that result in changes to the fish population within a computational unit, DETAILS will produce before and after tables. `Switches can be set for the DETAILS process to detail only a subset of the Time, Stage, Class, or CU indicated in the subsequent process.`

Graduate - Graduation is the re-classification of cohorts according to growth. The graduation process is typically invoked after all growth (see Growth process) has taken place to advance the non-adult lifestages. Graduation does not, however, create adults from the last juvenile lifestage; the MATURE process is used for that function. **Note** that the juveniles will grow only as large as the largest size listed in SPECIES.DAT.

Immigration - All moving fish (whether habitat-induced, seasonal-induced, or freshet-induced) are placed in a "virtual stream" that conceptually stands beside the real stream. While in the virtual stream, fish are not subjected to further processes. The IMMIGRATION process is a computational, rather than biological, process that moves fish from the virtual stream back to the actual stream,

typically after all other movement has taken place. Only after fish return to the "real" stream will additional processes affect them.

<u>Process Specifications</u>

   The simulation processes outlined above provide the structure for calculation of the population dynamics. The type and order of processes to be performed on the respective species and lifestages are designated by their order in the CONTROL.DAT file and optional switches that accompany them specifying time periods and computational units that indicate when and where each process occurs. The list of processes (up to 30) is performed by SALMOD in order for each time step. Spawning, graduation, and immigration processes can only occur once for each time step, and spawning must precede mortality.   A complete list of SALMOD's processes and their optional switches is found in Table 2.

Table 2. Alphabetical list of SALMOD processes as specified in the CONTROL file, their applicable optional switches, and defaults. Note that the /SPECIES switch may be used for ALL processes if necessary.

Process name	Description	Switches	Defaults
BIOMASS	Computes biomass in each computational unit in order to calculate capacity limits.	None allowed	None
CARRY	Determines when females carry eggs for calculation of in vivo egg mortality.	/TIME	All
CATASTROPHE	Allows for mortality due to any catastrophic event.	/DATE /RATE	Required Input 100%
COLLAPSE	Collapses cohorts of like stage/class to reduce the overall number of cohorts. Only necessary if computation time is a problem.	/TIME	All
DETAILS	Prints details for the process immediately following the details line.	/TIME /CU /STAGE /CLASS	All All All All
FRESHET MOVEMENT	Performs fish movement due to freshet events.	/TIME /STAGE /CLASS /CU /OPTION	All All All All 2xPorA (see below)
GRADUATE	Updates stage/class of fish based on their length.	/TIME /STAGE /CLASS /CU /EMERGE	All All All All -99.0
GROWTH	Calculates growth as a function of water temperature.	/TIME /STAGE /CLASS /CU	All All All All
HABITAT MOVEMENT	Performs movement based on habitat constraints.	/TIME /STAGE /CLASS /CU /MOVE	All All All All Down100
IMMIGRATION	Moves fish from the "virtual stream" back into the stream. This is a mechanical, rather than biological, process.	None allowed	None

MATURE	Allows juvenile fish to mature into adults.	/TIME /STAGE /CLASS /CU	Time step 52 All All All
MORTALITY	Performs mortality based on mortality functions specified in RELATION.DAT.	/INVIVO	none
SEASONAL MOVEMENT	Performs movement based on time of year.	/TIME /STAGE /CLASS /MOVE	All All All Down100
SPAWN	Performs spawning based on the parameters in SPAWN.DAT. (Must precede MORTALITY)	/SI /TIME*	Random All
SUPPLEMENT	Adds returning spawners or hatchery fish to the stream based on the parameters in SUPLMENT.DAT	/Time /Time=0**	All

* TIME may be used for these processes; however as the time steps are defined in the data files specifying the time in the process is largely redundant.
** Special case to seed the stream prior to any process.

Process Switches

   Switches can be added to processes listed in the control file to provide limits or option selections for the various processes. Many processes can be repeated several times with the same or different process switches. Some switches are applicable to all processes whereas some switches are process specific. Switches applicable to all processes may have one or two values listed. For example, the *Time*, *Species*, *Stage*, *Class*, and *CU* switch values for a process can be given as a range or single value. If a range or value is not provided, SALMOD defaults to performing the process for the complete range (i.e., all time periods, all species, etc.). Single values represent the specific value for the switch. For example, /*Time*=10 will result in the associated process being run only during the tenth time step of a year. If two values are used, they are separated by a comma and represent a range of values. For example, /*Time*=10,20 will result in the associated process being run during each time step between 10 and 20 inclusive. A range is always defined by only two values, one the lower value and one the upper, never a list of values.

Note: When values are entered for the /*Time* switch, these time steps are relative to the beginning of the simulation year. Therefore, if *Timesteps*=104 is entered, and /*Time*=10,52 is specified for a process, the process will be executed in time steps 10 through 52 and time steps 62 through 104 (relative time steps 10 through 52 in the second year). As mentioned, the /*Time=0* option may be used for the SUPPLEMENT process to seed the stream prior to any other process.

Note: Legal values for process times are 1 to 52 only and may not "wrap" the biological year boundary. Even if fish are supplemented at time step 55, this will be dealt with by the SUPPLEMENT process during time step 3 in the second year. Time parameters entered in "reverse," such as 40,10 will get "turned around" to be 10,40 and not work as expected. If

you need to span a biological year boundary, simply use two process lines, one for early in the year and one for later.

When entering values for the stage switch, the names entered for the stages in SPECIES.DAT may be used, or the numerical ID may be used. Each stage is assigned a numerical ID based on the order listed in SPECIES.DAT. Values used for the class switch are entered in a similar fashion. **Note** that ranges for lifestages do not "wrap around" the life stage/class continuum in terms of the calculation order shown in Table 1, though SALMOD automatically adjusts the order in the specified range (i.e., *fry, immature smolts* is equivalent to *immature smolts, fry*). That is, if you wish to include all stages except eggs, the process must be invoked at least twice, once for lifestages "below" eggs and once for those "above."

Movement processes have switches specific to movement. The FRESHET movement process has a */Option*=<option> switch that defines how a freshet event will be identified. The options currently available are defined as follows:

2xPorA - a freshet event occurs when the current time step's flow is greater than or equal to twice the previous time step's flow *or* when the current flow is greater than or equal to twice the average of the previous three flows.

2xPandA - a freshet event occurs when the current time step's flow is greater than or equal to twice the previous time step's flow *and* is greater than or equal to twice the average of the three previous time step's flows.

Userspec - a freshet event occurs when the flow for a given time step is entered as a negative number. These must be defined by the user in FLOW.DAT.

The SEASONAL and HABITAT MOVEMENT processes have a switch, */Move*=<option>, to determine the direction of movement. The format for the option is either *Upxxx* or *Downxxx*, where xxx is the percent moving in the given direction and is specified as an integer from 1 to 100. No spaces should be entered between the direction and the percent value. For example, */Move=Up*15 would result in 15% of the moving fish in the specified move to move upstream and the remaining 85% to move downstream. The default for both processes is 100% downstream. Movement in the FRESHET MOVEMENT process is always downstream.

Note: The three movement processes (habitat, freshet, seasonal) collectively present a special case. In each case, the moving fish are placed into a "virtual stream" for storage until the immigration process is executed. Fish in the virtual stream are not affected by any other in-stream processes; therefore, they will not be subjected to further movement and the associated mortality. For example, in a test run the number of out-migrant pre-smolts was 40% lower when seasonal movement occurred after habitat movement as opposed to before habitat movement. The user must decide the appropriate sequence for movement processes, generally placing the process with the most dominant effect first.

The SPAWN process has an *SI* switch to determine the method for redd superimposition. Available methods are *Random*, *Contagious*, and *Avoidance*. In the *random* method spawners choose from available spawning area randomly. For the *avoidance* method, spawners avoid previously constructed redds, and in the *contagious* method, spawners choose previously constructed redd sites. If this option is not specified, the system will default to the Random model.

A summary of process switches may be found in Table 3.

Table 3. Summary of optional process switches.

Switch name	Description	Number of arguments	Argument options	Argument notes
Time	Limits time steps.	1 or 2	Valid time step.	See special notes for SPAWN and Supplement processes
Species	Limits species	1 or 2	Valid species name.	For multi-species runs
Stage	Limits stage.	1 or 2	Valid stage name.	
Class	Limits class.	1 or 2	Valid class name.	
CU	Limits computational units.	1 or 2	Valid comp unit.	
Option	Determines method of defining freshets.	1	2xPorA 2xPandA Userspec	See text
Move	Determines percent of fish moving up or down stream.	1	UP*xxx* DOWN*xxx*	Only one is used with remaining fish moving in the opposite direction.
SI	Determines redd superimposition type.	1	Random Contagious Avoidance	See text
Invivo	Limits time for in invivo egg mortality.	1 or 2	Valid time step	
Emerge	Minimum temperature for emergence.	1	Temperature	Defaults to -99.0
Date	Catastrophic event date.	1		Event data in format mm/dd/yy
Rate	Catastrophic event mortality rate.	1	Percent	This is the percent of fish that die when the event occurs.

Processing CONTROL.DAT

   Errors that may occur reading the various switches in CONTROL.DAT may not cause execution of the model to stop; rather, default values may be used. For example, if a /Time switch is used and an invalid number is read, the system will default to running the model for timesteps 1 through 52. If any errors of this type occur, SALMOD will display the following message:

> 2 error(s) occurred reading the process control
> file. These errors result in default values being
> used for process options.
>
> Do you wish to continue (Y or N)?

If you respond with a 'Y', SALMOD will continue execution with the default values; otherwise, execution will be terminated.

Note: Title lines are not valid in this file; however, full line comments are.

Format

TIMESTEP=Number of time steps;
DATE=Begin Date in format mm/dd/yy;
CAPACITY=NUMBERS or BIOMASS;
SUMMARIZE=UNITS/CU=A, B or TIME/Time=x, y;
POPULATION=ANADROMOUS or RESIDENT;

Then, for each process (maximum 30), the following format is used:

PROCESS NAME /*Time*=A<,B> /*Stage*=C<,D> /*Class*=E<,F> /*CU*=G<,H>/*other*;

where the <> delimiters indicate an optional parameter. That is, if the switch has a single parameter, such as a single time step, it only applies to that time step. If two parameters are used to define a range, the switch applies to the range, inclusive. In no case can there be more than two parameters for a given switch.

Example 1 - *Anadromous* Model

```
; Options
Timesteps=52;
Date=9/2/1986;
Capacity=Biomass;
Population=Anadromous;
; Processes
Supplement /Time=0,15;
Spawn /Time=1,15 /SI=Random;
Freshet Movement /Stage=Fry, Immature Smolts /Option=2xPorA;
Seasonal Movement /Time=35,39 /Stage=Fry, Immature Smolts;
Biomass computation; Habitat moves in the following order force
smallest size classes to move first
Habitat Movement /Time=10,52 /Stage=Fry /Class=F1;
Habitat Movement /Time=10,52 /Stage=Fry /Class=F2;
Habitat Movement /Time=10,52 /Stage=Pre-smolts /Class=P1;
Habitat Movement /Time=10,52 /Stage=Pre-smolts /Class=P2;
Habitat Movement /Time=10,52 /Stage=Pre-smolts /Class=P3;
Habitat Movement /Time=10,52 /Stage=Immature smolts /Class=S1;
Habitat Movement /Time=10,52 /Stage=Immature smolts /Class=S2;
Growth /Stage=Eggs, Immature Smolts;
Detail;
Mortality;
Immigration /Stage=Fry, Immature Smolts;
Graduate /Stage='Eggs/Alevins',Immature Smolts;
```

In the preceding example, SALMOD will run for a total of 52 time steps with a starting date of September 2, 1986, with an anadromous population. Habitat capacity for each computational unit will be determined by total biomass rather than number of fish, and HABITAT MOVEMENT has been structured to move the smallest fish first to relieve that constraint. Redd superimposition will be determined randomly, and spawners will be distributed temporally based on the data supplied in SPAWN.DAT.

Sixteen processes have been specified in the process list. During each time step, the processes will be executed in the order given. For the above example, SUPPLEMENT will be executed in time step zero, followed by the processes beginning in time step one, in the following order: SUPPLEMENT, SPAWN, FRESHET MOVEMENT, BIOMASS COMPUTATION, GROWTH, MORTALITY, IMMIGRATION, AND GRADUATION. HABITAT MOVEMENT is not executed in time step one, as the time switch specifies execution from time step 10 to 52 only. Likewise, SEASONAL MOVEMENT will be executed beginning time step 35 and ending time step 39. Movement for HABITAT and SEASONAL MOVEMENT is 100% downstream. Detailed output will be provided for the MORTALITY process in each time step.

As mentioned, processes are executed in the order listed in CONTROL.DAT. Note in the example above that GRADUATE is the last process listed. Even though the habitat moves have been governed by the computational unit capacity, any particular computational unit could find itself several thousand percent over capacity due to graduation of one stage to the next. This is particularly true with eggs graduating to fry.   Thus, any over capacity "problems" will show up in the next time step. Process order is also important for the habitat moves and the biomass computation. The habitat moves will be based on the previously executed BIOMASS computation; therefore, it is advisable to place the biomass computation prior to the habitat moves in CONTROL.DAT.

Our advice is to carefully plan out the order of processes and make sure you carefully understand the implications of that order prior to making your first run. At times, it may not be possible to achieve exactly what you want, but you can probably get close. Then, periodically review the order in light of the output you are getting to see if the order of calculations is influencing any problematic results.

Example 2 - *Resident* Model
```
; Sample brown trout model
Timesteps=286;
Date=09/27/1991;
Capacity=Numbers;
Population=Resident;
Supplement /Time=0; Step 0 establishes standing crop by seeding stream
Biomass computation;
; Habitat movement must be done in two steps so eggs don't try to move
Habitat Movement /Time=1,52 /Stage=Adult Females, Spawning Males
/Move=UP050;
Habitat Movement /Time=1,52 /Stage=Fry, Yearlings /Move=UP050;
Growth /Stage='Eggs/Alevins',Fry; moving fry don't grow
Growth /Stage=Adult Females;
Growth /Stage=Adult Males;
Growth /Stage=Parr, Yearlings;
; Immigration from virtual stream must be done in two steps so eggs
don't move
Immigration /Stage=Adult Females, Spawning Males;
Immigration /Stage=Fry, Yearlings;
Spawn /Time=1,7 /SI=Random; Puttnam per. comm.
Mortality;
Graduate;
Mature /stage=yearlings /class=Y3;
```

SPAWN.DAT

Spawning information and distribution are provided in SPAWN.DAT. Spawning temperatures, area per redd, number of *in vivo* eggs per female, and time steps when spawning occurs are indicated for each species. The proportion spawning in each time step is entered as a decimal, and the sum of all proportions must equal 1.0.

Note: Title lines and full line comments are not valid.

<u>Format</u>

Species Name (1)
  Avg Area Per Redd
  Min spawn temp, max spawn temp
  Avg weight of fry upon maturation
  Beginning Spawning TimeStep (b)
  Proportion Spawning in time step b
  Proportion Spawning in time step b+1
  . . .
  . . .
  . . .
  Proportion Spawning in time step b+n   **Note**: proportions <u>must</u> total 1.0!
     (n need not be fixed ahead of time)
  . . .
  . . .
  . . .
Species Name (Number Of Species)
  Avg Area Per Redd
  Min spawn temp, max spawn temp
  Number of *in vivo* eggs/female
  Beginning Spawning Time Step (b)
  Proportion Spawning in time step b
  Proportion Spawning in time step b+1
  . . .
  . . .
  . . .
  Proportion Spawning in time step b+n (n need not be fixed ahead of time)

<u>Example</u>

```
Chinook Salmon     ;identifies species for multi-species runs
4.5                ;average area per redd (m**2)
5.6 13.9           ;min-max spawn temperatures(C)
.396               ;average wt of fry upon maturation(g)
1                  ;beginning spawn time step within year
    .01            ;spawn distribution (fraction spawn in each time
step)
    .01
    .04
    .03
    .11
    .18
    .34
    .16
    .04
    .05
    .02
    .01
```

RELATION.DAT

RELATION.DAT contains information on movement and mortality rates. The relationships provided are described below in order of appearance in the file. In cases where a value required by SALMOD falls between two values listed in the file, the required value will be interpolated. No extrapolation will be performed; if a value is outside the range of the pairwise values, the relevant maximum or minimum value will be used after an appropriate warning message. To eliminate warning messages, simply increase the outside range if possible.

Freshet Movement parameters include the distance moved, proportion moved, and associated mortality rate. These parameters are required for each juvenile life stage in the anadromous model, and all life stages in the resident model, by size class.

Seasonal Movement parameters include the time-step when seasonal movement occurs, the distance moved, the proportion moved, and the associated mortality rate. Seasonal Movement parameters are required for each juvenile life stage in the anadromous model, and all life stages in the resident model, by size class.

A *Temperature vs. Growth relationship* is required for every non-adult life stage and provides the growth factor for specific temperature values.

The *Base Mortality Rate* indicates the proportion of the population dying each week from causes other than movement or temperature. A base mortality rate is required for each stage.

A *Temperature-induced Mortality Rate* is also required for each stage. This relationship indicates the proportion of the population dying each week at various temperatures.

The *Temperature-induced in vivo Egg Mortality Rate* indicates the proportion of eggs dying each week at various temperatures. This relationship is required for each species.

A *Weight vs. Length relationship* is also required for each species.

The *Habitat-induced Movement Mortality Rate* indicates the proportion of the population that dies from moving a certain distance. The last distance provided in this distance versus mortality rate relationship is the maximum distance that a fish can move in one time step. Any fish required to move beyond this maximum distance dies. This relationship is required for each juvenile stage in the anadromous model, and all life stages in the resident model, by size class.

The *Density-induced Mortality Rate* is required for each life stage. This relationship is expressed in density as number of fish in number/m^2 (or biomass in gm/m^2, depending on **Capacity** designation in CONTROL.DAT) per unit area versus the weekly mortality rate. The density levels provided are significant even if the mortality rate does not vary. The upper density limit provided is the habitat carrying capacity that triggers habitat-induced movement.

A *Female Weight vs. Number of Eggs* relationship for each species is the final relationship contained in this file.

Note: Title lines and full line comments are not valid.

<u>Format</u>

[Freshet Movement Parameters - repeats for each class, stage, and species]
Species
  Stage
    Class
      Distance Moved, Proportion Moved, Proportion Dying
[Seasonal Movement Parameters - repeats for each class, stage and species]
Species
  Stage
    Class
      Timestep, Distance Moved, Proportion Moved, Proportion Dying

[Temperature vs. Growth Parameters - repeats for each stage and species]
Species
  Stage
    Temperature1, Daily Growth Rate1
    Temperature2, Daily Growth Rate2
     . . .   . . .
     . . .   . . .
[Base Mortality Rate - repeats for each stage and species]
Species
  Stage
    Proportion Dying per week

[Temperature Mortality Rate - repeats for each stage and species]
Species
  Stage
    Temperature1, Proportion Dying per week1
    Temperature2, Proportion Dying per week2
     . . .   . . .
     . . .   . . .
[Temperature vs. In vivo Egg Mortality Rate - repeats for each species]
Species
  Temperature1, Proportion Dying1
  Temperature2, Proportion Dying2
   . . .   . . .
   . . .   . . .
[Weight vs. Length Parameters - repeats for each species]
Species
  Weight1, Length1
  Weight2, Length2
   . . .   . . .
   . . .   . . .
[Distance vs. Mortality Parameters - repeats for each class, stage and species]
Species
  Stage
    Class
      Distance Moved1, Proportion Dying1
      Distance Moved2, Proportion Dying2
       . . .   . . .

. . .   . . .
. . .   . . .
[Density vs. Mortality Parameters - repeats for each stage and species]
Species
  Stage
   Density1, Proportion Dying1
   Density2, Proportion Dying2
   . . . . . .
   . . . . . .
[Weight vs. Number of Eggs Parameters - repeats for each species]
Species
  Weight1, Number of Eggs1
  Weight2, Number of Eggs2
  . . .   . . .
  . . .   . . .

Example

```
Chinook Salmon            ; freshet movement parameters
Fry
 F1
   3780 .90  .1           ; Distance Moved, Prop. Moved, Prop. Dying
 F2
   4860 .10  .1
Pre-Smolts
 P1
   5940 .8   .05
 P2
   7020 1.0  .04
 P3
   8100 .8   .03
Immature Smolts
 S1
   9180 .8   .02
 S2
  10260 .8   .01
Chinook Salmon            ; seasonal movement parameters
Pre-Smolts
 P1
35  20000 .80  .05        ;  time, distance, proportion, mortality
36  20000 .80  .05
 P2
35  20000 .85  .04
36  20000 .85  .04
 P3
35  20000 .90  .03
36  20000 .90  .03
Immature Smolts
 S1
35  20000 .95  .02
36  20000 .95  .02
```

```
  S2
35   20000 1.0   .01
36   20000 1.0   .01
Chinook Salmon                  ; temperature vs. growth relation
Eggs/Alevins                    ;          -per/day (additive)
           0  0.0022
           1  0.0028
           2  0.0034
           3  0.0042
           4  0.0051
           5  0.0061
           6  0.0072
           7  0.0085
           8  0.0098
           9  0.0112
          10  0.0126
          11  0.0141
          12  0.0156
          13  0.0170
          14  0.0184
          15  0.0196
          16  0.0207
          17  0.0216
          18  0.0222
          19  0.0227
          20  0.0229
Fry                             ; - per day (multiplicative)
           1                    0.008
           5                    .021
          10                    .05
          15                    .065
          20                    .06
          24                    -.002
Pre-Smolts                      ;      -per day (multiplicative)
           1              0.003
           5              0.009
          10               .018
          15               .025
          20               .017
          24              -.002
Immature Smolts                 ;      -per day (multiplicative)
           1              0.002
           5              0.0075
          10               .0125
          15               .014
          20               .011
          24              -.002
```

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```
Chinook Salmon                         ; base mortality rate
Eggs/Alevins
0.02
Fry
0.06
Pre-Smolts
0.016
Immature Smolts
0.004
Adult Females
0.001
Spawning Females=Adult Females
Adult Males=Adult Females
Spawning Males=Adult Females
Chinook Salmon                         ; temperature vs. mortality
relation - per week (mult)
Eggs/Alevins
        0.00      .00
        13.33     .00
        13.89     .016
        14.44     .034
        15.00     .081
        15.56     .272
        16.11     .460
        16.67     .867
        17.22     .934
        17.78    1.000
        19.00    1.000                ; maximum allowable value
before warning message
Fry
        0.00      0.00
        12.22     0.00
        13.39     .2500
        17.44     .5000
        19.78     .7500
        21.11    1.0
        37.78    1.0
Pre-Smolts
        0.00      0.00
        12.22     0.00
        13.39     .2500
        17.44     .5000
        19.78     .7500
        21.11     1.00
        37.78     1.00
Immature Smolts
        0.00      0.00
        12.22     0.00
        13.39     .2500
        17.44     .5000
        19.78     .7500
```

```
        21.11    1.0000
        37.78    1.0000
Adult Females
           0          0
        12.8          0
          24        0.7
          35        0.7
Spawning Females=Adult Females
Adult Males=Adult Females
Spawning Males=Adult Females
Chinook Salmon                          ;   temperature vs. in vivo
egg mortality relation
         0.00       .00
        13.33       .00
        13.89       .028
        14.44       .048
        15.00       .084
        15.56       .257
        16.11       .317
        16.67       .455
        17.22       .483
        17.78       .652
        19.00       .652
Chinook Salmon                          ; weight vs. length relation
      0.31          30
      0.74          40
      1.44          50
      2.48          60
      3.94          70
      5.89          80
      8.38          90
     11.50         100
     . . .
   5888.00         800
   7062.44         850
   8383.50         900
Chinook Salmon                          ; distance moved vs.
mortality rate relation - per step
Fry                                     ; --- last distance specified
is the maximum distance
   F1
     0      .0
     500   1.0
   F2
     0      .0
     750   1.0
Pre-Smolts
   P1
     0      .00
     2000  1.0
   P2
```

```
      0     .00
      3000 1.0
   P3
      0     .00
      7000  1.0
Immature Smolts
   S1
      0     .00
      10000 1.0
   S2
      0     .00
      10000 1.0
Chinook Salmon      ;    density vs. mortality relation - weekly
Fry                 ;    --- density is biomass (gm)/m**2
      0  0.00        ;    Even if there is no direct density-dependent
mortality
      25  0.01       ;       the upper limit of density triggers the
habitat-
Adult Females        ;       induced movement
      0   0.00
   1800   0.00
Immature Smolts
      0   0.00
      25  0.20
Eggs/Alevins
      0   0.0         ;   --- density-independent relationship
   1000   0.0         ;       upper bound not relevant for eggs
Pre-Smolts
      0   0.0
      15   0.04
Spawning Females=Adult Females
Adult Males=Adult Females
Spawning Males=Adult Females
Chinook Salmon                     ;  weight vs. # eggs relation
2000   2666
4000   3732
7000   4666
```

WUA.DAT

   This data file contains the detailed (weighted) usable area versus flow data for each habitat type, species, and life stage. Flow is in cubic feet per second and usable area in square feet per foot of stream. There is a limit of 30 flow versus usable area pairs per lifestage. The indentation shown is simply for convenience and is not required. Information on more habitat types than required can be included in this file. This flexibility allows the user to create one WUA.DAT file that can be used for a number of model runs with different CONTROL.DAT and STREAM.DAT file configurations.

Note: Title lines and full line comments are not valid.
Note: Usable area values are in ft^2/ft, not $ft^2/1000$ ft as would be typical PHABSIM output.

<u>Format</u>

```
Habitat Type Name (1)
  Species Name (1)
    Life Stage Name          ; Life stages can be in any order
      Flow Value, UA         ; however, each life stage must be
      . . .                  ; accounted for.
      . . .
      . . .
      Flow Value, UA
    . . .
    . . .
    . . .
    Life Stage Name
      Flow Value, UA
      . . .
      . . .
      . . .
      Flow Value, UA
  . . .
  . . .
  . . .
  WUA for life stages can also be listed by their relationship to previously defined life stages in the format:
    Life Stage Name = Previously defined Life Stage Name * Multiplier
  Species Name (Number Of Species)
    Life Stage Name
      Flow Value, UA
      . . .
      . . .
      . . .
      Flow Value, UA
    . . .
    . . .
    . . .
    Life Stage Name
      Flow Value, UA
      . . .
      . . .
      . . .
      Flow Value, UA
  . . .
  . . .
  . . .
Habitat Type Name (Number Of Habitat Types)
  . . .
  . . .
  . . .
```

```
    C1                  ; Habitat Type
    Chinook Salmon ; Species
    Fry          ; Life Stage
 150    7.7            ; Flow - WUA pairs
 350    4.8
 450    3.8
 800    2.5
2000   33.3
    Pre-Smolts           ; Life Stage 2
 150   48.0            ; Flow - WUA pairs
 350   28.7
 450   27.2
 800   17.7
2000   32.1
   Spawning Females      ; Life Stage 3
150   5.1841           ; Flow - WUA pairs
350  15.2016
800   8.8439
Adult Females=Pre-Smolts*5.0  ; Life Stage 4
Adult Males=Adult Females      ; Life Stage 5
Spawning Males = Adult Males  ; Life Stage 6
Eggs/Alevins=Spawning Females*3.0        ; Life Stage 7
Immature Smolts=Pre-Smolts    ; Life Stage 8
    C2               ; Second Habitat Type
    Chinook Salmon ; Same Species
    Fry
 150    5.5
 350    4.5
 450    6.9
 800    6.6
2000    4.6
    Pre-Smolts
 150   28.3
 350   23.2
 450   20.7
 800   16.1
2000   21.4
   Spawning Females
150   2.0219
350   2.7536
800    0.172
Adult Females=Pre-Smolts*5.0
Adult Males=Adult Females
Spawning Males = Adult Males
Eggs/Alevins=Spawning Females*3.0
Immature Smolts=Pre-Smolts
```

FLOW.DAT

   This is the stream flow data file. One set of flows can be provided for the entire study reach, or the stream can be divided into 'flow segments' with a corresponding set of flow data provided for each segment. Data on each line represent flows at a single time step. The flow segments are defined in the STREAM.DAT file. Note that if /Option=UserSpec is used with the freshet movement process, then flow values for those time steps where freshet events are to occur must be entered as negative values.

Note: Full line comments are valid in FLOW.DAT.

<u>Format</u>

Flow(1,1) Flow(1,2) ... Flow(1, Number Of Flow Segments)

. . .

. . .

. . .

Flow(Number Of Time Steps, 1) ... Flow(Number Of Time Steps, Number Of Flow Segments)

<u>Example</u>

```
 351.57    354.00     ;water year 1986 beginning Sept. 2
 349.88    352.00
 326.71    334.00
 333.29    335.00
 326.86    330.00
 320.29    323.00
 317.29    320.00
 315.71    316.00
 303.29    316.00
 304.00    321.00
 307.71    322.00
 312.57    323.00
 317.86    320.00
 319.00    320.00
 314.43    320.00
 310.43    311.00
 308.14    309.00
 312.29    322.00
 305.57    308.00
 311.00    314.00
 307.14    309.00
 463.57   1260.00     ;(see note below)
1211.43   1750.00     ;(          |          )
2581.43   2680.00     ;(          |          )
3840.00   6150.00     ;(          |          )
6200.00   6250.00     ;(          V          )
2847.57   5730.00
 423.57    518.00
 427.86    480.00
```

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```
407.43    415.00
406.00    407.00
   .  .  .
   .  .  .
   .  .  .
624.43    631.00
609.57    623.00
485.86    503.00
299.14    302.00
301.43    305.00
304.43    308.00
```

Note: Looking at the section of the FLOW.DAT file noted, for flow segment 1, the values 1211.43 and 2581.43 above would produce freshet events under options 1 (2xPorA) and 2 (2xPandA). The values 3840 and 6200 would produce freshet events under option 2 only. For flow segment 2, the value 1260 would produce a freshet event under option 1 or 2, while the values 1750 and 2680 would produce freshet events under option 1 only. The value 6150 would again produce a freshet event under option 1 or 2.

SUPLMENT.DAT

This file provides information for the model to add fish into the population at the appropriate time and location. Most of SALMOD's references to time are weeks within a biological year. SUPPLEMENT is different in that the time steps specified are a sequential count from the beginning of the simulation run, and may optionally include zero for seeding the stream prior to any other process. For example, if spawning occurred regularly, SUPPLEMENT may be used for time step one, fifty three, etc.. Location can be given as a range of either computational units (indicated as integer values) or distances from the top of the study reach (indicated as real values). Fish are apportioned to the range of CU's designated in proportion to the habitat available for them at the time that they are introduced, with adults going to adult habitat in the *resident* variant and to spawning habitat in the *anadromous* variant. If no habitat is available for the computation units specified for the flow at the time of introduction, the fish will be apportioned based on length of the computation units alone, with a warning message issued. One exception to the habitat apportionment exists — in the *Anadromous* variant, adults are apportioned based on female spawning habitat, and, as mentioned, in the *anadromous* variant, SUPPLEMENT forces spawners to be created at the beginning of any time step during which spawning occurs.

If adding adult fish, the locations, number of adults, sex ratio (actually ratio of spawners to non-spawning adults), and the weight for males and females are indicated. For juveniles, enter the location where they appear, the number of fish, and weight only; the sex ratio will be assumed to be 50:50. In other words, adults get six parameters and non-adults get four.

Note: Title lines and full line comments are not valid.

Format

Time Step
  Species Name
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # adults, Sex ratio,
      weight for males, weight for females
    . . .
    . . .
    . . .
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # adults, Sex ratio,
      weight for males, weight for females
  . . .
  . . .
  . . .
  Species Name
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # adults, Sex ratio,
      weight for males, weight for females
    . . .
    . . .
    . . .
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # juveniles, weight
. . .
. . .
. . .
Time Step
  Species Name
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # adults, Sex ratio,
      weight for males, weight for females
    . . .
    . . .
    . . .
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # adults, Sex ratio,
      weight for males, weight for females
  . . .
  . . .
  . . .
  Species Name
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # adults, Sex ratio,
      weight for males, weight for females
    . . .
    . . .
    . . .
    Upstream Comp Unit #/Distance, Downstream Comp Unit #/Distance, # juveniles, weight

```
0                            ; Zero time step to seed stream
Chinook Salmon                    ; Species Name
    0.0  1794.4 3788 .33 4000 4000   ; Upstream Distance, Downstream
distance, # Adults
 1794.4 27814.8 4508 .33 4000 4000        ; Proportion  of  spawners,
                         male and female
27814.8 39934.8  402 .33 4000 4000        ; weights
25                            ; Time step 25
Chinook Salmon                    ; Species name
 95 95 2500 1.25                     ; Juveniles entering at a
specific computation unit
53                                ; Only time step 53
Chinook Salmon
    0.0  1794.4 3788 .33 4000 4000
 1794.4 27814.8 4508 .33 4000 4000
27814.8 39934.8  402 .33 4000 4000
```

TEMP.DAT

The stream temperature data are provided in a file similar to the stream flow file. Temperatures are entered for one time step per line. If data are available for more than one location, the stream is divided into 'temperature segments.' The temperature segments are defined in STREAM.DAT.

Note: Full line comments are valid.

Format

Temp(1,1) Temp(1,2) ... Temp(1, Number Of Temp Segments)

.

.

.

Temp(Number Of Time Steps, 1)...Temp(Number Of Time Steps, Number Of Temp Segments)

Example

```
    9.44    11.11    ;Seg 1 is Lewiston to Grass Valley
    9.44    10.56    ;Seg 2 is Grass Valley to Douglas City
    9.17    10.00
    8.89     9.44
    8.61     8.89
     . . .
     . . .
     . . .
    7.78     7.78
   10.00    11.11
   10.00    11.39
   10.00    11.67
```

10.00   12.22
10.00   12.22
10.00   12.22

SALMOD's PROGRAM LIMITS

SPECIES LIMITS
        Maximum number of fish species modeled (2)
        Maximum number of life stages for each species (12)
        Maximum number of size classes for fry - juveniles (5)

STREAM LIMITS
        Maximum number of computational units (1000)
        Maximum number of stream segments defining flow regime (10)
        Maximum number of stream segments for temperature regimes (10)
        Maximum number of habitat classification types (60)
        Maximum number of stream segments for supplementing fish (20)

RELATION LIMITS
        Maximum number of density: mortality pairs (20)
        Maximum number of distance: mortality rate pairs (10)
        Maximum number of flow values to for flow : WUA relation (30)
        Maximum number of temperature :mortality, temperature: growth pairs (30)
        Maximum number of weight:: length pairs (30)
        Max number of seasonal time step movements (15)

SPAWN LIMITS
        Maximum number of time steps for spawning (30)

OTHER LIMITS
        Maximum number of characters in filenames (30)
        Maximum number of cohorts per species per computational unit (25)
        Maximum number of population processes to perform per time step (30)

STEPS IN ORGANIZING AND RUNNING SALMOD

1. Decide if SALMOD is appropriate for your problem or situation. The program should have a measure of "face validity" for the type of problem you are facing, i.e., is habitat a principal limiting factor in your situation? Are the management objectives, potential control options, and constraints (data, legal, regulatory, and economic) such that using a model like SALMOD, with its spatial and temporal resolution, would be helpful. Is there a simpler model, consistent with data and the problem at hand, that will work?

2. Assemble data, using sample data sets as a guideline. To the degree possible, make sure the physical data (flows, temperatures, habitat types) are well specified so that level of uncertainty is "removed" from the model, leaving the biological realm as the most uncertain. Data assembly can be a daunting task; however, procrastination will get you nowhere.

3. All simulation models contain unobservable or poorly quantified values. Annotate data files with:
    a. the source of all data
    b. any assumptions you have made about the input data
    c. the implications for the domain of the model's applicability, i.e., what are the ranges of flows and water temperatures within which the model should be appropriate?

4. "Verify" data by running SALMOD with the -i0 (and eventually -i1) switches
    1. look for any messages in SALMOD.OUT. In particular, 1) look for error, warning, or informative messages, 2) correct the errors, and 3) be satisfied about the meaning of the others.
    b. compare data in INPUT.LST with original data files,
    c. review the process list in INPUT.LST to insure the processes and their switches are what you expected,

5. Run SALMOD with -s switch for a single biological year. Examine SALMOD.OUT and SUMMARY.OUT for meaningful results. Do they corroborate the knowledge of local experts?

6. Run PLOTSTAT (and PLOTMORT if possible) and examine the population's dynamics. Look to see if the model is behaving as you might expect. If not, try the DETAILS and/or SUMMARY switches.

7. If appropriate, run SALMOD for multiple years, under different environmental conditions, looking for reasonable behavior. Set the model at risk by trying extreme conditions. Extreme conditions can also include non-varying conditions. Turn various control options off and on to confirm their effect. Does the model behave plausibly?

8. Data permitting, calibrate SALMOD to growth, numbers, outmigrants, etc., by adjustment of parameters within a reasonable range to improve the agreement between model output and real-world observations. Simple goodness-of-fit measures are all that are necessary with SALMOD as the data are likely too noisy to do much else. Beware using single measures; one that captures trend (like R^2) and one that captures closeness of fit (like RMSE) would be preferable. Again, data permitting, run the calibrated model for other data sets (typically years) to see if it holds up to additional scrutiny. This helps to confirm the calibration.

9. If you haven't already effectively done so, determine the sensitivity of the model by noting those parameters causing significant change in the model's behavior. Though there are various forms of sensitivity analysis, SALMOD lends itself to simple first-order analysis by varying relevant parameters by a set percentage up and down.

10. Decide if the model mimics the real world well enough to satisfy your purposes. This implies that you have objective measures of what "good enough" means.

11. Combining elements of steps 6, 7, 8, 9, and 10, decide how much confidence to place in inferences about the real system based on model results. Clearly state whether your confidence is qualitative or quantitative. *All models are wrong, but some are useful*.

12. Exercise SALMOD in the evaluation of alternatives.

13. Organize the results for communication to others. Include all important assumptions, noting which were modified through learning — a model is an assumption analyzer.

14. Document adjustments necessary to the model and/or to the observed data to improve the whole modeling process. Both are moving targets.

15. Resources permitting, attempt to invalidate the model by comparing a priori predictions against real-world measures, the so called post-audit validation.

Note: For a reasonable, if long winded, discussion of testing (verifying and validating) ecological models, see Rykiel (1996).

SALMOD's VERSION HISTORY

Version 1 - This version is the original version.

Version 1.01 - Modifications made from 6/14/93 to 8/6/93
1 - Upstream and downstream movement has been incorporated.
2 - Gates have been installed at each end of the study area to regulate movement into and out of the study area.
3 - The appropriate tables have been added to the output for the upstream sink.
4 - Last in first out changes made.
5 - Comp Units processed in a random order.

Version 1.02 - Modifications made from 8/6/93 to 8/23/93
1 - Call InitMovement Statistics to clear out old data when a new year begins.
2 - Main routine modified to call SALMODINIT, SALMODCLOSE, and SALMODPROC in preparation for link with the water model.
3 - Added switch to turn on the resident model. ex. POPULATION=Resident
4 - Added a process to mature immature smolts to adults at a specified time step. Used in the resident model. ex. MATURATION /Time=1 /Stage=Yearlings
5 - Modified movement to allow adults to move without searching for an empty group in new comp units. Adults are kept in a single cohort, saving memory for juvenile cohorts.
6 - Went to old version of mort.for as mortality calculations were determined to be more accurate.

Version 1.03 - Modifications made from 8/24/93 to 2/2/94
1 - Modified the binary search code in ReadHabLabel. Old version would return a value in certain conditions where a match was not found.
2 - SI option now a switch on SPAWN process. ex. SPAWN /SI=Random
3 - CARRY process specifies when females carry eggs. This process is required. If CARRY is not included in the Control file, females will never carry eggs. ex. CARRY /Time=1,52 (Currently defaults to 1,52)
4 - Invivo switch added to MORTALITY process. Specifies when Invivo Egg mortality is calculated. ex. MORTALITY /Invivo=1,52 (Currently defaults to 0,0)

Version 1.04 - Modifications made from 2/3/94 to 3/10/94
1 - New process call CATASTROPHY. Specify species, stage, class to be affected by CATASTROPHY as with other processes.   Specify date of catastrophy as /DATE=mm/dd/yyyy. This will only occur on the specified date. Specify percent losses with /RATE=xx where xx is a whole number expressing percent losses.
2 - New switch added to the GRADUATE process. Temperature above or equal to emergence can occur. /EMERGENCE TEMPERATURE = xx.x where xx.x is temperature in C.

Version 1.5 - Modifications made from 3/11/94 to 9/9/94
1 - Modified output subroutine so all textual output is within double quotes.
2 - Modified the -I option to include all user comments.
3 - Added -b and -b1 switches to create brief summaries.

Version 1.51 - Modification made 9/16/94
1 - Fixed a bug in the SUPPLEMENT process. The previous version allowed some adult fish to not be added to the river under conditions where the last computation unit in the list for a spawn segment had no weighted usable area.
2 - Fixed a bug in the subroutine that reads input files. Previous version was not reading computation units for spawning segment definitions.

Version 2.00 - Modifications made 5/97
1 - SUPPLEMENT process modified to allow juvenile fish to be added to the system.
2 - Model=Spawner option was removed.
3 - General bug fixes to SALMOD in general and the Population=Resident option in particular.
4 - Fixes to PLOTSTAT to accommodate SALMOD's new limits.

Version 2.01 - Modifications made from June to August, 1997
1 - Limit on the number of flow and/or temperature segments was increased to 10.
2 - CreateSpawners was moved from the beginning of the spawn process to the beginning of the timestep in which spawning occurs.
3 - Created the "Salmod.err" file. This file is created at the beginning of a Salmod run and is deleted at the end. If the file exists, Salmod bombed. This was created primarily for Siam to allow the system to detect if Salmod run successfully or not.
4 - Fixed a bug in the initialization routine to remove resident population stage requirements from anadromous populations.

Version 2.05 - Modifications September, 1997
1 - Modified the SUPPLEMENT process to apportion fish based on comp unit length if there is no habitat. Also added the */Time=0* option.
2 - Fixed a bug where adult cohorts did not have a stage setting. This caused some adult cohorts to be ignored in some processes. Fixing this bug fixed several apparent problems in the output.
3 - The "Numbers Reaching Stage" table was modified to a "Mass Balance" table. This involved adding adult stages to the table and tallying supplements, graduates, mortality, exiters, and those remaining instream.
4 - Added the RemoveSpawners subroutine. This subroutine is called at the beginning of the first time step after spawning has completed, and returns any remaining spawners back to the adult stages.
5 - A bug in the mortality rate calculation was fixed.

Version 2.06 - Modifications November, 1997
1 - Modified the SUPPLEMENT process to create spawners at the beginning of any time step during which spawning occurs for the *anadromous* variant. Note that it has been problematic getting spawning to "work" properly for both model variants, and for both a single and a multi-year run.

SAMPLE SALMOD MODEL OUTPUT

It has been our desire to make SALMOD's output useful, relatively easy to read and deal with, and understandable without being too lengthy. Simultaneously achieving these goals is always difficult, if not impossible, with a computer program such as SALMOD.

Some items in the *mortality table* require explanation:
♦ the *Spawned* category, for both male and female spawners, tallies fish that die after spawning.
♦ the *InVivo* category tallies eggs that died within their mother due to water temperatures. These eggs are <u>not</u> counted in the mass balance table as they were never successfully deposited.
♦ the *Resorbed eggs* category tallies eggs that "belonged" to female *resident* spawners who had not spawned by the completion of the spawning season for whatever reason and return to the adult female lifestage. These eggs are <u>not</u> counted in the mass balance table as they were never successfully deposited. In the *anadromous* variant, non-spawned adults should die and these eggs are not tallied anywhere.
♦ the *Habitat Loss* category tallies eggs that die when there is not enough spawning habitat for all the spawning females in a computation unit when they spawn. It is assumed that these eggs are shed, but as they are alive when leaving the female spawners, they <u>are</u> tallied in the mass balance table.
♦ the *Incubation Loss* category tallies eggs lost if redds (or portions of redds) are lost due to changing egg incubation habitat through the duration of the incubation season.

The Mass Balance table also requires explanation. Columns in the Mass Balance table represent the following information:

Entrants	Fish entering the system through the supplement process, upstream or downstream gates, or as deposited eggs.
Graduates	Fish reaching the specific stage through graduation or maturation from the prior stage.
Exiters	Fish exiting the system through either the upstream or downstream gates.
Deaths	Total mortality for the stage.
InStream	Those fish for the given stage remaining in the stream at the end of the year.
Total	Total number of fish reaching the stage. This number is cumulative, so will increase each year.

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Mass Balance Example

Consider the following supplements when viewing the Mass Balance Tables that follow.

```
Supplements in time step
0, 1992 30538     adults
        2268      parr
        6369      fingerlings
        28499     yearlings
```

```
1992 Mass Balance for Brown Trout
```

Remaining Stage InStream	Cumulative Total	Incoming Entrants	Graduates	Exiters	Deaths
Adult Females		18383	11941	0	1993
28331	30324				
Adult Males		12255	11941	0	1722
22474	24196				
Eggs/Alevins		11066145	0	0	11044614
0	11066145				
Fry		0	21531	0	17570
0	21531				
Parr		2268	3961	0	2151
2810	6229				
Fingerlings		6369	1268	0	556
610	7637				
Yearlings		28499	6471	0	4751
6337	34970				

For the 1992 mass balance (see above), the total number of adult male (12255) and female (18383) entrants is equal to the number of supplemented adults (30638), the total number of entrants for Eggs/Alevins (11066145) will be the number of eggs successfully deposited through the spawn process, and the total number of entrants for the juvenile stages will equal the number of supplemented fish for the stage (2268 parr, 6369 fingerlings, and 28499 yearlings.)

In the first year of a simulation, the "Total" column equals the number of entrants plus the number of graduates during that year. In subsequent years, the "Total" column equals the sum of the number of entrants, the number of graduates, and the previous total.

In any given year, the following equation holds true:

Graduates(B) =   InStream(A, previous year) + Entrants(A) + Graduates(A) - Exiters(A) - Deaths(A) - InStream(A)

where A = any particular lifestage, and B = the next lifestage after A. (See note below for the case where B represents the adult life stages.)

Some   examples   for   the 1992 mass balance:

```
AdulttFemalesEntrantss
      1838255
-----------------------------------
-------
Supplemented Adults
     30638
```

```
FryyGEadruanbtes
+21531   0
Fry Exiters                         -
    0
Fry Deaths                          -
17570
Fry Instream                        -
    0
-----------------------------------
-------
Parr Graduates
   3961
```

Some examples for the   1993 mass balance:

```
Ffinggerrlliingssnmtreeam  (from  1992)
     +     0610
Fingerling Graduates
     + 2691
Fingerling Exiters
     -     0
Fingerling Deaths
     -  198
Fingerlings InStream
     -  544
--------------------------------------
-------------
Yearling Graduates
```

```
Yearlingg25559nStream  (from  1992)
     +     6337
Yearling Graduates
     + 2559
Yearling Exiters
     -     0
Yearling Deaths
     -  131
Yearlings InStream
     - 3233
-----------------------------------
```

Note that Graduates to the Adult lifestages is always at a 50:50 sex ratio, unlike the Supplement process for which the sex ratio may be specified.

```
SALMOD   --- A Salmonid Fish Population Model v2.05
10/09/1997
 National Ecology Research Center, USFWS
   10:05


                 Full Trinity River Model - Biological Year 88-89


  Input Files from Files.Dat
  -----------------------------------------
  Flow Data            : Q8889.PRN
  Stream Definition    : ..\Stream.DAT
  Spawning Parameters  : Spawn.88
  Population Definition : ..\Species.DAT
  Functional Relations : ..\Relation.DAT
  Temperature Data     : T8889.REG
  Useable Area Functions: ..\Wua.DAT
  Returning Spawners   : Suplment.88
  Process Definition   : Control.88

  Output Files
  -----------------------------------------
  Exiting Smolts       : Sink.dat
  Numbers/Biomass Stats : Stats.dat
  Transactions         : Trans.dat
  Summary              : summary.out

  Temporary Files
  -----------------------------------------
  Habitat-Flow Functions: Hab.tmp
  Mover Temporary File  : move.tmp
  State variable Storage: SV.tmp
  Comment Line:  Options
  Comment Line:  Processes

  Comment Line:  Don't let freshet and seasonal movement overlap in time
```

```
SALMOD  --- A Salmonid Fish Population Model v2.05
10/09/1997
 National Ecology Research Center, USFWS
    10:05


                  Full Trinity River Model - Biological Year 88-89




  "*********************************"
  "Yearly/Final summary - 1989        "
  "*********************************"


  "Numbers remaining in stream         "
  "-------------------------           "


  "----------------                    "
  "Stream Summary                      "
  "----------------                    "
  "Chinook Salmon                      "
  "---------------------------------"
  "# of cohorts =  3307                " "Numbers" "Avg Wt " "Avg Len" "
  Repr.  "
  "                                    " "        " "(grams)" " (mm)   "
"#eggs/fem"

  "--------------------------------------------------------------------
------"
  " Adult Females                      "         0       .0       .00
       0.
  " Spawning Females                   "         0       .0       .00
       0.
  " Adult Males                        "        17   2000.0    553.75
  " Spawning Males                     "         0       .0       .00
  " Eggs/Alevins                       "         0
  "   Prop. Mature 0-.33               "         0
  "   Prop. Mature .33-.67             "         0
  "   Prop. Mature .67-1.00            "         0
  " Fry                                "         0       .0       .00
  "   F1                               "         0       .0       .00
  "   F2                               "         0       .0       .00
  " Pre-Smolts                         "     70902      2.4     62.68
  "   P1                               "      8105      1.8     57.27
  "   P2                               "     59759      2.4     62.91
  "   P3                               "      3038      3.6     72.60
  " Immature Smolts                    "       300      5.8     85.41
  "   S1                               "       300      5.8     85.41
  "   S2                               "         0       .0       .00
  "   S3                               "         0       .0       .00
  " Total Young                        "     71202      2.4     62.78
```

```
SALMOD  --- A Salmonid Fish Population Model v2.05
10/09/1997
 National Ecology Research Center, USFWS
   10:05


                 Full Trinity River Model - Biological Year 88-89



 "Cumulative Mortality Statistics"
 "-----------------------------"
 "Chinook Salmon                  "  "Number"   "Percent"   "Rate"
 "     Adult Females              "
 "           All                  "      315.      1.000     .0271
 "           Base                 "       60.       .190     .0052
 "           Temperature          "      255.       .810     .0220
 "           Density Dependent    "        0.       .000
 "           Habitat Movement     "        0.       .000
 "           Freshet Movement     "        0.       .000
 "           Seasonal Movement    "        0.       .000
 "     Spawning Females           "
 "           All                  "    11290.      1.000
 "           Base                 "        0.       .000
 "           Temperature          "        0.       .000
 "           Density Dependent    "        0.       .000
 "           Habitat Movement     "        0.       .000
 "           Freshet Movement     "        0.       .000
 "           Seasonal Movement    "        0.       .000
 "           Spawned              "    11290.      1.000
 "     Adult Males                "
 "           All                  "      653.      1.000     .0303
 "           Base                 "      130.       .199     .0060
 "           Temperature          "      523.       .801     .0243
 "           Density Dependent    "        0.       .000
 "           Habitat Movement     "        0.       .000
 "           Freshet Movement     "        0.       .000
 "           Seasonal Movement    "        0.       .000
 "     Spawning Males             "
 "           All                  "    20884.      1.000
 "           Base                 "        0.       .000
 "           Temperature          "        2.       .000
 "           Density Dependent    "        0.       .000
 "           Habitat Movement     "        0.       .000
 "           Freshet Movement     "        0.       .000
 "           Seasonal Movement    "        0.       .000
 "           Spawned              "    20882.      1.000
 "     InVivo Eggs                "   127156.
```

```
"       Eggs/Alevins             "
"           All                  " 20885840.    1.000      .6967
"           Base                 " 11675010.     .559      .3894
"           Temperature          "     1466.     .000      .0000
"           Density Dependent    "        0.     .000
"           Incubation Loss      "   759884.     .036      .0253
"           Superimposition      "  8438848.     .404      .2815
"           Habitat Loss         "    10625.     .001      .0004
"           Catastrophic         "        0.     .000
"       Fry                      "
"           All                  "  6469095.    1.000      .7113
"           Base                 "   245156.     .038      .0270
"           Temperature          "        0.     .000
"           Density Dependent    "        0.     .000
"           Habitat Movement     "  6203480.     .959      .6821
"           Freshet Movement     "    20459.     .003      .0022
"           Seasonal Movement    "        0.     .000
"           Catastrophic         "        0.     .000
"       Pre-Smolts               "
"           All                  "  1535699.    1.000      .5907
"           Base                 "    99822.     .065      .0384
"           Temperature          "    14009.     .009      .0054
"           Density Dependent    "        0.     .000
"           Habitat Movement     "   984105.     .641      .3785
"           Freshet Movement     "        0.     .000
"           Seasonal Movement    "   437763.     .285      .1684
"           Catastrophic         "        0.     .000
"       Immature Smolts          "
"           All                  "     1823.    1.000      .1231
"           Base                 "        1.     .001      .0001
"           Temperature          "      264.     .145      .0178
"           Density Dependent    "        0.     .000
"           Habitat Movement     "        0.     .000
"           Freshet Movement     "        0.     .000
"           Seasonal Movement    "     1558.     .855      .1052
"           Catastrophic         "        0.     .000
```

```
"Cumulative Movement Statistics "
"---------------------------- "
"Chinook Salmon                    "
"                         ""      ""Dying Movers""        " "   ""Surviving
Movers""      "
"                         ""Groups" "Number" "Avg Dist" "Groups" "Number"
"Avg Dist"
"                         "                        "(meters)"
   "(meters)"
```

"Chinook Salmon"		"Dying Movers"			"Surviving Movers"		
		"Groups"	"Number"	"Avg Dist (meters)"	"Groups"	"Number"	"Avg Dist (meters)"
"Fry	"						
" F1	"						
" Habitat	"	7527	6073272	297.	3234	1962460	188.
" Freshet	"	300	12943	20000.	300	260	20000.
" Seasonal	"	0	0	0.	0	0	0.
" F2	"						
" Habitat	"	2114	130208	367.	899	238155	219.
" Freshet	"	448	7516	20000.	455	17499	20000.
" Seasonal	"	0	0	0.	0	0	0.
"Pre-Smolts	"						
" P1	"						
" Habitat	"	14162	670144	620.	4151	731346	363.
" Freshet	"	0	0	0.	0	0	0.
" Seasonal	"	3907	128542	7000.	3998	774202	7000.
" P2	"						
" Habitat	"	16120	305688	805.	4152	371497	436.
" Freshet	"	0	0	0.	0	0	0.
" Seasonal	"	16859	203288	14000.	18696	1315286	14000.
" P3	"						
" Habitat	"	1915	8273	459.	819	46521	305.
" Freshet	"	0	0	0.	0	0	0.
" Seasonal	"	11574	105933	21000.	13986	681400	21000.
"Immature Smolts	"						
" S1	"						
" Habitat	"	0	0	0.	0	0	0.

" Freshet "	0	0	0.	0	0	0.
" Seasonal "	566	1558	28000.	1260	13594	28000.
" S2 "						
" Habitat "	0	0	0.	0	0	0.
" Freshet "	0	0	0.	0	0	0.
" Seasonal "	0	0	0.	0	0	0.
" S3 "						
" Habitat "	0	0	0.	0	0	0.
" Freshet "	0	0	0.	0	0	0.
" Seasonal "	0	0	0.	0	0	0.

Note: Surviving Movers represent ALL moves and cohorts
      that move more than once in a given category will
      be tabulated for each move.

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1989 Mass Balance for Chinook Salmon

Stage	Entrants	Graduates	Exiters	Deaths	InStream Total
Adult Females	11605	0	0	11605	0 11605
Adult Males	21554	0	0	21537	17 21554
Eggs/Alevins	29980091	0	0	21012991	0 29980091
Fry	0	9094256	25230	6469095	0 9094256
Pre-Smolts	0	2599931	978517	1535699	70902 2599931
Immature Smolts	0	14813	12690	1823	300 14813

```
                      "     Summary of Out-Migrant Fish     "
                      "-------------------------------------"


                      "   ***   Upstream Out-Migrants   ***   "
                      "   -------------------------------   "

                      "          No Out-Migrants            "


                      "   ***  Downstream Out-Migrants  ***   "
                      "   -------------------------------   "
 "Out-Migrants at time step =   24  Date =  2/10/1989"
 "Chinook Salmon                 "
 "-------------------------------"
 "# of cohorts =     2                " "Numbers" "Avg Wt " "Avg Len" "
 Repr.   "
 "                                " " "         " "(grams)" " (mm)   "
"#eggs/fem"

 "-------------------------------------------------------------------
 ------"
 " Adult Females                  "        0       .0       .00
     0.
 " Spawning Females               "        0       .0       .00
     0.
 " Adult Males                    "        0       .0       .00
 " Spawning Males                 "        0       .0       .00
 " Eggs/Alevins                   "        0
 "   Prop. Mature 0-.33           "        0
```

```
"     Prop. Mature .33-.67            "         0
"     Prop. Mature .67-1.00           "         0
" Fry                                 "      3594        .5       35.91
"   F1                                "      3594        .5       35.91
"   F2                                "         0        .0        .00
" Pre-Smolts                          "         0        .0        .00
"   P1                                "         0        .0        .00
"   P2                                "         0        .0        .00
"   P3                                "         0        .0        .00
" Immature Smolts                     "         0        .0        .00
"   S1                                "         0        .0        .00
"   S2                                "         0        .0        .00
"   S3                                "         0        .0        .00
" Total Young                         "      3594        .5       35.91
```
Other outmigrant summaries for time steps omitted here

```
"Out-Migrants summarized across time"
"-----------------------------------"
"Chinook Salmon                      "
"-----------------------------------"
"# of cohorts = 19767                " "Numbers" "Avg Wt " "Avg Len" "
Repr.   "
"                                    " "       " "(grams)" " (mm)    "
"#eggs/fem"

"-------------------------------------------------------------------
------"
" Adult Females                      "         0        .0        .00
     0.
" Spawning Females                   "         0        .0        .00
     0.
" Adult Males                        "         0        .0        .00
" Spawning Males                     "         0        .0        .00
" Eggs/Alevins                       "         0
"   Prop. Mature 0-.33               "         0
"   Prop. Mature .33-.67             "         0
"   Prop. Mature .67-1.00            "         0
" Fry                                "     25230        .6       39.07
"   F1                               "      9432        .5       35.91
"   F2                               "     15798        .7       40.95
" Pre-Smolts                         "    978517       2.7       65.05
"   P1                               "     34446       1.5       53.71
"   P2                               "    465795       2.2       60.90
"   P3                               "    478276       3.2       69.92
" Immature Smolts                    "     12690       5.0       81.66
"   S1                               "     12690       5.0       81.66
"   S2                               "         0        .0        .00
"   S3                               "         0        .0        .00
" Total Young                        "   1016437       2.7       64.61
```

Sample output file when using the -b1 switch.

```
" Date : 8/24/1994"
" Time : 8:52      "
" Title:    Full Trinity River Model - Biological Year 88-89      "

"    " "Fry    " "        " "Pre-Smolts" "   " "Immature" "Smolts"
"    " " "      " " Ave. " "        " " Ave. " "        " " Ave. " "Total"
"Week" "Numbers" "Length" "Numbers" "Length" "Numbers" "Length"
"Numbers"
"--------"        "----------"        "----------"        "----------"
"----------""----------" "---------" "----------"
```

Week	Fry Numbers	Fry Ave. Length	Pre-Smolts Numbers	Pre-Smolts Ave. Length	Immature/Smolts Numbers	Ave. Length	Total Numbers
1	0.	.00	0.	.00	0.	.00	0.
2	0.	.00	0.	.00	0.	.00	0.
3	0.	.00	0.	.00	0.	.00	0.

.
.weeks 4 through 14 listed here
.

Week	Fry Numbers	Fry Ave. Length	Pre-Smolts Numbers	Pre-Smolts Ave. Length	Immature/Smolts Numbers	Ave. Length	Total Numbers
15	0.	.00	0.	.00	0.	.00	0.
16	8260.	35.91	0.	.00	0.	.00	8260.
17	30.	35.91	0.	.00	0.	.00	30.
18	7847.	35.91	0.	.00	0.	.00	7847.
19	313.	39.14	0.	.00	0.	.00	313.
20	254.	36.45	0.	.00	0.	.00	254.
21	5288.	36.12	0.	.00	0.	.00	5288.
22	0.	.00	0.	.00	0.	.00	0.
23	4793.	35.91	653.	51.05	0.	.00	5446.
24	36.	38.64	682.	50.64	0.	.00	718.
25	4737.	36.03	2237.	51.89	0.	.00	6974.
26	0.	.00	282.	51.17	0.	.00	282.
27	20478.	40.00	66992.	55.47	0.	.00	87470.
28	650.	41.51	5157.	57.15	0.	.00	5807.
29	7491.	35.91	287.	53.40	0.	.00	7778.
30	14675.	35.91	1158.	53.45	0.	.00	15833.
31	4942.	35.91	0.	.00	0.	.00	4942.
32	2183.	36.39	154078.	62.39	0.	.00	156261.
33	2183.	35.91	325892.	59.47	0.	.00	328075.
34	1908.	36.74	364505.	60.06	0.	.00	366413.
35	842.	35.91	318717.	59.31	58.	81.09	319617.
36	315.	35.91	336154.	57.82	6919.	80.77	343388.
37	642.	35.91	343708.	56.35	8350.	82.24	352700.
38	0.	.00	192519.	55.79	4309.	84.57	196828.
39	0.	.00	97624.	55.74	1952.	87.12	99576.
40	0.	.00	25516.	54.90	283.	89.39	25799.

```
"MIN"        0."          "         0."          "         0."          "
0.
"MAX"   20478."          "   364505."          "      8350."          "   366413.
"AVE"    2197."          "    55904."          "       547."          "    58647.
"MED"      15."          "        0."          "         0."          "      516.
"STD"    4357."          "   115723."          "      1812."          "   116660.
```

PLOTSTAT Version 1.7

Description

 PLOTSTAT is an output display module for the SALMOD Fish Population Dynamics Model, allowing the user to view the contents of the statistics or sink file in graphs and tables. The statistics file is created by running SALMOD with the *-s* switch; the file contains information detailing the numbers, weight, and length of fish by species, stage, and class for each cohort within all computational units, and at all time steps. The sink file is created automatically and contains identical information as in the statistics file for fish exiting the system. Data may be displayed across time steps or computational units and may be modified on a "per meter" or "per square meter" basis when appropriate. PLOTSTAT replaces the previous PLOT program.

Program Execution

   To execute PLOTSTAT, type PLOTSTAT at the DOS prompt. If the PLOTSTAT.EXE file is not located in the current directory or a directory listed in your DOS PATH, you will have to enter the full path name. For example, if the program is in a directory called *utility*, enter *c:\utility\plotstat*.

   PLOTSTAT requires the following files from the SALMOD project:

1.	the *filenames* file,
2.	the *control* file,
3.	the *species* definition file,
4.	the *stream* definition file,
5.	the *flows* file,
6.	the *weighted usable area* file,
7.	the *relations* file, and
8.	the output *statistics* and *sink* files.

   If any of these files are missing an error message will result.

   The *filenames* file may be specified on the command line with the *-f* switch immediately followed by the filename (for example, *plotstat -ffiles.dat*). In addition, values plotted per unit weighted usable area can be changed to values per hectare stream area by using the *-h* switch with a value for the average stream width in meters (for example, *plotstat -h10.5*).

   In general, the user specifies the data file to be read, the type of output desired, the range of time steps or computational units to view, and the life stages and primary attribute to include and then selects the *Display* option. PLOTSTAT will display a window informing the user that the data file is being read, along with the percent completion. When the data file has been read and any required calculations made, PLOTSTAT will display the graph. If output is being sent to a file, a window will open prompting the user for the output file name before the graph is displayed.

Program Conventions

Viewing the Options

Bar Menus

The PLOTSTAT main menu is presented as a bar menu. Each option is contained in a bar along the top of the window. Each option has a hot key associated with it that will be shown when the <ALT> key is pressed.

List Menus

The input file and forms menus are presented as list menus. The highlight bar may be moved by using the <up arrow> and <down arrow> keys, or by using the mouse. The list scrolls if there are more items than can be displayed in the list window.

Option Boxes

Option boxes are displayed where only one of several choices may be selected. Each available option is listed with a selection point denoted by parentheses to the left of the option. The current option will be marked by a point between the parentheses as shown below.

( ) Option 1
( ) Option 2
(•) Option 3

Only the marked option will be selected.

Check Boxes

Check boxes are displayed where any number of multiple selections may be made. Each option is listed with a selection point denoted by brackets to the left of the option. Those options currently selected will be marked with an X between the brackets as shown below.

[ ] Option 1
[X] Option 2
[X] Option 3
[ ] Option 4

Only those options marked by the X will be selected.

Note: Option boxes and check boxes may exist within the same window.

Text Input Boxes

Certain options will require keyboard input. These options display a text input box. The text input boxes have command buttons to accept the text displayed or to *Cancel*. Enter the desired text, and select the appropriate button. If *Cancel* is selected, any text currently shown will not be accepted.

Verification Boxes

Verification boxes are displayed whenever PLOTSTAT wants to verify a user response. The box will display a prompt with command buttons to continue with the execution or to *Cancel*. Select the desired choice.

Disabled Options

In certain circumstances, some options may be disabled. When an option is disabled, it appears in gray, rather than black, and hot keys are not displayed.

Negotiating the Options

Mouse

All menu options, check boxes, option boxes, and buttons may be selected by "clicking" on the option with the mouse. To select any option using this method, move the mouse cursor to the desired item, check box, or option box, and click the left mouse button.

Note: A mouse driver, MOUSE.SYS or MOUSE.COM, must be present before running PLOTMORT if the mouse is to be used.

Tab

Each menu option, check box, option box, or button in a window is given a tab index. Note that when option boxes are contained within a frame, the frame itself is given focus, and the option boxes are selected with the arrow keys (see below). By pressing the <TAB> key, the focus for the window is moved to the next item in the tab index. If <SHIFT><TAB> is pressed, the focus moves back to the previous item. The item that currently has focus will contain the cursor (for check boxes, option boxes, or text boxes) or will be highlighted (for menu options and buttons).

Alt Key

The <ALT> key will highlight the hot keys for menu items and buttons. To select an item using the hot keys, press <ALT><hot key>.

Arrow Keys

The arrow keys may be used to move through lists of options similar to the <TAB> key; however, when the focus has moved to a list of option boxes within a frame, the arrow keys cannot be used to move focus away from the frame.

Selection

When the focus is on menu items or buttons, the <ENTER> key may be used to make the selection. The <SPACE> bar is used to make selections for check boxes or buttons.

The Main Window

When PLOTSTAT is executed without the *-f* switch, the file list window is displayed (see File option below). After file selection, the main window is displayed (Figure 2).

```
┌─────────────────────────────────────────────────────────────────────┐
│                       SALMOD PLOTSTAT Ver 1.1                         │
│   File  Data_File  Output_Type  Chart_Type  Y-Axis  X-Axis  Forms     │
│                                                                       │
│                       Current Graph Settings                          │
│            Y-Axis                              X-Axis                  │
│   ┌──────────────────────────────┐  ┌─────────────────────────────┐   │
│   │ Value   : [Numbers        ]  │  │              Low      High   │   │
│   │ Scale   : [None           ]  │  │                             │   │
│   │                              │  │ : :Spatial    [1    ] [390 ] │   │
│   │ Species : [Chinook Salmon ]  │  │ : :Temporal   [1    ] [52  ] │   │
│   │           [Chinook Salmon ]  │  │                             │   │
│   │ Stage   : [Adult Females  ]  │  │                             │   │
│   │           [Immature Smolts]  │  │                             │   │
│   │ Class   : [Prop. Mature 0-.33 ] │                             │   │
│   │           [S3             ]  │  │                             │   │
│   │                              │  │                             │   │
│   │ Plot by STAGE                │  │                             │   │
│   │ Data Source: Stats.out       │  │                             │   │
│   └                              └                                    │
│                                                                       │
│        ┌─────────┐      ┌─────────┐      ┌─────────┐                  │
│        │ Reset   │      │ Display │      │ Exit    │                  │
│        └─────────┘      └─────────┘      └─────────┘                  │
└─────────────────────────────────────────────────────────────────────┘
```

The following options are available on the main window (hot keys are shown in bold print):

File   -   allows the user to specify the *files* list filename.

Data_File   -   allows the user to specify the *statistics* file or *sink* file as the data source.

Output_Type   -   allows the user to select output type. Output may be sent to the screen as graphs, to file, or to both. The user may also choose to include a horizontal grid on the graph.

Chart_Type   -   allows the user to determine which type of graph is displayed. The three graph types are line graphs, bar charts, and stacked bar charts.

Y-Axis   -   allows the user to define the Y axis. This definition includes the range of species, stages, or classes, the attribute to plot, along with any modifiers to the attribute.

X-**A**xis   -   allows the user to define ranges for time increments and computational units and to specify which is to be used for the X axis. **Note** that there is a limit of 520 values that can be plotted on the x axis.

For**m**s   -   allows the user to save the current graph definition.

A table listing all current settings is displayed below the main menu. This table provides complete definition for the current graph.

In addition to the main menu, three command buttons exist on the main screen. These buttons are *Reset, Display*, and *Exit*. The *Reset* button returns the default (full range) values to the graph definition, the *Display* button is selected when the user wishes to plot the graph, and the *Exit* button exits the program. All menu options and command buttons are discussed in detail below.

Option Descriptions

File

When the *File* option is selected, PLOTSTAT displays a file list window (Figure 3). Select the input file by moving the highlight bar to the desired file name and press <Enter>, or click on the *Select* button. The file may also be selected by double clicking on the desired file. When the file is selected, PLOTSTAT will search the input file for the names of all other required files.
This window is not displayed if a valid filename was specified on the command line.

NOTE:If the *Display, X-Axis/Spatial or Temporal, Y-Axis/Ranges, or Forms* option is selected before a valid file name has been entered, an error message is displayed.

```
┌──┤        File List        ├──┐
│                               │
│   ┌─────────────────────┐     │
│   │ CONTROL.88          │     │
│   │ DOSXMSF.EXE         │     │
│   │ █FILES.88█          │     │
│   │ FLOW.DAT            │     │
│   │ PLOTSTAT.EXE        │     │
│   │ Q8889.PRN           │     │
│   │ RELATION.DAT        │     │
│   │ SALMOD.EXE          │     │
│   │ SALMOD.OUT          │     │
│   │ SINK.OUT            │     │
│   │ SPAWN.88            │     │
│   └─────────────────────┘     │
│                               │
│      ┌──────┐   ┌──────┐      │
│      │Select│   │Cancel│      │
│      └──────┘   └──────┘      │
│                               │
└───────────────────────────────┘
```
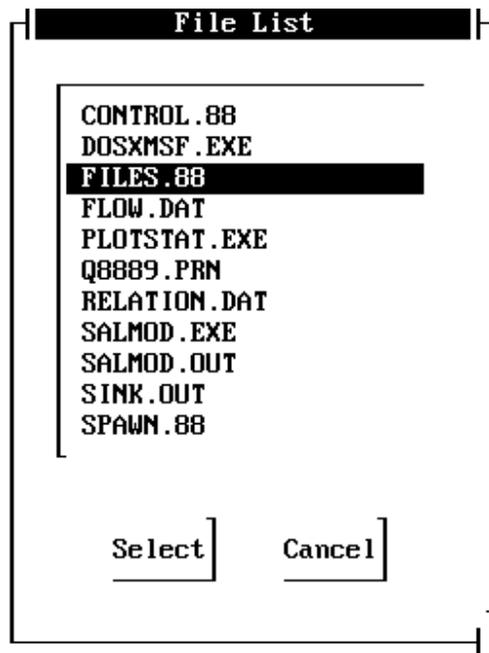
Data File

The *Data File* option allows the user to specify either the statistics file or the sink file as the source for data. When this option is selected, PLOTSTAT displays the *Data File* selection window (Figure 4). Select the desired file, followed by *Exit* to return to the main window.

```
┌─╫───────────────╫─┐
  ║   Data File   ║
  
    (•) Statistics
    ( ) Sink


         ┌─────┐
         │Exit │
         │     │
         └─────┘

└───────────────────┘
```
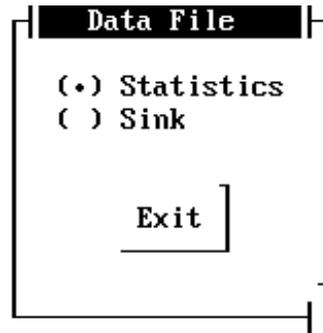
Output Type

PLOTSTAT can send output to the screen in the form of graphs, to a file in the form of tables, or to both. When *Output_Type* is selected, the Output Type options are displayed with check boxes (Figure 5).
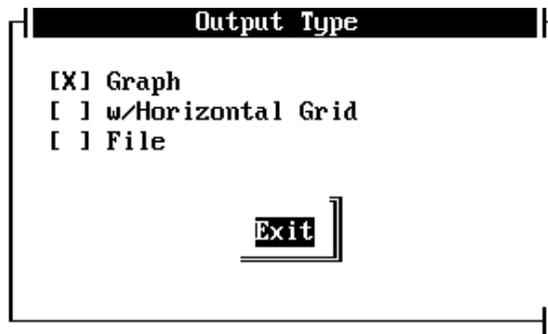
```
┌─╫─────────────────────────╫─┐
  ║        Output Type      ║
  
    [X] Graph
    [ ] w/Horizontal Grid
    [ ] File


              ┌──────┐
              │ Exit │
              └──────┘

└─────────────────────────────┘
```

Select *Graph* to display a graph on screen. Select *File* to create a table to be sent to a file. Both options may be selected if desired. If neither option is selected, the system defaults to the current option. The *w/Horizontal Grid* option may also be selected; however, it is ignored if the *Graph* option is not selected.

Chart Type

The *Chart_Type* option allows the user to select the type of graph to be displayed. When this option is selected, PLOTSTAT displays the *Chart_Type* options (Figure 6). Select the chart type desired, and then select *Exit*. Only one chart type may be selected.

```
┌──────────────────────────────┐
│█████ Chart Type █████         │
│                              │
│  (•) Line Graph              │
│  ( ) Bar Graph               │
│  ( ) Stacked Bar Graph       │
│                              │
│         ┌──────┐             │
│         │ Exit │             │
│         └──────                │
│                              │
└──────────────────────────────┘
```
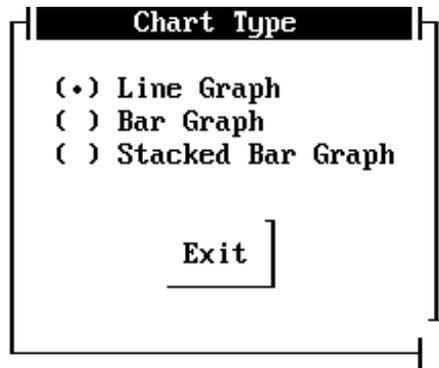
Y-Axis

The *Y-Axis* option allows the user to define population range to be graphed and the values to graph. After selecting *Y-Axis*, PLOTSTAT displays a pulldown menu containing the Y-Axis information categories, including Y-Axis value, scale modifier, and ranges.

   Value

When the *Values* option is selected, the Y Axis values window is displayed (Figure 7).

```
┌──────────────────────────────────┐
│████████ Y-Axis Values ████████   │
│                                  │
│   ┌───────────────────────┐      │
│   │  (•) Numbers (fish)            │
│   │  ( ) Numbers (fish/m)          │
│   │  ( ) Numbers (fish/m**2)       │
│   │  ( ) Biomass (g/m**2)          │
│   │  ( ) Weight (g)                │
│   │  ( ) Length (mm)               │
│   │  ( ) Capacity (%)              │
│   │  ( ) Area (m**2)               │
│   │                                │
│   │  [X] Flow                      │
│   └                                │
│                                  │
│                                  │
│              ┌──────┐            │
│              │█Exit█│            │
│              └──────              │
│                                  │
└──────────────────────────────────┘
```
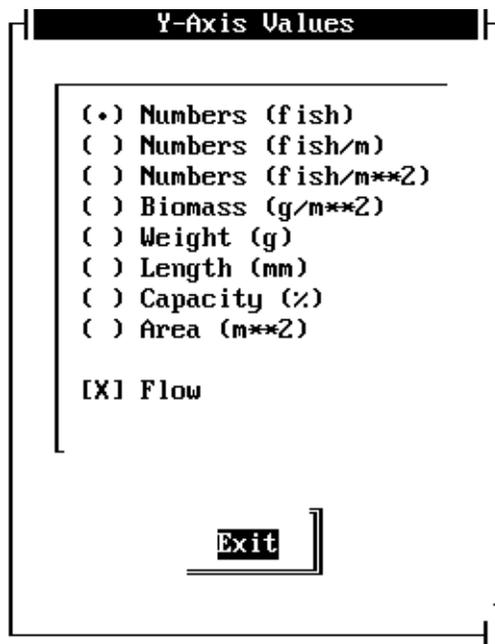
The *Value* option determines what numbers will be graphed. The following options are available:

Numbers (fish) - the absolute number of fish

Numbers (fish/m) - the number of fish per meter of river

Numbers (fish/m**2) - the number of fish per square meter of
            weighted usable area

Biomass - grams/square meter of weighted usable area

Weight - the average weight of fish in grams

Length - the average length of fish in millimeters

Capacity - the percent capacity of the computational unit

Area - the weighted usable area of the computational unit in square meters

Flow - the flow for a given time step in flow segment 1

Note: Flow may be selected in addition to one of the other values. When the graph
            is displayed, the numbers, but not the units, on the Y-axis label will pertain to
            the flow. Flow is always measured in cfs. The flow values on the graph may
            be modified by a factor of ten. This factor is represented in the series key on
            the right side of the graph.

Scale Modifier

The *Scale Modifier* option allows the user to select a Y-scale modifier to alter the appearance and plotting characteristics of the graph. When the *Scale Modifier* option is selected, the options window opens (Figure 8).

```
┌──────── Y-Axis Scale Modifier ────────┐

   ┌─────────────────────────────────
   │ (•) No Modifier
   │ ( ) Log Scale
   │ ( ) Relative (Max=1.0)


              ┌─────────┐
              │  Exit   │
              └─────────┘

└───────────────────────────────────────┘
```
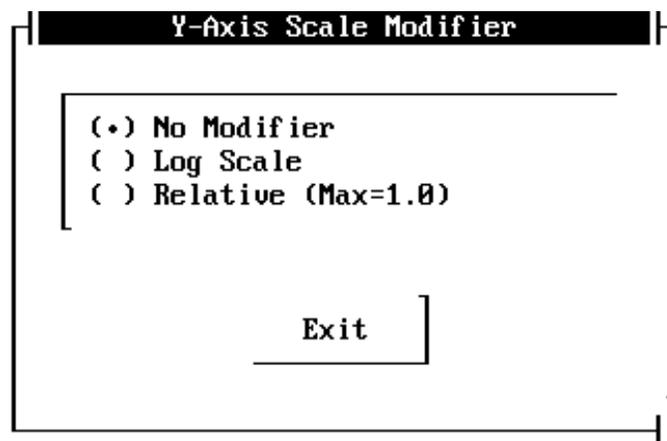
Select the desired option. *No Modifier* plots the graph with no modifications to the Y-axis. The *Relative* option divides all values by the maximum; therefore, all values will range from 0 to 1.0. The *Log* option will display the data on a Log 10 Y-axis (Figure 9). Values along the Y-axis of the log graph indicate powers of ten. After selecting the desired scale modifier, click on the *Exit* button to return to the main window.

Note: Compare the graph in figure 9 to that in figure 14. These graphs show identical data on log and normal scales.
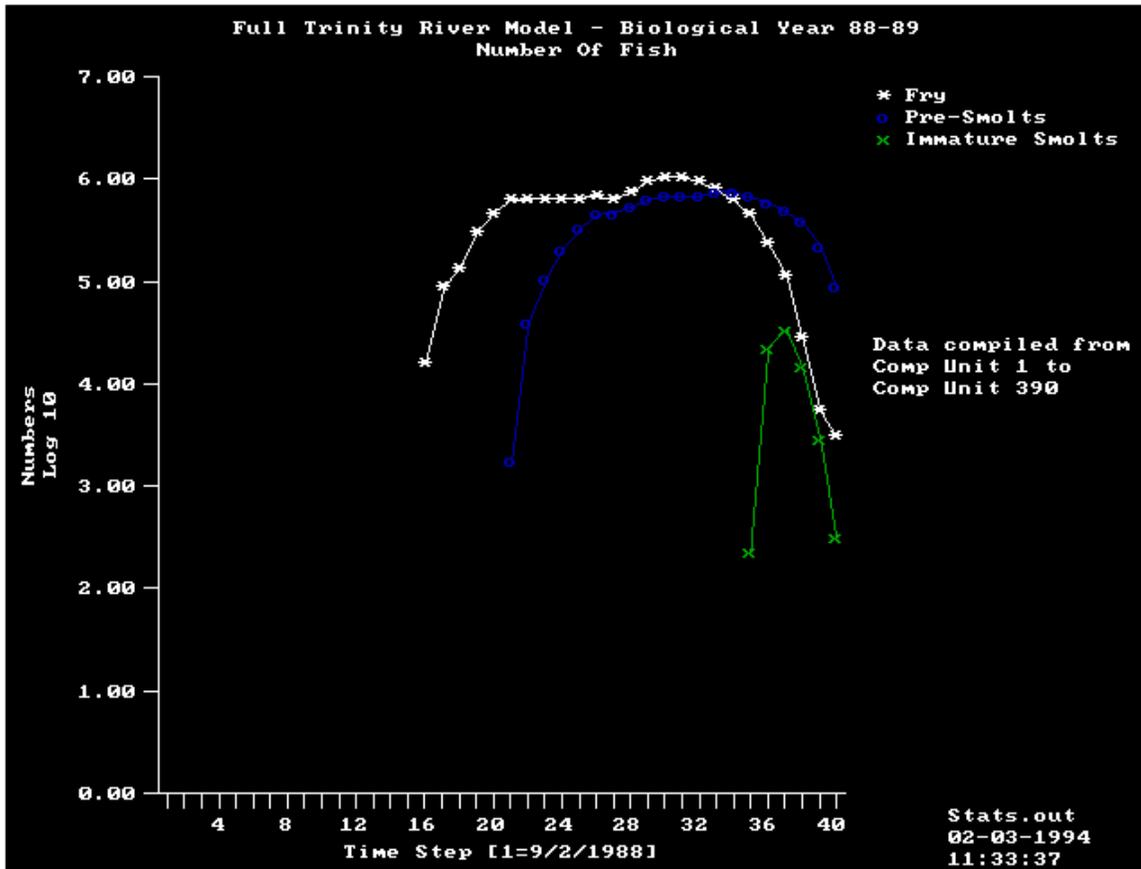
Ranges

The *Ranges* option allows the user to define the series to plot. Data may be compiled by species, stage, or class, and the range of the appropriate type may be set. For example, data may be graphed by stage with only juvenile stages being plotted. When the *Ranges* option is selected, the input window is displayed (Figure 10).

```
┌──────────────────────────────────────────────────────────────┐
│                           Ranges                             ■│
│                                                               │
│              High                    Low           Series     │
│                                                    Attribute   │
│                      ↑                    ↑                    │
│ Species │Chinook Salmon│ ■  │Chinook Salmon│ ■   ( )           │
│                      ↓                    ↓                    │
│                                                               │
│                      ↑                    ↑                    │
│ Stage   │Immature Smolts│ ■  │Adult Females│ ■   (•)          │
│                      ↓                    ↓                    │
│                                                               │
│                      ↑                    ↑                    │
│ Class   │S3│           ■  │Prop. Mature 0-.33│ ■   ( )        │
│                      ↓                    ↓                    │
│                                                               │
│                      Exit                                     │
│                                                               │
└──────────────────────────────────────────────────────────────┘
```

The input window contains text windows for the high and low values for species, stage, and class. Along the side of each window is a scroll bar. The scroll bar may be used to change the respective value. To modify a value, use the mouse or <Tab> to change focus to the desired population definition type. The <Up Arrow> and <Down Arrow> keys may be used, or the mouse cursor may be positioned over the appropriate arrow on the scroll bar. When using the mouse, the left mouse button may be kept down for rapid changes.

Note: PLOTSTAT prevents the low value for each from going above the high value and vice versa. Setting the low and high values the same will result in only one value being compiled.

In addition, the user may select the Series Attribute from the options displayed on the right side of the Ranges window. The Series Attribute determines the categorization for data plotted on the graph. For example, if the Stage button is selected, each data line on the graph will represent one population life stage.

Note: If using <Tab> to move between options, the highlight moves from low to high value for species, stage, and class, to the series attribute box, then to the exit button.

Note: All settings are used to limit the data; therefore, if two species are selected, but only three of eight stages are selected, the data will represent the three stages for the two species, and the remaining five stages will be ignored.

Note: These settings can be used to plot totals. By setting the option button to Species and limiting the stages to fry and older, a graph representing totals for juveniles can be displayed.

When the population definition settings are completed, select the *Exit* button to return to the main window.

X-Axis

The *X-Axis* option allows the user to set the ranges for time steps, computational units, or both. In addition, the value to use for the X-axis is set here. After selecting *X-Axis*, a pulldown menu is displayed offering the options for Spatial or Temporal input.

Spatial

Select *Spatial* to define the range of computational units to include. When Spatial is selected, the system will display a window showing the starting and ending computational units and their respective distances (Figure 11). Default values are set to include the maximum range possible.
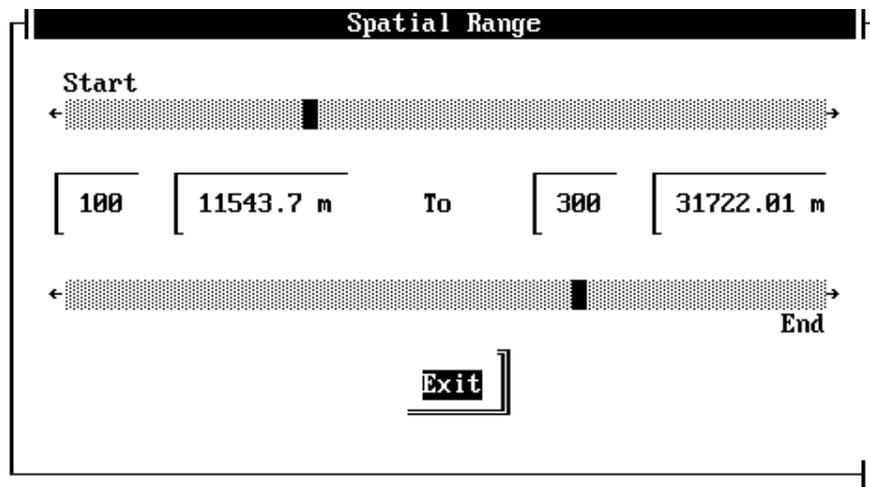
On the top and bottom of the window are the scroll bars for the associated values. Each scroll bar has a left and right arrow. Select the left arrow to move down through the list of values and the right arrow to move up. Using the arrows results in an increment of 1 for each mouse button press. In addition, each scroll bar has a scroll box displayed as a darker box along the bar. This scroll box represents the current value in relation to the minimum and maximum possible values; therefore, if the minimum value is 1 and the maximum value is 390, a current value of 195 would place the scroll box in the middle of the bar. The scroll box may also be used to move rapidly through the values by dragging the box to the left or right. The user may also scroll through the list in increments of 10 by clicking with the mouse along the scroll bar to the left or right of the scroll box.

Note: The maximum number of x-axis values is 520. If the difference between the high and low values is greater then 520, an error message will be displayed.

Note: The minimum value may never move above the maximum, and the maximum value may never move below the minimum.

Note: As the scroll box represents the relative position of the current value to its minimum and maximum, and the minimum and maximum values may change based on current settings, one scroll box may move based on the changes to the opposite value.

When the desired changes have been made, select *Exit* to return to the main window.

Temporal

Select *Temporal* to define the range of time steps to include. When Temporal is selected, the system will display a window showing the starting and ending time steps. As with the Spatial window, defaults are set to the maximum range possible (Figure 12).

Changes to the time step range are made in the same manner as the Spatial changes. When the desired changes have been made, select *Exit* to return to the main window.

Note: When exiting the window, the X-axis definition is set to that option and range. However, both factors will be used when compiling data; that is, if the spatial option is set from computational unit 10 to computational unit 20, and the timesteps are set from 1 to 40, then only those data that meet both criteria will be compiled.

Forms

The *Forms* option allows the user to store and reselect the settings for the current graph. After selecting *Forms*, the Forms window is displayed (Figure 13). Forms are stored in a file named *STFORMS.LST*.

```
┌─────────────────────────────Forms─────────────────────────────┐
│ Form Descriptions              Y-Axis Definition               │
│                                                                │
│  ┌───────────────────────┐      ┌─────────────────────────┐   │
│  │ Default Values        │      │ Y Value    :[Numbers   ] │   │
│  │                       │      │ Y Scale    :[None      ] │   │
│  │                       │      │ Population :[Stage      ] │   │
│  │                       │      │ Spec. Low  :[1         ] │   │
│  │                       │      │ Spec. High :[1         ] │   │
│  │                       │      │ Stage Low  :[1         ] │   │
│  │                       │      │ Stage High :[8         ] │   │
│  │                       │      │ Class Low  :[1         ] │   │
│  │                       │      │ Class High :[11        ] │   │
│  └───────────────────────┘      └─────────────────────────┘   │
│                                                                │
│ Additional Attributes          X-Axis Definition               │
│                                                                │
│  ┌───────────────────────┐      ┌─────────────────────────┐   │
│  │ Graph Type  :[Line    ]│      │ X Value    :[Temporal  ] │   │
│  │ Output Type :[Graph   ]│      │ CU Low     :[1         ] │   │
│  │ Data Source :[Stats File]│    │ CU High    :[390       ] │   │
│  │                        │      │ Time Low   :[1         ] │   │
│  │                        │      │ Time High  :[40        ] │   │
│  └───────────────────────┘      └─────────────────────────┘   │
│                                                                │
│       < Create >      < Delete >      < Select >    < Exit >   │
└────────────────────────────────────────────────────────────────┘
```

There are several components within the *Forms* window: the Forms Description frame, the Y-Axis Definition frame, the X-Axis Definition frame, the Additional Attributes frame, and the command buttons along the bottom of the window.

The Forms Description contains a short description of each form available. The user may scroll through this listing with the arrow keys or may move directly to a form description with the mouse button. As new forms are highlighted, the definition frames display the specific items that are defined by the form. In addition to the description and definition frames, the Forms window contains four command buttons: *Create, Delete, Select*, and *Exit*.

Create

The *Create* button allows the user to create a new form saving the current graph settings. After selecting the *Create* button, the system displays an input window prompting for the new form description. While the input form allows more than 30 characters, only the first 30 characters are stored. When the new form is created, it will be the highlighted form in the description window, and its parameters are displayed in the definition window.

Delete

To delete a form, move the highlight bar in the forms description frame to the desired form, and click on the *Delete* button. The system then displays a prompt window requiring the user to verify the deletion. When a form is deleted, there is no highlighted form, and the definition frame is cleared.

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Select

　　　　To select a form, move the highlight bar in the forms description frame to the desired form, and click on the *Select* button. The form values are set, and PLOTSTAT exits the Forms window.

Cancel

　　　　The *Exit* button allows the user to exit the Forms window without selecting a form.

Reset

　　　　Reset returns the default settings to the graph definition. Default settings are as follows:

Time Steps	-	1 to the maximum number of time steps
Computational Units	-	1 to the maximum number of computational units
Species	-	1 to the maximum number of species
Stages	-	1 to the maximum number of stages
Classes	-	1 to the maximum number of classes
Population definition	-	stage
Y-Axis Value	-	numbers (and no flow)
Value Modifier	-	none
Y-Scale Modifier	-	none

Display

　　　　The *Display* option creates the desired output based on the user selections for output type, chart type, and data selections. When the Display option is selected, PLOTSTAT reads the data, displaying a percent complete window to keep the user informed of its progress. The percent complete window also contains a *Cancel* button. If a mistake has been made, the user may select the *Cancel* button to escape from reading the data. While the data are being read, the status window will display the message "Reading Data . . ." If calculations are required to convert the values to a per meter or per square meter basis, the window will read "Calculating . . ."   After the data have been read, if output is being directed to a file, a filename input box is displayed. Enter the name of the output file. This must be a file that does not currently exist.

Note: The *Cancel* button is disabled during the calculations portion of data preparation.

　　　　Figure 14 shows a sample graph, and the corresponding output table follows. For each graph, the project title as listed in the control file and the graph title appear at the top. The statistics filename, along with the date and time of program execution, is displayed in the lower right corner. Note that all graphs created during a single session will have the same date and time. All output tables will have text enclosed by double quotes for easy import into spreadsheets.

　　　　To return to the menu from the graph display, press any key.

　　　　To make a hard copy of the graph that is on the screen, the DOS GRAPHICS program must be loaded prior to running PLOTSTAT. For example, enter *graphics laserjetii* at the DOS prompt.

Exit

The *Exit* command button in the main window allows the user to exit PLOTSTAT. After selecting this option, the user is prompted to verify the exit.

Example Output Table

```
"02-17-1994  14:29:01
         "
"Full Trinity River Model - Biological Year 88-89
         "
"Data File: Stats.out
         "
"
         "
"                                        Number of Fish
         "
"
         "
"Stage IDs (For CompUnit  1 to  390)
         "
"
         "
"     6   Fry
         "
"     7   Pre-Smolts
         "
"     8   Immature Smolts
         "
"
         "
"                      Stage
         "
"TimeStep"  6          7          8
"------""-------""-------""-------"
    1           0          0          0
    2           0          0          0
    3           0          0          0
    4           0          0          0
    5           0          0          0
    6           0          0          0
    7           0          0          0
    8           0          0          0
    9           0          0          0
   10           0          0          0
   11           0          0          0
   12           0          0          0
   13           0          0          0
   14           0          0          0
   15           0          0          0
   16       16041          0          0
   17       85725          0          0
   . . .
   . . .
   . . .
   27      639178     468169          0
```
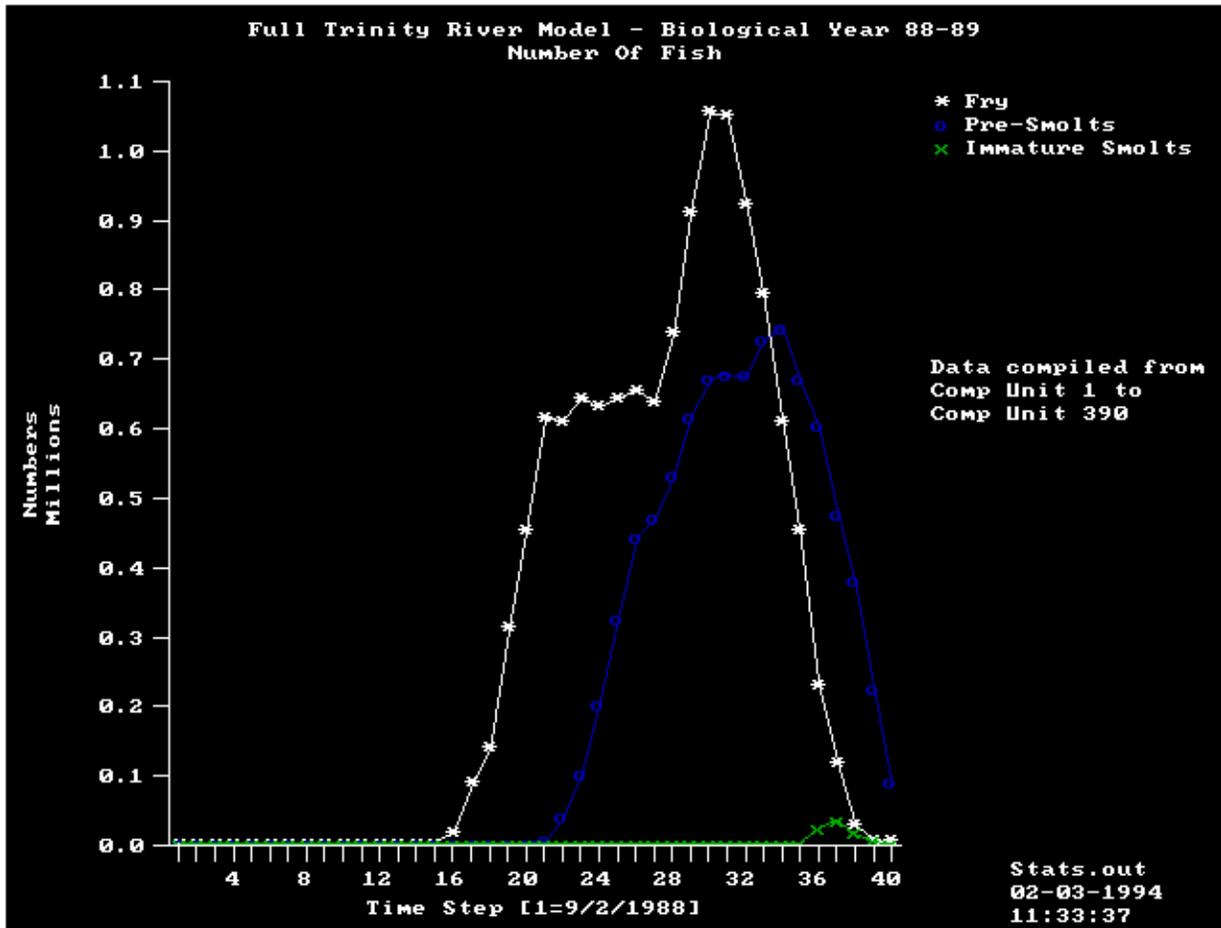
```
28      734876      529342          0
29      911946      616310          0
30     1054476      667820          0
31     1052701      678078          0
32      923795      674337          0
33      791922      726186          0
34      610821      743480          0
35      451038      669444        214
36      230203      601299      22501
37      116119      474811      32881
38       27372      377138      14156
39        5242      219796       2834
40        2924       85578        300
```

Error Messages

The following error messages may occur during execution of PLOTSTAT:

ERROR: File *filename* does not exist!

This error occurs when one of the files listed in the *FILENAMES* file is zero length.

ERROR: Opening *filename*!

This error occurs if a file listed in the *FILENAMES* file cannot be opened.

ERROR attempting to read *FILETYPE* file.
File = *filename*

This error occurs when the program attempts to read the files listed in the *FILENAMES* file. If the file listed is garbage, PLOTSTAT is trying to read a non-text file.

Zero length filename specified!

This error occurs when the *Select* button is pressed before the highlight bar has been moved to a file name. This can only occur when the file list window is opened initially.

No Form Selected!

This error is displayed when the *Select* or *Delete* option is selected in the *Forms* window.

Error switching to graphics mode!

This error occurs when PLOTSTAT cannot switch the display screen from text to graphics mode. Your computer may have no graphics available or may only have modes unrecognized by PLOTSTAT.

Data window cannot be displayed in available space.
Invalid legend coordinates.
Too few series to plot.
No data in series.
BASIC error # occurred.

Charting error # occurred.

These errors are returned by the charting software. If one of these errors occurs, contact the Midcontinent Ecological Science Center at (970) 226-9100.

PLOTMORT Version 1.7

Description

PLOTMORT is an output display module for SALMOD, allowing the user to view, in graphs and tables, the contents of the transactions file. The transactions file is created by running SALMOD with the *-t* switch and contains all transactions that result in a change in the number of fish. More specifically, PLOTMORT displays mortality by week, life stage, and cause. PLOTMORT can display up to 52 weeks of data.

Note: PLOTMORT has many hard-coded items and has limited utility outside of the Trinity River Chinook SALMOD dataset, or for runs beyond one year.

Program Execution

To execute PLOTMORT, enter PLOTMORT at the DOS prompt. If the PLOTMORT.EXE file is not located in the current directory or a directory listed in your DOS PATH, you will have to enter the full path name. For example, if PLOTMORT is in a directory called *utility*, enter *c:\utility\plotmort*.

PLOTMORT requires three files from the SALMOD project: the file names file, the control file, and the output transactions file. If any of these files are missing, an error message will result.

The input file name may be specified on the command line with the *-f* switch immediately followed by the file name (for example, *plotmort -ffiles.dat*).

In general, the user specifies the data file to be read, the type of output desired, and the life stages and mortality causes to include and then selects the *Plot* option. If this is the first graph or table to be made with the selected data file, PLOTMORT will display a window informing the user that the data file is being read, along with the percent completion. When the data file has been read, PLOTMORT will display the graph. If output is being sent to a file, a window will open prompting the user for the output file name before the graph is displayed. Additional stage, cause, and output type combinations may be plotted without rereading the data file.

When PLOTMORT is executed, the file list window is displayed (see FileName below). After file selection, the main window is displayed (Figure 15).

```
╔════════════════ Plot Mortality Ver. 1.2 ════════════════╗
  FileName  Output  ChartType  Selections  Plot  Forms  Exit
```

The following options are available on the main menu (hot keys are underlined):

FileName   -   allows the user to specify the files list filename.

Output   -   allows the user to select output type. Output may be sent to the screen
                         as graphs or to file.

ChartType   -   allows the user to determine which type of graph is displayed. The
                         three graph types are line graphs, bar charts, and stacked bar charts.

Selections   -   presents a window with check boxes for each of the eight life stages
                         and ten mortality causes. Any or all of these may be checked for
                         inclusion in the graph. In addition, option buttons are displayed for
                         summing the data by stage, cause, or both.

Plot   -   reads the data file when required and sends the output to either
                         or both of the output destinations.

Forms   -   allows the user to save the current chart, stage, and cause
                         settings as a form. Forms may be loaded, and these settings
                         will be used for the next graph.
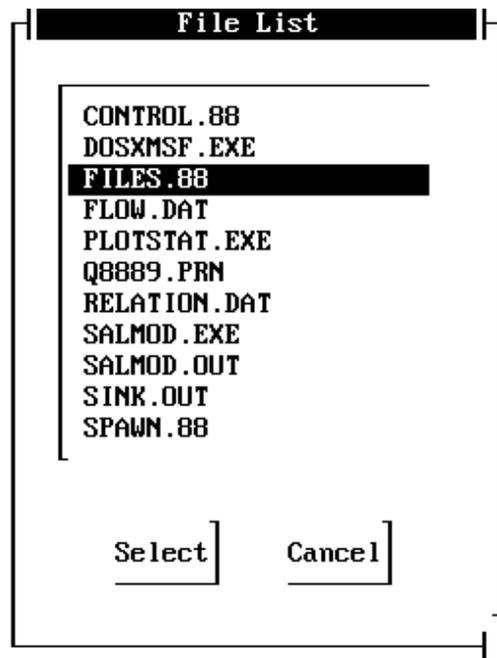
Exit   -   exits PLOTMORT.

Program Conventions

Program conventions are identical to those listed for PLOTSTAT. Please refer to the appropriate
section in the PLOTSTAT chapter for viewing and negotiating options.

Option Descriptions

FileName

When the *FileName* option is selected, PLOTMORT opens the file list window for selection of the FILES file name (Figure 16). When the file name is selected, PLOTMORT will search the input file for the control file filename and the transactions file filename. The control file will be read for the number of weeks in the simulation. PLOTMORT is currently set up to handle up to 52 weeks. If the file name entered by the user does not exist, an error message will be displayed, and the user is prompted to reenter the file name. You may escape any time during file name entry.

```
┌─┤         File List          ├─┐
│  ┌──────────────────────────┐  │
│  │ CONTROL.88               │  │
│  │ DOSXMSF.EXE              │  │
│  │ ███FILES.88██████████    │  │
│  │ FLOW.DAT                 │  │
│  │ PLOTSTAT.EXE             │  │
│  │ Q8889.PRN                │  │
│  │ RELATION.DAT             │  │
│  │ SALMOD.EXE               │  │
│  │ SALMOD.OUT               │  │
│  │ SINK.OUT                 │  │
│  │ SPAWN.88                 │  │
│  └                          │  │
│                                │  │
│     ┌───────┐   ┌───────┐      │
│     │Select │   │Cancel │      │
│     └───────┘   └───────┘      │
│                                │
└────────────────────────────┤  │
```

NOTE: If the *Plot* option is selected before a valid file name has been entered, an error message is displayed. This message is also displayed if *Plot* is selected and PLOTMORT has identified errors in reading the input files. Also note that entering a new file name will cause PLOTMORT to read the data when the *Plot* option is selected.
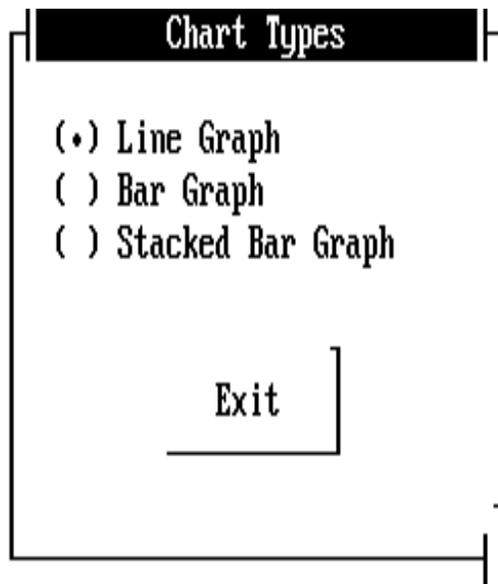
Output

    PLOTMORT can send output to the screen in the form of graphs, to a file in the form of tables, or to both. When the *Output* option is selected, the Output Types window is displayed with check boxes for the output type options (Figure 17).
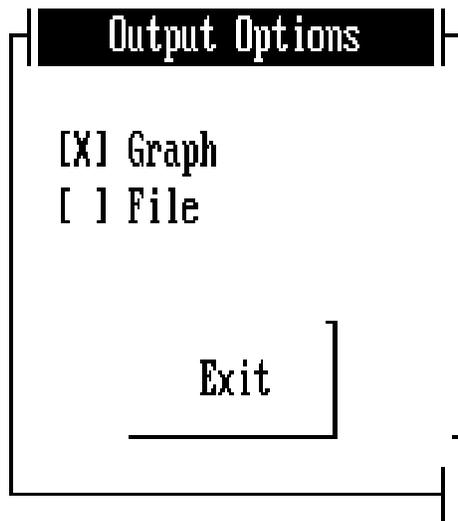
    Select *Graph* to display a graph on screen. Select *File* to create a table to be sent to a file. Both options may be selected if desired. If neither option is selected, the system will default to *Graph*.

ChartType

    The *ChartType* option allows the user to select the type of graph to be displayed. When this option is selected, PLOTMORT displays the *ChartType* selection window (Figure 18). Select the chart type desired, and then select *Exit*. Only one chart type may be selected.

```
 ┌──────────────────────────────┐
 │       Chart Types            │
 │                              │
 │                              │
 │  (•) Line Graph              │
 │  ( ) Bar Graph               │
 │  ( ) Stacked Bar Graph       │
 │                              │
 │                              │
 │                              │
 │            Exit              │
 │                              │
 │                              │
 └──────────────────────────────┘
```

Selections

The *Selections* option allows the user to select those life stages and mortality causes of interest. When this option is selected, the *Selections* window is displayed on screen (Figure 19). The user may then select those stages and causes desired.

In addition, the user may select which values to sum. If *Sum Over Stages* is selected, the graph will show one data line for each selected cause. If *Sum Over Causes* is selected, the graph will show a single data line for each selected life stage. If *Sum Over Both* is selected, the graph will show a single data line representing the total value for all selected stages and causes.

The following default values are displayed when the *Selections* window is entered for the first time during a session. These default values can be reset by selecting the *Default* button.

Life Stages: Fry, Pre-Smolts, and Immature Smolts.
Mortality Causes: Habitat Related Mortality
Sum Over Causes

```
┌──────────────────────────────────────────────┐
│                  Selections                    │
├──────────────────────────────────────────────┤
│                                                │
│  ┌ Life Stages ─────────    ┌ Mortality Causes ─────────── │
│  [ ] Female Adults          [ ] Base Mortality             │
│  [ ] Female Spawners        [ ] Temperature Related Mortality │
│  [ ] Male Adults            [ ] Density Related Mortality   │
│  [ ] Male Spawners          [ ] Incubation                 │
│  [ ] Eggs/Alevins           [ ] Superimposition            │
│  [X] Fry                    [X] Habitat Related Mortality   │
│  [X] Pre-Smolts             [X] Freshet Movement Mortality  │
│  [X] Immature Smolts        [X] Seasonal Movement Mortality │
│                             [ ] Lost Eggs                  │
│                             [ ] Dying Spawners             │
│  ┌─────────────────────     [ ] Catastrophic              │
│  ( ) Sum Over Stages        [ ] InVivo Eggs               │
│  (•) Sum Over Causes                                       │
│  ( ) Sum Over Both                                         │
│                                                            │
│                                                            │
│        ┌ Defaults ┐              ┌ Exit ┐                 │
│                                                            │
└──────────────────────────────────────────────┘
```

Forms

The *Forms* option allows the user to store and reselect the settings for the current graph. After selecting *Forms*, the Forms window is displayed (Figure 20). Forms are stored in a file named *forms.lst*.

```
┌──────────────────────────────────────────────┐
│                   Form List                    │
├──────────────────────────────────────────────┤
│                                                │
│  ┌─────────────────────────────┐              │
│  │ All Causes Summed, Juveniles │    ┌ Add ┐  │
│  │ Egg Mortality                │              │
│  │                              │              │
│  │                              │    ┌ List ┐ │
│  │                              │              │
│  │                              │              │
│  │                              │    ┌ Load ┐ │
│  │                              │              │
│  └─────────────────────────────┘              │
│                                                │
│   Stage Setting     Cause Setting   ┌ Delete ┐│
│                                                │
│   ┌──────────┐      ┌──────────┐              │
│   │          │      │          │     ┌ Exit ┐ │
│   └──────────┘      └──────────┘              │
│                                                │
└──────────────────────────────────────────────┘
```

The *Forms* window contains a list box, two text boxes, and option buttons for *Add*, *List*, *Load*, *Delete*, and *Exit*.

List Box

The List box displays all available forms. As new forms are created, they are placed in the list box. The user may also select forms to *List*, *Load*, or *Delete* by selecting the desired form. If no forms have been created, the list box will display the message "No Forms Available."

Text Boxes

Two text boxes are displayed in the forms window, one for the stages selected and one for the causes selected. These settings are simplified flags for the stages and causes selected. Each is shown as a string of Y's or N's showing which stages and causes will be used. The strings are read left to right and represent, in order, those stages and causes listed in the Selections window. For example, if the stage settings are NNNNYYYY, then Eggs/Alevins, Fry, Pre-Smolts, and Immature Smolts are selected. The stage and cause settings are displayed for the selected form by clicking on the *List* button. They are also displayed for the selected form when the form is *Load*ed.

Add

The *Add* button allows the user to add a new form to the list. The user is prompted for a form description (which will appear in the list box), and a form is created with the current system settings. If no form name is entered or the *Cancel* button is selected, the form add is aborted. The form list will store up to 30 characters in the description.

List

The *List* button displays the stage and cause settings for the currently selected form.

Load

The *Load* button loads the selected form into the system settings, including the stage and cause settings and the chart type. These settings will be used in the next plot, or the settings can be edited in the *Selections* options on the main menu.

Delete

The *Delete* button deletes the currently selected form. The user is required to answer a verification prompt before the form is actually deleted.

Exit

The *Exit* button exits the Forms window.

Plot

The *Plot* option creates the desired output based on the user selections for output type, chart type, stages, and causes. If this is the first graph or table created with the current data file, PLOTMORT reads the data, displaying a percent complete window to keep the user informed of its progress. The percent complete window also contains a *Cancel* button. If a mistake has been made, the user may select the *Cancel* button to escape from reading the data. After the data have been read, if output is being directed to a file, a filename input box is displayed. Enter the name of the output file. This must be a file that does not currently exist.

Figure 21 shows a sample graph, and the corresponding output table follows. For each graph, the project title as listed in the control file and the graph title appear at the top. The transactions file name, along with the date and time of program execution, is displayed in the lower right corner. Note that all graphs created during a single session will have the same date and time.

To return to the menu from the graph display, press any key.

To make a hard copy of the graph that is on the screen, the DOS GRAPHICS program must be loaded prior to running PLOTMORT. For example, enter *graphics laserjetii* at the DOS prompt.
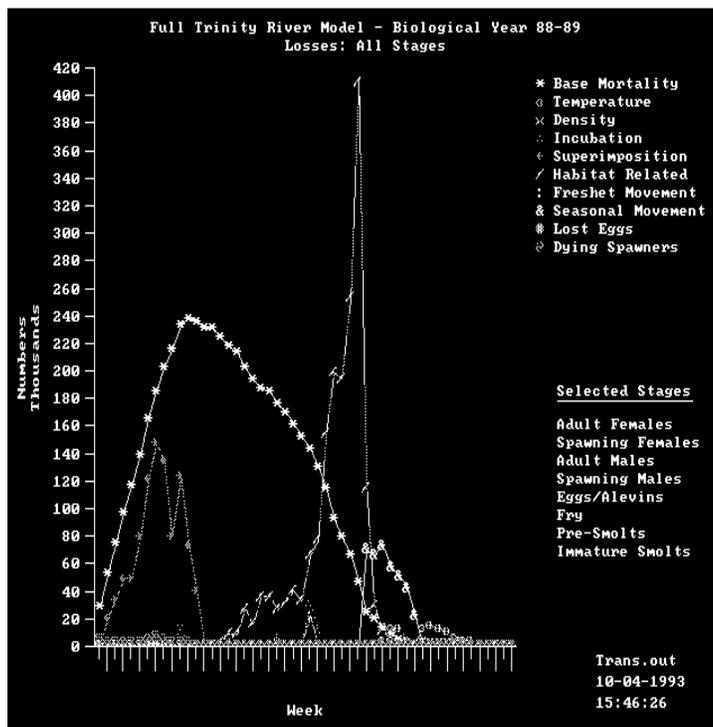
For all tables, the life stages and mortality causes are listed, with those selected being denoted by an asterisk. The numeric column headings for stages or causes relate to the number given in the lists. The file is also set up for import into standard spreadsheet programs.

```
"09-28-1993  14:54:56
         "
"Full Trinity River Model - Biological Year 88-89
         "
"Weekly Mortality by Cause
         "
"
         "
"                        Stages                    Causes
         "
"              --------------------    --------------------
         "
"              1  Adult Females*       1  Base Mortality*
         "
"              2  Spawning Females*    2  Temperature*
         "
"              3  Adult Males*         3  Density*
         "
"              4  Spawning Males*      4  Incubation*
         "
"              5  Eggs/Alevins*        5  Superimposition*
         "
"              6  Fry*                 6  Habitat Related*
         "
"              7  Pre-Smolts*          7  Freshet Movement*
         "
"              8  Immature Smolts*     8  Seasonal Movement*
         "
"                                      9  Lost Eggs*
         "
"                                      10 Dying Spawners*
         "
"                                      11 Catastrophic
         "
"                                      12 InVivo Eggs
         "
"
         "
" * - selected stages and causes
         "
"
         "
"                                         Cause
         "
"TimeStep" 1      2      3      4      5      6      7      8      9
     10
```

```
"-----------------------------------------------------------------------
-------"
```

1	27107	128	0	0	0	0	0	0	109	3402
2	51782	2	0	0	19788	0	0	0	0	2707
3	74070	0	0	0	32925	0	0	0	0	2039
4	96575	0	0	0	47645	0	0	0	0	2354
5	116230	0	0	0	48666	0	0	0	258	1666
6	139265	0	0	0	78472	0	0	0	0	2667
7	165434	0	0	0	120312	0	0	0	144	4611
8	184805	0	0	0	146505	0	0	0	177	6470
9	201550	0	0	0	134932	0	0	0	0	3214
10	214842	0	0	2402	78489	0	0	0	0	946
11	232932	0	0	12295	121898	0	0	0	27	1911
. . .										
. . .										
. . .										
38	4363	11794	0	0	0	965	0	50975	0	0
39	641	3470	0	0	0	267	0	42310	0	0
40	112	1358	0	0	0	0	0	21912	0	0
41	1418	12560	0	0	0	1542	0	0	0	0
42	1437	14400	0	0	0	105	0	0	0	0
43	1110	12624	0	0	0	0	0	0	0	0
44	804	9537	0	0	0	7	0	0	0	0
45	612	6957	0	0	0	0	0	0	0	0
46	446	4946	0	0	0	0	0	0	0	0
47	354	3324	0	0	0	0	0	0	0	0
48	328	2059	0	0	0	0	0	0	0	0
49	333	1031	0	0	0	0	0	0	0	0

50		275	495	0	0	0	0	0	0
0	0								
51		256	276	0	0	0	0	0	0
0	0								
52		245	153	0	0	0	0	0	0
0	0								

Exit

The *Exit* option on the main menu allows the user to exit PLOTMORT. After selecting this option, the user is prompted to verify the exit.

Error Messages

The following error messages may occur during execution of PLOTMORT:

Error: File *filename* does not exist!

This error may occur on the file names file, the control file, or the transactions file. If the file names file is the cause, the system will prompt for reentry of the name. For the control or transactions files, exit the system and check the location of the files and the names of the files compared to the names listed in the file names file. If the transactions file is less than 24 bytes, this error will occur.

ERROR reading project title!
ERROR reading CONTROL file!
ERROR reading TRANSACTIONS file!

These errors may occur if there is a system error reading the data files. Check the appropriate data file for invalid characters.

Error: Number of weeks is zero!
Error: Number of weeks is greater than 52!

These errors occur when the control file is read. If the number of weeks is zero, correct the control file and rerun SALMOD. If the number of weeks is greater than 52, SALMOD must be run for a shorter simulation length before PLOTMORT can be used.

An error occurred reading your input file.
Please check your input files before plotting.

This error occurs when the plot option is selected before any input file errors have been corrected.

No Stages Selected!
No Causes Selected!

These errors occur when the plot option has been selected, but all stages or causes are not selected.

No Form Selected!

This error is displayed when the *Load*, *List*, or *Delete* option is selected in the *Forms* window.

Error switching to graphics mode!

This error occurs when PLOTMORT cannot switch the display screen from text to graphics mode.

Data window cannot be displayed in available space.
Invalid legend coordinates.
Too few series to plot.
No data in series.
BASIC error # occurred.
Charting error # occurred.

These errors are returned by the charting software. If one of these errors occurs, contact the Midcontinent Ecological Science Center at (970) 226-9100.

SALOPT

Description

SALOPT is a flow sensitivity analysis and optimizing utility program for SALMOD. SALOPT allows the user to make numerous SALMOD runs with incremental changes to the flows and corresponding temperatures to determine which changes have the greatest impact on out-migrating fish. The number of out-migrants from each run is stored and may be imported into spreadsheets. In addition, SALOPT can be set to run continuously, making changes to the flows and temperatures, in search of an optimum flow pattern.

In general, SALOPT modifies the flows and temperatures for user-specified periods and runs SALMOD to determine the effect of each change on out-migrating fish. The number of SALMOD runs, and consequently the length of time required, is dependent on the number of changes to make and the period's length. For example, if the period length is 4 weeks (total of 10 periods in a 40-week simulation), the low change is -50, the high change is 50, and the change increment is 50 (total of two changes: -50 and +50 with the zero change ignored), SALMOD will run 21 times. The first run will be the baseline with no changes made. When all runs are completed, the round is completed. If the optimizing switch is ON, a new baseline is created using the best result from the first round, and SALOPT begins again with the new baseline. Optimizing runs will continue until all changes for a round result in zero or negative changes in out-migrating fish.

Program Requirements

SALOPT includes the following files:

    SALOPT.EXE   - the executable file

    TAIL.EXE - extracts the summary data from the SALMOD output file

    SEN.BAT - renames files and runs the TAIL program

The following files are required:

All normal files required by SALMOD. The original flows file must be named FLOWS.BL, and the original temperatures file must be named TEMPS.BL. The flows and temperatures files should be listed in the filenames file with names other than flows.bl and temps.bl. The number of time steps in the control file must be set to 40.

NOTE: Copies of the original flows and temperatures files should be saved with different names or in a different directory, as the .bl files will be overwritten with the new flow and temperature information.

The following files are created by SALOPT:

SENSTAB.ALL - tabular output from non-optimizing run
FLOWOPT.LOG - log file for all changes made in optimizing run

Program Execution

To execute SALOPT, enter SALOPT at the DOS prompt. SALOPT displays the main screen. <TAB> is used to move forward through the options, and <SHIFT><TAB> moves back.

Seven entries are made on the main screen:

Evaluation Period sets the number of timesteps that will be changed for any given SALMOD run. For example, if the evaluation period is set to 4, then changes are made to 4 weeks each time SALMOD is run.

Low Change sets the lowest absolute change that can occur.

High Change sets the highest change that can occur.

Change Increment sets the amount by which the change increases each round. SALOPT starts with the low change and works up to the high change for each period.

Maximum Flow sets the maximum allowable flow. Changes that would result in higher flows remain at the maximum allowable.

Minimum Flow sets the minimum allowable flow. Changes that would result in lower flows remain at the minimum flow, with the exception that flows will never go below zero.

Optimize is a check box option that, when checked, will cause SALOPT to make continuous rounds, modifying the baseline flows and temperatures based on the best result from the previous round.

Maintain Annual Water Balance is a check box (recently added) that, when checked, makes paired changes to flows, one positive and one negative, such that the annual total flow allocation remains the same. This option may be used in conjunction with the **Optimize** check box.

Note: No error control at this point.

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FEEDBACK

We are interested in your feedback on SALMOD, constructive or otherwise. Obviously, we are interested in extending the features of SALMOD if the needs warrant. Some features that have been suggested are (1) adding other "gates" in the middle of the study area to simulate diversions and associated passage problems, (2) adding river network topology to handle tributary production, (3) beefing up the handling of adults, such as tabulating their movement and allowing size classes, (4) fixing known bugs and redoing PLOTMORT and PLOTSTAT into a single module also callable from a supervisory program such as SIAM, and (5) adding age as a cohort attribute so that processes such as mature could operate as a function of age as well as length or lifestage. Let us know.

Feedback may be sent to John_Bartholow@USGS.Gov or to the address/phone listed on the cover.