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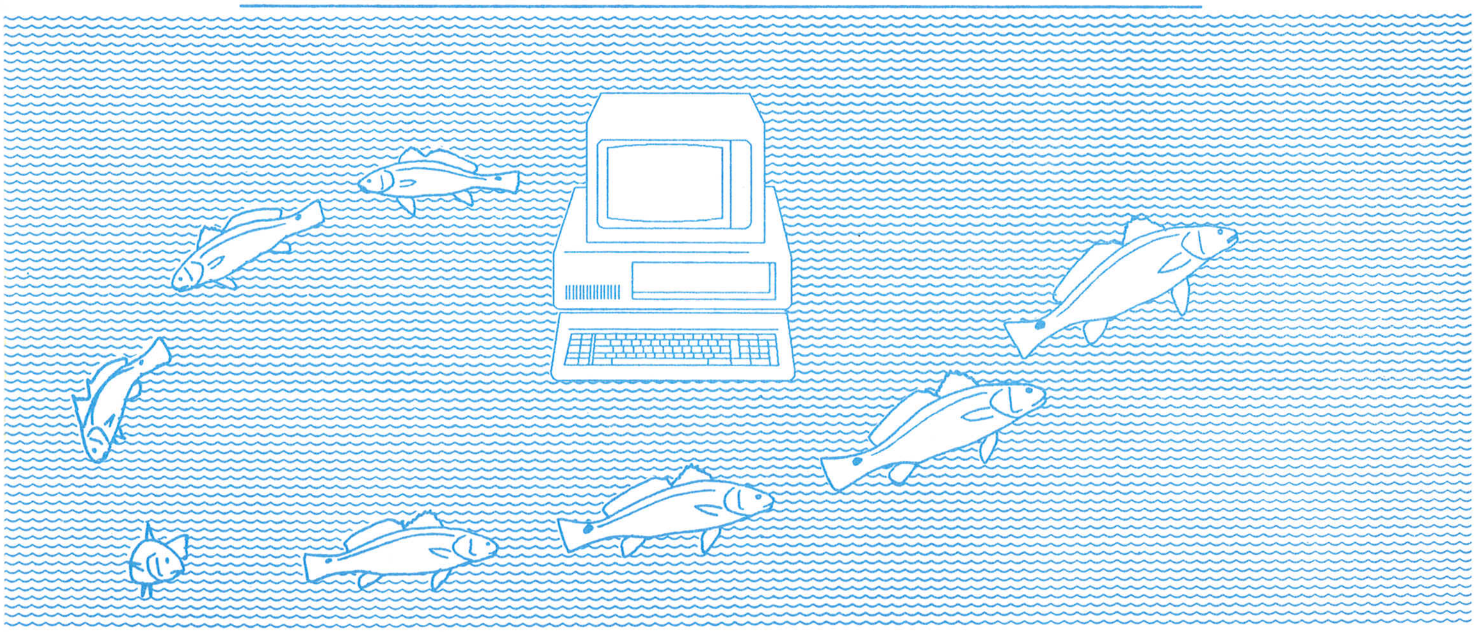
C. Phillip Goodyear



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
Miami Laboratory
75 Virginia Beach Drive
Miami, Florida 33149

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by

C. Phillip Goodyear

U.S. DEPARTMENT OF COMMERCE
Robert Mosbacher, Sr., Secretary

National Oceanic and Atmospheric Administration
William E. Evans, Administrator

National Marine Fisheries Service
James W. Brennan, Assistant Administrator for Fisheries

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NOTICE

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SYSTEM OVERVIEW

LSIM (Length-based Fish Population **SIM**ulation) is the *acronym* for an interactive set of programs for various analyses of fish populations. It consists of a core module, **FSIM**, and supporting programs (Figure 1). FSIM simulates the dynamics of a fish population and the fishery it supports. The other modules are used to either analyze and format input data for FSIM or to analyze the simulation results. Full implementation of the system involves the creation and/or analysis of a dozen or more data files depending on the problem being investigated.

Both executable and source codes (Microsoft QuickBASIC 4.0) are available for implementation on IBM-PC compatible computers. Maximum problem size is constrained by the MS-DOS 640K memory limit. All graphics routines require IBM Enhanced Graphics Adapter (EGA) capability. The system provides for graphic output in HP Laserjet II format. Math coprocessor support is highly recommended.

Brief descriptions of each module (program) and associated data files are presented below.

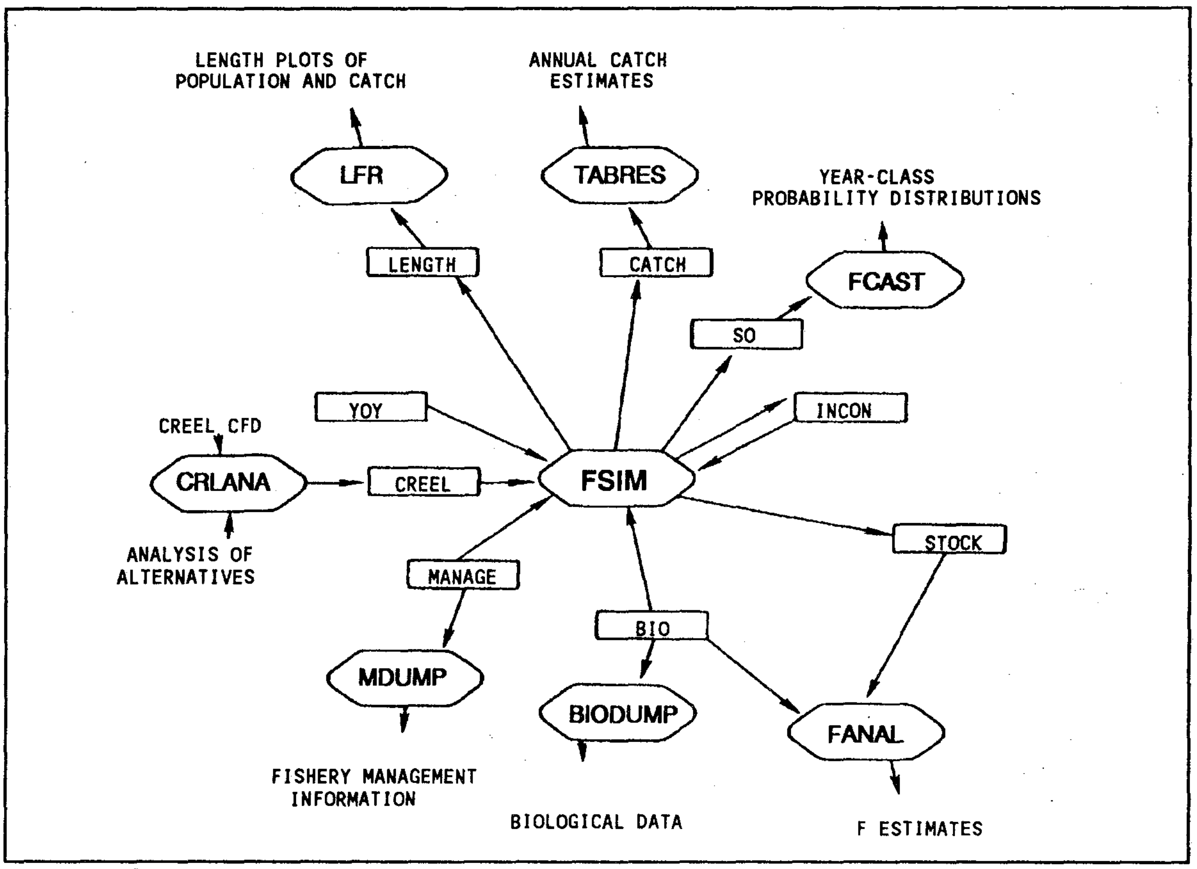


Figure 1. Overview of programs and files employed by LSIM. The arrows point in the direction of information flow. Rectangles are data files.

FSIM[.EXE] - This is the core module of the system of programs. It is used to simulate the dynamics of the fish population and its fishery. Its primary use is to forecast the impact of alternative management options, but it is also useful for exploring the consequences of existing, but untestable, alternative hypotheses regarding growth, migration, mortality, or reproduction.

Data are read from three to five separate files depending on the particular requirement. These files and the information they contain are:

BIO[.DAT] - Biological characteristics such as natural mortality, length-weight equations, lengths at age, coefficients of variation for length at age, fecundity, stock-recruitment information, emigration rates, and availabilities of emigrants to fisheries in their former habitats (used to simulate seasonal migrations to and from spawning or nursery areas). This file also contains a scaler to relate recruitment indices to actual recruitment and specifies the dimensionality of the model. The filename for this file may be specified on the DOS command line, otherwise it defaults to **BIO.DAT**.

CREEL[.DAT] - The cumulative frequency distribution (CFD) of the number of fish in the creel of anglers at a given stock size and with no creel limit imposed. The content and format of the file is produced by the program CRLANA. The name of this file is fixed but the file is only required if the management options include creel limits.

INCON[.DAT] - The initial conditions for the simulation. This file is output at the end of a previous run to save execution time for the examination of future alternatives. It may be named any valid filename. and is requested at runtime.

MANAGE[.DAT] - Fishery-related data for each year of the simulation. The data include size limits, fishing mortality, creel limits, quotas by gear, and non-catch fishing mortality rates (e.g., release mortality). Fishing mortality is read in as a "Base F" and an array of vulnerabilities by gear, age, and location. In the absence of management measures, the simulated fishing mortality at age is the sum of the products of the vulnerabilities and the "Base F" weighted by the spatial distribution of the age class. In most applications the actual fishing mortality rate is an emergent property of the system and depends on the management measures imposed in the simulation. The name of this file may be any valid filename and is requested at runtime.

YOY[.DAT] - The year that is the first year for the simulation, mean recruitment for years preceding annual recruitment measurements, young-of-the-year recruitment indices, and year-class specific deviations from mean growth rates for each year of the simulation. The name of this file may be any valid filename and is requested at runtime.

The results of the simulation may be output to as many as five files. In addition to **INCON**, these include:

CATCH[.DAT] - This file is the main output file of the simulation. It receives the simulated catches by gear, age, and location for years where an output is desired. It also receives estimated reproductive effort (in eggs or biomass of the adult stock). The program, **TABRES[.EXE]**, is used to tabularize results selected from this file.

LENGTHS[.DAT] - Lengths of fish in the population or in the catch are output to this file for later analysis by the LSIM module, **LFR[.EXE]**.

S0[.DAT] - If sufficient years of recruitment indices are available to fill the adult age structure, FSIM will estimate annual egg to recruit survival as the ratio of the simulated population fecundity and the juvenile index for the year. The data are saved in this file for later analysis by another LSIM module, **FCAST[.EXE]**, which provides estimates of future year-class strength probabilities. Forecasts for future years (for which no juvenile indices are available) with FSIM itself presently assume constant mean egg to recruit survival estimated from this procedure.

STOCK[.DAT] - This file receives the state variables for each year of the simulation where an output is desired. This file is the input file for an LSIM module, **FANAL[.EXE]**, which is used to examine F and year-class abundances that result from the simulation.

BIODUMP[.EXE] - This program reads BIO.DAT and outputs the biological characteristics of the population employed in the simulation, including the platoon lengths by age.

CRLANA - This module consists of procedures to analyze creel data and to format the CFD of catch per angler for use in estimating the impact of creel limits on the associated component of fishing mortality (F). It provides the ability to examine the effect of alternative creel limits on catch and F as a function of the size of the [fish] population in relation to the baseline population that existed when the creel data were collected.

FANAL[.EXE] - A program to estimate F by age and spatial component of the population. The effects of creel limits, quotas, and minimum sizes on F are interdependent and influenced by the size of the population. As a consequence, the fishing mortality rate that results from a particular set of management options is often not easily estimated but rather is an emergent property of the system. This program provides estimates of F by age and location from the seasonal changes in stock size saved in the **STOCK** data file using the natural mortality and migration rates from **BIO.DAT**. It also provides for sex ratios by age, season, and location if the sex dimension is set at 2.

MDUMP[.EXE] - This program reads the management definition file and outputs Base F, gear-specific vulnerabilities, and management options employed in the simulation.

LFR[.EXE] - This program provides the capability to interactively examine simulated length frequencies of the catch or population. It reads data from the file, **LENGTH.DAT**. A switch in the management definition file is used to specify whether or not the length information is to be saved in the current year of the simulation and whether or not to save the lengths of the catch or of the population. This program requires EGA support.

FCAST[.EXE] - This program uses the survival and population fecundity estimates from **S0** to forecast the probability distribution of future year-class strengths. The reliability of the forecasts deteriorates with distance into the future, particularly beyond the number of years required for females to mature.

TABRES[.EXE] - This program provides the capability to interactively select catch output for examination and analysis. [If so instructed, FSIM will produce a prodigious (i.e., unmanageable) amount of output.]

VIEWPLOT[.EXE] - This is a utility program to view saved graphics output, to add/edit figure captions, and to print them on a HP Laserjet printer. It requires EGA support.

FSIM

FSIM is a length-based simulation model for fish populations in which females spawn with an annual periodicity throughout their adult lives. It is designed to facilitate analyses of the dynamics of such populations, forecast consequences of management alternatives, and explore the implications of alternative hypotheses concerning such things as growth, mortality, migration or reproduction.

The model is length-based in the sense that each member of the modeled population has a length attribute. This attribute is a function of age, sex, year class, season, and platoon. Reproductive effort is influenced by length in that larger individuals produce more gametes. Fishing mortality is influenced by length through minimum vulnerable sizes and possible minimum and maximum size limits if they are specified as management options.

The computer program that implements the model provides for the preparation of simulated data sets for a number of ancillary analyses. Since each member of the model population has a length attribute, it is possible to generate and save the length distribution of the model population by sex, age, and location, and the length distributions of catches by gear, sex, age, and location. These simulated data provide a convenient means to compare model results to sample data for verification, calibration and hypothesis testing.

Many other such analyses of the simulated data are available through program options that save the results of intermediate calculations in data files for subsequent analyses by the various LSIM modules.

The dimensions of the problem to be investigated are established at runtime by reading a series of maximum values from the biological definition file (BIO.DAT). The specification of a minimum value for each of the dimensions, except age, collapses the model to the equivalent of a simple Leslie Matrix with all age-specific survival probabilities adjusted at annual intervals.

MODEL DESCRIPTION

GROWTH - Variation in length by age is incorporated through the use of cohorts, termed platoons, of individuals of the same age and mean length. The mean length of each platoon is typically drawn from a normal distribution. The number of individuals initially recruited to each platoon of a year class is the same.

The initial mean lengths of each age class and sex are read from BIO.DAT. The mean length at age of each platoon, (L_{IAFP}), at the beginning of the year ($I=1$) is determined from the relation

$$L_{IASP} = Y\bar{L}_{AS} + Y\bar{L}_{AS}VX_P$$

where:

$\bar{L}_{AS}$ = mean length of fish of sex S at age A at the beginning of the year (season 1)
L_{IASP} = mean length of age A, sex S, platoon P individuals at the beginning of season I
Y = coefficient to adjust for variation in growth of individual year classes
V = coefficient of variation (fraction) of length at age
X_P = deviate for the center of P^{th} percentile for the distribution of lengths at a given age.

The X_P are either read from BIO.DAT or are the computed standard normal deviates (drawn from the normal distribution).

Platoon weights, W_{ISAP}, and lengths, L_{IASP}, are related by sex-specific length-weight equations of the form

$$W_{ISAP} = a_S L_{IASP}^{\ b_S}$$

where:

a_S = scaler coefficient of the length-weight equation for sex S
b_S = exponent of the length-weight equation for sex S
W_{ISAP} = mean weight of sex S, age A, platoon P survivors at the beginning of a season I.

Lengths are estimated from weights using the complementary function

$$L_{IASP} = e^{\log(W_{ISAP} / a_S) / b_S}$$

Growth of each platoon during the year is estimated from the annual instantaneous growth rate, Q_{SAP}, determined as the natural log of the ratio of the platoon weights at age and age+1 where weights are estimated from corresponding lengths; i.e.,

$$Q_{SAP} = \log(W_{1A+1SP}/W_{1ASP})$$

Seasonal growth rates for each sex, age, and platoon G_{ISAP}, are then estimated from

$$G_{ISAP} = Q_{SAP}H_I$$

where:

H_I = seasonal proportions of the total annual growth.

REPRODUCTION - Annual reproductive potential of the population, P, is estimated as

$$P = \sum_{A=0}^{NAGE} \sum_{P=1}^{NPLT} \sum_{L=1}^{NLOC} N_{WFAPL} E_{AP} / C$$

where:

NAGE = the number of ages considered,
NPLT = the number of length groups (platoons) considered,
NLOC = the number of areas considered (1 or 2),
F = NSEX,
NSEX = the number of sex groups considered (1 or 2),
N_{ISAPL} = Number of survivors at beginning of season I, sex S, age A, platoon P and area L
W = spawning season
E_{AP} = Average reproductive potential of age A females of platoon P
C = Correction term for the number of sexes (= 2 if nsex=1, 1 if nsex=2).

E_{AP} is estimated from the relation

$$E_{AP} = AL_{DAFP}^{\;B}$$

where:

L_{DAFP} = length of age A females of platoon P during the spawning season D
A = scaler coefficient of length-fecundity relationship
B = exponent of length-fecundity relationship.

Minimum length at maturity is accommodated by limiting the evaluation of E_{FAP} to fish above a lower critical length. Similarly, E_{FAP} is truncated at a specified maximum value.

Alternatively, the E_{FAP} may be assigned mean fecundities at age. In this case the platoon lengths do not influence fecundity estimates. The selected option is specified by a switch in the biological definition file, with a value of 1 selecting the length-fecundity model and a value of 2 selecting mean fecundities at age.

SPAWNING STOCK RATIO - The spawning stock ratio (SSR) is the ratio of the spawning stock biomass per recruit in the existing stock to that which would exist in the absence of fishing. Spawning stock biomass per recruit SSB/R is the sum of the of eggs produced per recruit for each age class in the population. It is evaluated as the reproductive potential of each age class divided by the original number of recruits to the year class which constitutes the age class. It therefore retains memory of the exploitation history of all year classes contributing to reproduction and is not based on equilibrium assumptions. The SSR estimate for a given year is estimated as the ratio of SSB/R for that year and the equilibrium SSB/R in the absence of any fishing mortality.

RECRUITMENT - If the year-class strength, J, is defined by a value read in from the YOY data file, that value is used to set the strength of the recruiting year class in the model population. In this case, the year-class-strength estimate is divided by the model-generated estimate of reproductive potential (FEC). This ratio is referred to as S_0 since it is an estimate of that year's survival from the egg to the juvenile stage. These values may be saved in a file (SO.DAT) for later analyses with FCAST.

If the year-class strength is not defined, then one of four options is employed to estimate recruitment.

Option 1:
Recruitment is not estimated. In this case recruitment is set to zero and the model population will begin to reflect missing year classes.

Option 2:
Recruitment is estimated from the mean of a selected set of S_0 estimates from previous model years. The range of annual S_0 is selected by specifying the first year to be included. The resulting range is from the specified first year to the last year where the juvenile recruitment from the recruitment definition file (YOY.DAT) is a non-zero value. In this case, the number of recruits is estimated as the product of mean S_0 and the present year's estimate of total egg production (P).

Options 3 and 4.
Recruitment is estimated from a spawner-recruit curve which may be either a standard Ricker model (option 3) or a Beverton-Holt curve (option 4). In both cases, the density-dependent mortality is keyed to the size of the annual fecundity estimate; i.e., the value of parental stock size in the standard notation for both equations is set equal to the value of P as defined above. In terms of the present model notation, the Ricker model would be:

$$J = \alpha P e^{-\beta P}$$

and the Beverton-Holt model would be:

$$J = 1/(\alpha + \beta/P)$$

Where a sufficient time series of juvenile indices are available, it is possible to fit these stock-recruitment curves to the FSIM-generated P estimates and realized year-class strengths. This procedure has the advantage of avoiding the difficulty of deriving appropriate scaling factors for converting fitted estimates (from real-world samples) among real-world population, real-world sample, and FSIM units. This approach will not, however, alleviate the difficulties inherent in model selection and the uncertainty in the validity of the fitted parameter estimates.

Once the year-class strength (J) is estimated and adjusted to the proper scale, the recruits are distributed to age 0 according to

$$N_{RSOPL} = JU_L \,/\, (NPLT)(NSEX)$$

where:

U_L = fraction of recruitment that occurs in area L,
R = the season of the year when the juveniles recruit to the population.

MIGRATION - When the spatial dimension is set to 2, migration rates are required for each sex. The migration rates are the proportions of age classes in area 1 that transfer to area 2. The transfer occurs at the beginning of a season specified to be the migration season in the biological definition file. The transfers occur according to

$$N_{ISAP2} = N_{ISAP2} + N_{ISAP1} m_{AS}$$

$$N_{ISAP1} = N_{ISAP1}(1 - m_{AS})$$

where:

m_{AS} = migrating proportion for age A and sex S
N_{ISAPL} = Number of survivors at beginning of season by sex, age, platoon and area (1 or 2)

The migration feature is useful for simulating the emigration of juveniles from spawning or nursery areas to adult habitat. An example would be the movement of red drum from their estuarine nursery grounds to the offshore environment typical for adults in the Gulf of Mexico.

Once the transfer occurs, the transferees are forever associated with the "adult" habitat (area 2) but may still be harvested in spawning/nursery habitat (area 1) during certain seasons, such as during annual spawning migrations. Provision is made for such movements by assigning seasonal availability factors (a_{SA}) to control the spatial distribution of the adult stock. These availabilities are the age- and sex-specific proportions of the stock in area 2 that are available for harvest in area 1 each season. No individuals of area 1 are available for harvest in area 2.

FISHING MORTALITY - Conceptually, fishing-induced elevations in the total mortality rate of exploited populations may result from three interrelated phenomena: the deaths of fish that are 1) caught and retained by fishermen, 2) released (or discarded) but do not survive the experience, and 3) never actually landed but suffer fatal encounters with fishing gear (e.g., hook-induced mortality, dropouts from gillnets). FSIM directly addresses the first two of these phenomena (termed fishing mortality and non-catch fishing mortality, respectively) but not the third (although aspects of the third may be incorporated or examined for some purposes through modifications of natural mortality rates and/or adjustments of fishing mortality rates).

In the absence of any adjustments for size limits, creel limits, or quotas, fishing mortality by sex, age, platoon, location, and gear (often referred to as partial F's) is given by

$$F_{ISAPLK} = \Omega V_{ISALK}$$

where:

Ω = a scaler multiple of fishing mortality (the "Base" fishing mortality rate)
V_{ISALK} = vulnerability during season I of individuals of sex S, age A, in area L, to gear K

Both the base fishing mortality and the V_{ISALK} are read from the management definition file (MANAGE.DAT) and may be modified on an annual basis.

Note that in the absence of size effects, fishing mortality is the same for all platoons of the same sex, location, and age. Two size effects are incorporated into the model: 1) a minimum size at which individuals become vulnerable to harvest by each gear, and 2) minimum and/or maximum size limits (by area) imposed as management actions.

F_{ISAPLK} is set to zero for any combination of ISAPLK where the platoon length at the end of the season is below the minimum vulnerable or legal size, or where the platoon length at the beginning of the season is above the maximum legal size. As a consequence, fish are subject to F_{ISAPLK} (and yield accumulated therefrom) only if they are of a legal size sometime during the season. No adjustment is made for the proportion of the season above/below size limitations.

Creel limits are accommodated by estimating the fraction of the unregulated harvest of legal fish that would continue to be harvested with the creel limit. This is accomplished using a sample empirical cumulative frequency distribution (CFD) of catch per angler with no creel regulations in place and the ratio of the estimated size the catchable stock to the reference (baseline) stock size (R_A in the equation below) that existed when the CFD measurements were taken.

It is assumed that the proportion of the available stock captured by each percentile in the population of fishermen remains the same and is represented by a cell in the CFD. Fish above the creel limit continue to be captured but are released. Under this assumption, the unregulated catch in each cell at some realized stock size is equal to the baseline catch per cell, B_C, multiplied by the ratio of the realized and baseline catchable stock sizes. For convenience, the reciprocal of the baseline catchable stock size is a FSIM input variable, crlcon. The harvest in a cell, H_C for any stock size is then estimated as

$$H_C = (crlcon_A)(stocksize_A)B_C$$

where:

B_C = the reference (or baseline) catch per cell
$stocksize_A$ = total number of fish of legal size in area A during the current season
$crlcon_A = 1/R_A$
R_A = reference (or baseline) catchable stock size in area A.

The creel/nocreel proportion for the particular area, $crlratio_A$, of the fish that are harvested for a particular stocksize is estimated as

$$crlratio_A = \left(\sum_{C=1}^{N} H_C + \sum_{C=N+1}^{NOBS} limit \right) / \sum_{C=1}^{NOBS} H_C$$

where:

N = number of cells in which H_C < limit
NOBS = number of cells in the empirical CFD
H_C = estimated harvest in cell c; = (crlcon)(stocksize)B_C
limit = the creel limit.

If the $crlratio_A$ is less than unity, the partial fishing mortality rates for gear 1, for all ages, sexes, and platoons of legal sizes for the area are reduced by the fraction, $crlratio_A$.

Quotas may be incorporated for each gear or a subset of consecutive gears. At the beginning of the quota year (a specified season), all quota sums are set to zero. Quotas are simulated by the simple convention of accumulating the total simulated landings for each gear during the simulated year. The total accumulated landings are compared to the amount of the quota at the beginning of each season. If the total exceeds the quota allocation, the partial fishing mortality rates for all gears involved are set to zero for the remainder of the quota year.

NON-CATCH FISHING MORTALITY - Fish above the minimum vulnerable size to a gear but which are outside a legal size range or captured beyond the allowable creel limit are assumed to be caught in the proportion dictated by the product of the base F and the vulnerabilities (i.e., ΩV_{ISALK}). They are assumed to suffer a release mortality ($relmort_A$) that depends on the area of capture. For fish outside the legal size range, this non-catch fishing mortality is estimated as the product ($relmort_A$)(ΩV_{ISALK}). The non-catch fishing mortality rate of legal-sized fish resulting from releases in excess of the creel limit is estimated as the product, (1-$crlratio_A$)($relmort_A$)(ΩV_{ISALK}). Non-catch fishing mortality is assumed to be zero for fish spared by quotas.

NATURAL MORTALITY - Natural mortality is read from BIO.DAT. It does not vary with population density but may vary with age and sex. The computer code is dimensioned for seasonal variation in natural mortality; however, the current version of FSIM does not implement this feature.

TOTAL MORTALITY - Total mortality is the sum of natural mortality, fishing mortality, and non-catch fishing mortality. Since natural mortality in this model is not density-dependent, total mortality does not incorporate any compensatory density-dependent effects. However, if management specifications include quotas or creel limits, the fishing mortality component of total mortality will be density-dependent and depensatory. In this situation, total mortality will also be depensatory. Total mortality by season, sex, age, platoon, and area is given by:

$$Z_{ISAPL} = M_{ISA} + \sum_{K=1}^{NGEAR} F_{ISAPLK} + O_{ISAPLK}$$

where:

M_{ISA} = natural mortality for sex S, and age A in season I
F_{ISAPLK} = fishing mortality for sex S, age A, platoon P, area L, and gear K, in season I
O_{ISAPLK} = non-catch fishing mortality for sex S, age A, platoon P, area L, and gear K, in season I.

SURVIVORSHIP - The number of survivors to the end of the season by sex, age and platoon in area 1 is estimated as

$$N_{ISAP1} = N_{ISAP1} e^{-Z_{ISAP1}}$$

and, if two areas are included in the problem, survivorship in area 2 is

$$N_{ESAP2} = N_{ISAP2}\,(1 - a_{SA}) e^{-Z_{ISAP2}} + N_{ISAP2} a_{SA} e^{-Z_{ISAP1}}$$

where:

N_{ISAPL} = Number of survivors at beginning of season I, sex S, age A, platoon P and area L
N_{ESAPL} = Number of survivors at the end of season I (I=E), sex S, age A, platoon P and area L.
a_{SA} = Seasonal availability of sex S, age A individuals of area 2 to fisheries in area 1.

The survivors at the beginning of a season are always the same as those at the end of the preceding season with certain exceptions. If the problem being evaluated has two spatial dimensions and if the season is the specified migration season, the migrants are transferred from area 1 to area 2. Similarly, if the last season evaluated was the last of the specified number of seasons in the problem, then the age assignments are updated and the survivors for age zero are set to zero. If the season is the recruitment season, the survivors for age zero are set to the recruitment estimate.

YIELD - Annual total yield, Y, is estimated as

$$Y = \sum_{I=1}^{NSZN} \sum_{S=1}^{NSEX} \sum_{A=0}^{NAGE} \sum_{P=1}^{NPLT} \sum_{L=1}^{NLOC} \sum_{K=1}^{NGEAR} [n_{ISAP1} W_{ISAP} Z_{ISAPL} F_{ISAPLK} A_{ISAPL} (e^{(G_{ISAP} - Z_{ISAPL})} - 1)/(G_{ISAP} - Z_{ISAPL})]/Z_{ISAPL}$$

where:

$n_{ISAP1} = N_{ISAP1} + N_{ISAPL} a_{SA}$

$n_{ISAP2} = N_{ISAP2} (1 - a_{SA})$

N_{ISAPL} = number of survivors at beginning of season I, sex S, age A, platoon P and area L
NSZN = the number of seasons within a year,
NGEAR = the number of gears in the fishery
Z_{ISAPL} = total mortality
F_{ISAPLK} = fishing mortality attributable to a particular gear (exclusive of noncatch fishing mortality)
A_{ISAPL} = fraction of initial survivors that die during the season
$= 1 - e^{-Z_{ISAPL}}$
G_{ISAP} = instantaneous seasonal growth rate (by age, sex and platoon).

Yield in numbers, YN, is estimated as

$$YN = \sum_{I=1}^{NSZN} \sum_{S=1}^{NSEX} \sum_{A=0}^{NAGE} \sum_{P=1}^{NPLT} \sum_{L=1}^{NLOC} \sum_{K=1}^{NGEAR} n_{ISAP1} Z_{ISAPL} F_{ISAPLK} A_{ISAPL} / Z_{ISAPL}$$

The results of intermediate calculations of total yield in numbers and weight may be saved for later analysis.

FSIM USER'S GUIDE

SYSTEM REQUIREMENTS - Both executable and source codes (Microsoft QuickBASIC 4.0) are provided for implementation on IBM PC-compatible computers running under MS-DOS. Array space is dynamically allocated by the dimensionality of the problem being investigated with a maximum equal to the DOS 640K limit. Math coprocessor support is not required but is highly recommended, particularly for large problems. Users who own a copy of QuickBASIC 4.0 and wish to alter the FSIM source code will need to load the huge memory module (i.e., C:> QB /aH) to run from within the QB environment.

FSIM itself does not require Enhanced Graphics Adapter (EGA) capability. However, CRLANA, VIEWPLOT, and LFR all require EGA support. These programs provide graphic output in HP Laserjet II format files.

Those users needing to adapt the source code of the LSIM modules that support graphic output will need to load the huge memory module and CPG.QLB with the QuickBASIC library option (e.g., C:> QB /lCPG /aH) and to link the object modules of these files with CPG.LIB.

Depending on the size (complexity) of a problem, FSIM may be executed from floppy disks. However, many (most) problems will require large amounts of disk storage for the intermediate output files, particularly if length frequencies of catches are being examined for a number of years and there are many contributing gears.

RUNNING FSIM - Many of the FSIM options and all of the input and output filenames are specified at runtime. The filename for BIO.DAT is specified on the command line; e.g.,

```
C:>FSIM bio.dat
```

If no filename is specified on the command line, the filename for the biological definition file defaults to BIO.DAT. This file is read by various LSIM modules including BIODUMP, MDUMP, FANAL and TABRES. For this reason, the same biological definition file should be used for all simulations and analyses of results with respect to any particular problem under investigation. This requirement is the reason that the name for the biological definition file is a command line option rather than a data request during the initialization sequence for FSIM.

It is recommended that the FSIM program files be located in a separate directory designated in the DOS PATH command. A DOS directory should also be established as a work directory for each problem. A copy of BIO.DAT in that directory can them be tailored to the specific problem. All program runs in that work directory would then access the same copy of the biological definition file.

Once the program and biological definitions are loaded, FSIM displays its version, the species description title, and the BIO.DAT filename. It then prompts the user to specify the conditions of the run and the filenames for the various input and output files. The default answer for each prompt (displayed in parentheses) will be accepted in response to a carriage return <CR>. An example of the FSIM initialization sequence is given in the box below.

FSIM (1.0) /cpg Dec 88

Biological definitions from BIO.DAT
Species = Red snapper
Remaining array space is 80692 of 107204 possible elements

INPUT DEFINITION

Infile for recruitment indices (yoy.dat) -> **yoy.dat**
Infile for initial stock conditions (nul) -> **nul**
Last year of simulation (2050) -> **1987**

OUTPUT DEFINITION

First year for output (1960) -> **1983**
Last year for output (2050) -> **1987**
Catch output data file (catch) -> **catch**
Stock output data file (stock) -> **stock**
Length output data file (length.dat) -> **length**
Title for run -> **test**
Save end as initial conds (N) -> **y**
Name for IC output file (incon.dat) -> **incon.dat**
Save survival estimates (N) -> **y**
Name for surv. output file (so.dat) -> **so.dat**
First year to save -> **1977**
Last year to save -> **1987**
Management data file (manage.dat) -> **manage.dat**

The user responses to the FSIM initialization prompts in the above example are in **bold** typeface. If <CR> with no other characters is issued in response to the prompt then the data indicated in parentheses will be accepted as the response. Other significant considerations relating to the responses include:

A. If the prompt, "Infile for initial stock conditions (nul) ->," is answered with any characters other than "nul," FSIM will attempt to load that file into memory.

B. If the query, "Save end as initial conds (N) ->," is answered in the negative then FSIM will not issue the next prompt requesting the name of the output file.

C. If the prompt, "Save survival estimates (N) ->," is answered in the negative then FSIM will not issue the next three prompts requesting the filename and years to save. If the recruitment option 2 is specified in BIO.DAT and any recruitment value in YOY.DAT is zero for the range of years in the simulation, then the response to this prompt must be "Y." The range of years to save requested in the subsequent prompts is the range of years to include in the estimate of mean egg to recruit survival (S_0) that FSIM will use to forecast year-class strengths.

RUN FILES - A run file is a list of responses to the FSIM prompts. Use of run files reduces the possibility of typing errors that can cause FSIM to halt execution. An example run file corresponding to the example FSIM initialization prompts above is given in the box to the left.

```
yoy.dat
nul
1987
1983
1987
catch
stock
length.dat
test
y
incon.dat
y
so.dat
1977
1987
manage.dat
```

EXAMPLE RUN FILE

An additional advantage is that run files can be specified in batch files which allow unattended execution of several problems. For example if the ASCII file "DOJOB.BAT" contains the following,

```
FSIM <RUN1 >LOG1
FSIM BIO.DAT <RUN1 >LOG1
FSIM REDBIO.DAT <RUN2 >LOG2
FSIM <RUN3 >LOG3
```

SAMPLE BATCH FILE

then the DOS command,

```
C:>DOJOB
```

will submit each of the FSIM problems listed in DOJOB.BAT to the system for execution in the order they appear in the file.

The example problems listed above in the sample batch file could also be submitted from the DOS command line. These problems illustrate the run-time options that can be submitted on the command line. The responses stored in the run files are submitted to FSIM using the input redirection option provided by MS-DOS (the less-than symbol, <). The output is directed to the LOG files by the analogous output redirection option (>).

Note that since BIO.DAT is the default biological definition file, the first two problems of DOJOB.BAT are the same.

```
BEGIN EXECUTION AT 08:08:43 11-10-1988

                    SUMMARY STATISTICS
------------------------------------------------------------
YEAR    YOY       SSB         SSR         SO        CATCH
----  ------  ---------  ---------  ---------  ---------

1972   43.0   0.718E+08   0.1501    0.987E+00      ---
1973   10.0   0.620E+08   0.1489    0.227E+00      ---
                  .
                  .
                  .
1986    6.0   0.160E+08   0.0189    0.187E+00  0.585E+07
1987   10.0*  0.153E+08   0.0186    0.326E+00  0.489E+07

TERMINATE EXECUTION AT 08:10:29 11-10-1988
```

SAMPLE LOG FILE OUTPUT

The LOG files specified in DOJOB.BAT will contain the information listed in the initialization sequence and some summary statistics associated with the run. The sample output was generated using the example run file above. The dashed lines in the catch column indicate that yield computations were not performed for those years. The asterisk after the 1987 YOY value indicates it is model generated rather than input from a file.

ERROR CHECKING - This program performs minimal error checking (almost none) and is not user friendly from that perspective.

BIO.DAT - BIOLOGICAL DEFINITION FILE

PROBLEM DEFINITION - The size of the problem to be investigated is established by the first line of data in the biological definition file (BIO.DAT); e.g.,

```
15, 11, 2, 5, 2, 12, 1960, 2050
```

These variables are: nage, nplt, narea, ngear, nsex, nszn, firstyear, and lastyear and are constrained as follows

nage = number of ages (≥ 1),
nplt = number of platoons (should be an odd integer),
narea = number of areas (1 or 2),
ngear = number of gears (the maximum number that will be evaluated),
nsex = number of sexes (1 or 2),
nszn = number of seasons within a year (the time step for calculations, ≥ 1),
firstyear = first year of the simulation,
lastyear = lastyear of the simulation.

The value of ngear read from this line is used to establish the dimensions for output variables related to yield. As a consequence, it must be the maximum value that will occur during the current simulation. This variable is also read from the management definition file for each year that gear vulnerabilities are read. The data read from the latter file control the number of gears actually simulated for a given year.

If a run is made using an initial conditions definition file created from a previous program run, the values of nage, nplt, nsex, and narea must be the same as in the previous run.

SPECIES DESCRIPTION - The second line of data in BIO.DAT is used to label the species definition for the problem. This field is a string of ASCII characters terminated by a carriage return. The species description is useful for identifying characteristics of the biological definitions; e.g.,

```
Red snapper (15 ages, 2 areas, sexes separate)
```

The next line in this file specifies the spawning season, the recruit season, and the scale factor, respectively. The juvenile index is multiplied by the scale factor to adjust recruitment to the scale of the population. The spawning season is the season of the year at the beginning of which the program computes the spawning potential of the stock. The recruit season is the season that the recruits are added to the population.

```
5, 9, 5e5
```

The next line in the file specifies the recruitment option to use when the juvenile index values are undefined and the α and β parameters of the stock-recruitment model, respectively. The recruitment option may be 1 (no estimate), 2 (use mean calculated juvenile survival), 3 (Ricker model), or 4 (Beverton-Holt model). The α and β parameters must be specified, even if the recruitment option specified does not involve the use of a stock-recruitment model. However, in such cases they will not be used and a dummy value may be used.

```
2, 2.5, 1e-6
```

FECUNDITY - The next block of data in the file specifies the spawning option (first data element in the block), and spawning parameters. These can be one (and only one) of two forms. If the spawning option is set to 1, then the spawning potential of an individual is calculated based on the individual length. In this case the coefficients of the length-fecundity equation (scaler and exponent), the minimum length at maturity, and an upper limit on individual spawning potential will be read. An example of this form is given in the following box.

```
1, 2.266e-7, 5.78, 0, 200
```

If the spawning option is set to 2, then FSIM will attempt to read mean fecundities for each age. An example data block of this form is given below.

```
2, 0, 0, 1.1E5, 2.0E5, • • • , 4.1E6
```

As in the preceding example, the first data element in the block is the spawning option switch. This is followed by mean spawning potentials (fecundities) for each age class in the population, beginning with age zero and ending with age = nage. In the example, spawning potentials for ages 0 and 1 are set to zero, spawning potential for age 2 individuals is set at 110,000 and that for the maximum age in the population is set at 4.1 million. The values specified should be for females only, even if sexes are combined since, under that option, the calculated reproductive potential of the stock is halved under the assumption that half are female.

SPATIAL DISTRIBUTION OF RECRUITMENT - If both areas 1 and 2 are to be evaluated then the next line of data specifies the proportion of the annual recruitment that will be distributed to each area. The example to the right specifies that 80% of the recruits will be distributed to area 1 and the remaining 20% will be distributed to area 2. The sum of these two data items must equal 1. If the problem being analyzed has only a single spatial dimension (narea = 1) then this line of data must be omitted.

```
0.8, 0.2
```

NATURAL MORALITY - The next block of data in the file specifies the annual instantaneous natural mortality rates by age and sex. The input routines used in this block illustrate the manner used to load repetitious data values in many routines. The first value in the data subblock (in this case a line of data) specifies the last age to which the next data values are applied. These values will then be used to define the values from the current age (beginning with 0) to the specified age.

```
 0, 0.30, 0.30
 1, 0.25, 0.25
15, 0.20, 0.18
```

In this example, the first data entry is zero, which specifies that the next two values are valid from age zero (because this is the first input in the block specifying natural mortalities) to age zero (the specified last age to which these data apply). The next two items specify the values to be used for males and females, respectively. Thus, this line specifies that age zero natural mortality rates are 0.3 for both males and females. Once FSIM makes these assignments, the current age is updated to the previous age specified +1. The process is repeated until the last age specified is equal to the number of ages specified for the problem. In the example, age 1 males and females are assigned an annual natural mortality of 0.25. Males are assigned a natural mortality rate of 0.20 for ages 2 through 15, and females are assigned rates of 0.18 for the same ages. If sexes are combined, then only a single mortality estimate should be included on each line in this block of data.

LENGTH-WEIGHT EQUATIONS - The next block of data specifies the parameters of the length-weight equation and coefficient of variation (as a fraction and not as a percentage) of length at age. If as in the example to the right, sexes are treated separately in the problem, there must be two lines of data in the block with the data for males preceding that for females.

```
4.139E-04, 3.070, 0.07
4.139E-04, 3.070, 0.08
```

SEASONAL GROWTH - The next block of data specifies the seasonal fractions of the total annual growth. There must be one value for each season of the year and the sum of the fractions should be 1.0. In the example below, the data specify equal growth fractions for each of 12 seasons (months).

```
0.0833, 0.0833, 0.0833, 0.0833, 0.0833, 0.0833
0.0833, 0.0833, 0.0833, 0.0833, 0.0833, 0.0833
```

PLATOON LENGTHS - The next block of data specifies an option to select the model used to assign platoon lengths. If the data value for the option is zero, FSIM will compute the standard normal deviates and distribute the platoon lengths according to the normal distribution. An example of this option is provided in the box to the left. If the data value for the option is not zero (as in the box to the right), then FSIM will read the deviates from BIO.DAT. In this case there must be one data entry for each of the platoons (for total of number of entries = nplt). The platoon lengths will then be assigned as if the deviates had been drawn from the normal distribution (see page 7).

```
0
```

```
1
-
1.5
.
.
.
1.5
```

The actual assignments of mean platoon lengths by the selected model can be examined for the first season of the year by running BIODUMP. The actual length of a platoon of a given year class during a season is computed from the seasonal growth pattern specified and the year-class growth deviations.

SPATIAL ATTRIBUTES - If the spatial dimension is set at 2, then the program requires that availability and migration estimates be supplied. If the spatial dimension is set to 1, these data must be omitted from BIO.DAT.

Availability estimates - These values are fractions of the population of a given age and sex in area 2 that are available for harvest in area 1 during a season. The input method is similar to that used to read natural mortality; i.e., the first value specifies the last age to which the next two lines od data apply. In this case, data are read for each season, beginning with season 1, first for males and then for females. If sexes are combined, then only one set of seasonal availabilities is read.

```
0
0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00
0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00
3
0.00, 0.00, 0.00, 0.30, 0.45, 0.30, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00
0.00, 0.00, 0.00, 0.20, 0.30, 0.10, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00
15
0.00, 0.10, 0.25, 0.50, 0.75, 0.50, 0.25, 0.00, 0.00, 0.00, 0.00, 0.00
0.00, 0.00, 0.10, 0.30, 0.40, 0.30, 0.10, 0.00, 0.00, 0.00, 0.00, 0.00
```

In the above example, the assigned availabilities for age zero individuals would be zero for all seasons and both sexes (the first three lines). The second block of three lines assigns values for ages 1 through 3. Males are assigned values of 0.3 for season 4, 0.45 for season 5 and 0.3 for season 6, and females are assigned availabilities of 0.2, 0.3 and 0.1 for the same seasons. The last three lines assign the availabilities for ages 4 through 15.

Migration rates - The next block of data specifies the migration season and transfer fractions. The first data item specifies the season in which the transfer is to occur (1 in the example below). If the specified season is not in the range of possible seasons (i.e., <1 or >nszn) then no transfers will occur.

```
1
0
0.00, 0.00
5
0.50, 0.75
15
0.00, 0.00
```

The next groups of values are the transfer rates by age and sex using the logic described for the natural mortality rates. The sample box to the left specifies that no migration transfers will occur in age zero (i.e., the fractions for both males and females are 0.0). Half (0.5) of age 1 to 5 males and 75% of the females of corresponding ages will be transferred in season 1 of each year. The example data also specify that no individuals of either sex will be transferred after age 5.

MEAN LENGTH AT AGE - The remainder of the data in BIO.DAT are used to describe length. The first group of data provides estimated mean lengths at the beginning of each season for fish of age zero. There must be one non-zero value for each season, and each successive value must be greater than or equal to the preceding value. Dummy values are acceptable for seasons where simulated catch or length information is not desired, but they must meet the requirement of monotonic increase to avoid an illegal function or other error condition.

```
1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0
```

The last block of data in BIO.DAT specifies mean lengths at the beginning of the year for males and females beyond the age of 0. The data are read in order beginning with age 1 and ending with length estimates for the oldest modeled age at the end of the year (or the beginning of the year for the age that is one greater than the oldest age in the model population). Thus, there should be NAGE+1 lines of length data in this block. If the problem specifies separate sexes, then there should be two length values on each line as in the example to the right. The first value specifies the mean length of males at the beginning of the year, and the second specifies the mean length of females. If sexes are combined, then only one length is entered on each line.

```
7.44, 7.44
11.43, 11.43
.
.
.
39.00, 39.00
39.00, 39.00
```

CREEL.DAT

If the problem calls for the evaluation of creel limits, then FSIM will read this file to obtain an estimate of the cumulative frequency distribution of catch per angler. FSIM will attempt to read this file on the first occasion that a creel limit is specified in the management definition file.

This is an ASCII file and may be edited with a text editor. For a further explanation of the format and contents of this file refer to the **CRLANA** documentation.

INCON.DAT - THE INITIAL CONDITIONS DEFINITION FILE

This data file is used to initialize the state of the population at the beginning of a run from that which existed at the termination of a previous run. This feature allows all subsequent runs to to begin with the same state of the population for simulations of alternative management options. Depending on the complexity of the problem this feature can save considerable time.

The mean egg to juvenile survival, number of years contributing to the mean, and the numerical value of the year following the termination of the previous run are also saved in this file. The former values are used to estimate unknown recruitment when the recruitment option switch is set to 2. The latter value is used to assure that the juvenile recruitment and management definitions which are read from separate files all refer to the same year.

The data in this file are stored in binary and may not be edited using a text editor.

MANAGE.DAT - MANAGEMENT OPTIONS DEFINITION FILE

The management options definition file specifies the historical and possible future patterns of fishing to be evaluated during a simulation. The data in this file may be used to alter the characteristics of the fishery on an annual basis by changing the "Base F," number of gears in the fishery, or gear vulnerabilities by sex, season, and location, or by adjusting minimum and maximum legal sizes, creel limits and/or establishing quotas. This file is an ASCII text file and may be created and edited with a suitable text editor.

I/O CONTROL LINE - FSIM reads at least one line of data from this file at the beginning of each year. The variables defined by this data specify certain input and output options; e.g.,

```
1972, 1.00, 1, 4, 1
```

The first item of data is the year (1972 in the example above) for which the rest of the information is valid. If this year does not match the current year of the simulation, FSIM will issue an error message and terminate execution.

The second item of data specifies the "Base F" (1.00 in the example), which is a scaler multiplied by the gear vulnerabilities to set fishing mortalities by gear.

The third item is a switch that controls whether MDUMP will create an output table for the current year. A value of 1 in this field causes the table to be created. Any other value will cause MDUMP to skip output for that year. This feature is useful for controlling the amount of output generated by MDUMP.

The fourth item (4 in the example) is a switch that controls the input of additional management data for the current year. The valid values for this field and their actions are given in the table below. Any other values outside this range will cause an error condition with unpredictable results.

VALUE	ACTION
1	no additional data are read
2	read quota definitions
3	read size/creel and quota definitions
4	read gear, size/creel and quota definitions

The value of this switch must be 4 for the first year of a simulation or fishing mortality rates will be undefined. This is true even if the simulation begins by loading the state variables from INCON.DAT. If the simulation begins with the population in an undefined state (does not use INCON.DAT) and the mean recruitment variable read from the recruitment definition file (YOY.DAT) is a non-zero value, then the fishery characteristics loaded from MANAGE.DAT will be used to define the preload fishing mortality (see the discussion under YOY.DAT for further information).

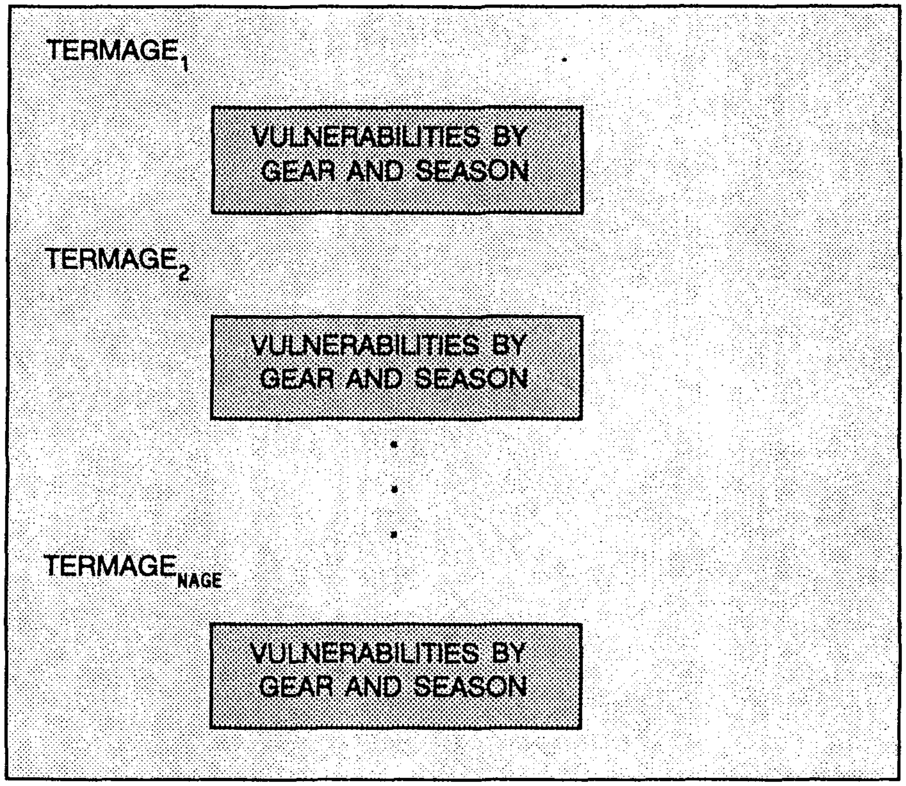
The last field in the I/O control line (1 in the example) is a length output switch which controls the output of simulated length distributions for later analysis. The valid values for this switch are given in the table below.

VALUE	ACTION
0	do not save any length data
1	save the length frequency of the population
2	save the length frequency of landings by gear
3	save lengths of both the population and catch.

GEAR DEFINITIONS - This data block defines the number of gears to include in the analysis and the minimum average size that would be captured by each gear in the absence of any size limits. The number of gears specified cannot be greater than the maximum number specified in the definition of the problem dimensions in the first line of the biological definition file.

```
3
10, 10, 10
```

VULNERABILITIES - The next groups of data define the vulnerabilities by sex, age, location and season. If sexes are separate then the males vulnerabilities are loaded first. The input



sequence follows the pattern described for the input of the natural mortality rates in BIO.DAT. The sequence begins by reading the terminal age to which the next block of data will apply (termage in the example above). Then the vulnerabilities are read by gear and location for each season, using the pattern in the box to the right. As evident in the sample data fragment below, the actual contents of the data block are the gear vulnerability estimates (which are symbolized by gear,...,ngear in the figure to the right).

AREA 1	AREA 2	SEASON
gear1, ..., ngear,	gear1, ..., ngear	1
gear1, ..., ngear,	gear1, ..., ngear	2
	.	.
	.	.
	.	.
gear1, ..., ngear,	gear1, ..., ngear	NSZN

Arrangement of contents of vulnerability estimates.

These values are assigned to all ages from the current age to the specified terminal age. The current age starts with age zero. Thus, if it were the first block of vulnerabilities, the sample data fragment on the next page would define the values for ages zero, 1, 2, and 3. The input sequence is then repeated until the specified terminal age is equal to the number of ages in the population. If the problem dimension for sex is 2, then the entire block is repeated for females after all data for males has been loaded.

```
3
0.0591, 0.0002, 0.0001,  0.0591, 0.0002, 0.0001
0.0591, 0.0002, 0.0001,  0.0591, 0.0002, 0.0001
0.0561, 0.0001, 0.0000,  0.0561, 0.0001, 0.0000
0.0561, 0.0001, 0.0000,  0.0561, 0.0001, 0.0000
0.0279, 0.0001, 0.0003,  0.0279, 0.0001, 0.0003
0.0279, 0.0002, 0.0001,  0.0279, 0.0002, 0.0001
0.0653, 0.0002, 0.0001,  0.0653, 0.0002, 0.0001
0.0653, 0.0001, 0.0003,  0.0653, 0.0001, 0.0003
0.0325, 0.0001, 0.0000,  0.0325, 0.0001, 0.0000
0.0325, 0.0001, 0.0001,  0.0325, 0.0001, 0.0001
0.0077, 0.0001, 0.0000,  0.0077, 0.0001, 0.0000
0.0077, 0.0001, 0.0001,  0.0077, 0.0001, 0.0001
```

Sample data fragment used to input vulnerabilities for 3 gears, in 2 areas and 12 seasons. The first entry specifies that age 3 is the last age for which this block applies.

SIZE/CREEL LIMITS - Minimum and maximum sizes and the release mortality fraction constitute the first line of data in this block. If no maximum size limit is desired then the value for the maximum size should be set greater than the maximum size of any fish in the population. The release mortality applies to fish that are captured and released as a result of being outside the legal size range or in excess of a creel limit. The value of the variable, crlcon, and the creel limit constitute the two entries on the next line of data. If the spatial dimension of the problem is set at 2 then the size limits and creel limits must be read for each area.

```
10.0,  99.9,  0.15
2.75E-6,  3
15.0,  99.9, 0.33
5.00E-6,  5
```

The example sets a 10 (inch) minimum size, a 99.9 (inch) maximum size and a release mortality of 0.15 for area 1. Also, the value of crlcon is set at 2.75E-6 and the creel limit is set at 3 for area 1. The corresponding data for area 2 are: minimum size = 15, maximum size = 99.9, release mortality = 0.33, crlcon = 5.0E-6, and creel limit = 5.

QUOTA DEFINITIONS - The quota definition begins with a line specifying the season of the year that begins the quota season and the number of quotas imposed on the fishery. Both items <u>must</u> be supplied even if no quota is imposed. If the number of quotas is greater than zero, then an additional line of data is required for each quota. The first item is the amount of the quota. The second and third items define the range of gears to include in the quota. Landings of all gears within the specified range will be included in the designated quota.

```
6,  2
1.0E6,  1,  1
1.5E6,  2,  3
```

In the example to the left, the first entry (6) causes the quota sums to be set to zero at the beginning of the sixth season of the year. The second entry (2) specifies the number of quotas to be 2. Data for the first quota are read in the second line and establish a quota of 1 million (pounds) for gear 1 (recreational fishermen). The next line establishes a quota of 1.5 million (pounds) for the sum of the catch by gears 2 and 3.

YOY.DAT - THE RECRUITMENT DEFINITION FILE

The recruitment definition file defines the beginning year for a simulation, year-class strengths, and year-class growth rates. It is a ASCII text file and may be created or modified by a text editor.

```
18, 1972
 1, 20
43,  1
10,  1.05
     .
     .
     .
 6,  .95
 0,  1
     .
     .
     .
```

I/O CONTROL LINE - The first line of the data file defines the number of year-class strength estimates to be read from the file and the beginning year of the simulation. The year specified on this line initializes a counter that is compared to data read from the management definition file and from the initial conditions definition file (if one is employed). This convention is used to assure agreement among the various input files. If an error is encountered, an error message will be printed and execution will be terminated

YEAR-CLASS GROWTH SWITCH - The first variable on the second line of the file specifies whether or not variable year-class growth rates are to be implemented. A value of 1 specifies that the growth rates will vary by year class. Any other value specifies that all year classes will conform to the mean growth rates defined by data in the biological definition file. Selection of the latter option significantly increases execution speed because the growth rates need to be computed only once during a simulation.

PRELOAD RECRUITMENT - The second variable on the second line of the file controls the state of the population at the beginning of a simulation.

A. If the value is zero, then the age classes in the population are not changed. This option should always be selected if the simulated population is initialized with data read from the initial conditions definition file.

B. If the value is non-zero, then the age structure of the population is initialized (preloaded) assuming constant annual year-class strengths of a magnitude equal to the specified value (i.e., that the value is the average year-class strength for the generation preceding the first year of the simulation). All year classes for the preload period are assumed to grow at the mean, regardless of the value of the year-class growth switch.

If the population vectors are preloaded using this option, then the status of the fishery for the preload period is assumed to be the same as defined for the first year of the management definition file.

If creel limits or quotas are specified for this period, the fishing mortality rates are then dependent on the size of the stock, which in turn is dependent on the fishing mortality rates. In this situation FSIM employs a two-pass algorithm to attempt to reduce the associated error. However, if possible, it is better to provide estimates of fishing mortality resulting from these management measures.

YEAR-CLASS INDICES - Subsequent lines of data contain the year-class strength estimates and growth-rate deviations for the number of year classes specified on the first line of the file.

The year-class-strength indices are multiplied by a scale factor read from the biological definition file to convert the indices to the population scale.

The growth-rate deviations are the ratios of the mean lengths at age of a year class to the mean lengths at age of all year classes (grand mean). A value of 1 causes year-class mean lengths at age to be equal to the grand mean, .95 would result in lengths that are 95% of the grand mean, 1.05 would equal 105%, etc. A year-class retains its assigned deviation throughout its lifetime. A value must be supplied regardless of the value of the year-class-growth switch. However, if this switch has a value other than 1, the values of the growth deviations are of no consequence.

If the year class-strength estimate is zero, then the value for recruitment for that year will depend on the recruitment option switch set in the biological definition file. If in this instance, the year-class-growth switch is 1 and the zero estimate of year-class strength is read from the recruitment definition file, then that year class will retain the growth specified by the growth-rate deviation read for that year class.

All year classes beyond those defined in this file are assumed to conform to the mean growth rates defined by data in the biological definition file.

PER-RECRUIT ANALYSES - Yield and other per-recruit analyses may be performed through the use of constant recruitment values in the recruitment definition file; e.g., assign 1.0 for the juvenile indices for all years.

OUTPUT FILES

Except for the log file, FSIM does not produce any files readily amenable to examination without the use of one of the ancillary programs. This is a consequence of attempting to minimize model output while maintaining substantial flexibility for the examination of simulation results from many different perspectives. This is accomplished by saving the model results for tabulation, examination, and analysis by other programs. Each file has an analogous program and is described in greater detail along with the documentation for that program. All, except for SO.DAT, are binary files and can neither be edited, printed, nor examined without their supporting program. The file titles used here are descriptive of their contents. The actual filenames are assigned at runtime. Each is briefly described below.

CATCH.DAT - This file is the main output file of the simulation. It receives the simulated catches by gear, age, and location for years where an output is desired. It also receives estimated reproductive potential (in units defined by the length-fecundity equation). It is examined/analyzed with the program TABRES.

LENGTH.DAT - Lengths of fish in the population or in the catch are output to this file for later analysis by LFR.

S0.DAT - If sufficient years of recruitment indices are available to fill the adult age structure, FSIM will estimate annual egg-to-recruit survival as the ratio of the simulated population fecundity and the juvenile index for the year. These data are saved in this file for later analysis by FCAST, which provides estimates of future year-class-strength probabilities.

STOCK.DAT - This file receives the state variables for each year of the simulation where an output is desired. This file is the input file for FANAL, which is used to examine F and year-class abundances that result from the simulation.

BIODUMP

BIODUMP is used to tabularize the contents of the biological definition file. It also prints a table of platoon lengths by age at the beginning of the year, which are the consequence of specified options.

BIODUMP is invoked by issuing the command

```
C:>BIODUMP bio.dat
```

The program will respond

```
BIODUMP(1.0)

FILE TO DUMP (BIO.DAT) ->BIO.DAT
Output file (PRN) -> PRN
```

If a filename is entered on the command line it will be the default value for the first filename requested.

The output will be similar to the following example, except that data for both sexes will be printed if the number of sexes is set to 2.

Dump of biological data from file -BIO.DAT
Species = Red snapper
Recruits per unit of juvenile index = 500000
Number of platoons considered = 11
Stock-recruit option = 3 -Recruits from Ricker model with alpha= 2.5 and beta= .000001

Spawning Stock calculation option = 1
Reproductive potential from 2.266E-07 *length^ 5.78
with minimum spawning length = 0 and maximum fecundity per individual = 200

Season that juveniles recruit to population = 6
Season that annual spawning stock computed = 4
Season for inshore-offshore transfer (Migration) = 1

Data for males
Weight = .0004139 *length^ 3.07
CV OF LENGTH AT AGE = .07

AVAILABILITY

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MIG	M
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.200
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.200
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.200
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.200
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.200
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200

LENGTHS AT BEGINNING OF YEAR BY AGE AND PLATOON

	PLATOON										
AGE	1	2	3	4	5	6	7	8	9	10	11
0	1.3	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.7
1	6.6	6.9	7.1	7.2	7.3	7.4	7.6	7.7	7.8	8.0	8.3
2	10.1	10.6	10.8	11.1	11.2	11.4	11.6	11.8	12.0	12.3	12.8
3	13.2	13.8	14.2	14.5	14.7	15.0	15.2	15.5	15.7	16.1	16.7
4	16.1	16.8	17.3	17.6	17.9	18.2	18.5	18.8	19.2	19.6	20.4
5	18.6	19.5	20.0	20.4	20.8	21.1	21.5	21.8	22.2	22.8	23.6
6	21.3	22.3	22.9	23.4	23.8	24.2	24.6	25.0	25.5	26.1	27.1
7	23.6	24.7	25.4	25.9	26.3	26.8	27.2	27.7	28.2	28.8	29.9
8	25.6	26.8	27.5	28.1	28.6	29.0	29.5	30.0	30.6	31.3	32.5
9	27.2	28.4	29.2	29.8	30.3	30.8	31.3	31.8	32.4	33.2	34.5
10	28.4	29.7	30.5	31.1	31.7	32.2	32.7	33.2	33.9	34.7	36.0
11	29.5	30.9	31.7	32.4	33.0	33.5	34.0	34.6	35.2	36.1	37.5
12	30.5	31.9	32.8	33.4	34.0	34.6	35.1	35.7	36.4	37.2	38.7
13	31.2	32.7	33.6	34.3	34.9	35.4	36.0	36.6	37.3	38.2	39.6
14	32.8	34.3	35.2	35.9	36.6	37.2	37.8	38.4	39.1	40.0	41.6
15	34.1	35.7	36.7	37.4	38.1	38.7	39.3	40.0	40.7	41.7	43.3

SAMPLE OF BIODUMP OUTPUT

CRLANA

CRLANA estimates the effect of creel limits on total fishing mortality and catch, given information on the cumulative frequency distribution (CFD) of catch per fisherman for a particular size of the exploited population. The methods employed in the analyses are analogous to the algorithm used in FSIM to adjust fishing mortality for the imposition of creel limits. As a consequence, this program provides the capability to examine some of the strengths and weaknesses of the creel module of FSIM.

The principal assumptions underlying the methodology are that: 1) the number of fish captured by anglers is (on average) directly proportional to the number of fish in the fishable stock, and 2) the frequency distribution of the proportion of the stock captured by individual anglers does not change with stock size. The empirical CFD of catch per angler for a given stock size is then used to estimate the impact of alternative creel limits. The main program menu provides the following choices.

```
        CRLANA(1.0) /cpg Nov 88

    File with sorted creel observations (CRLSRT.DAT)-> CRLSRT.DAT
    Title for plots (Untitled)-> GULF OF MEXICO RED SNAPPER

    H - Histogram depiction of effect of given creel w/ existing population
    F - Plots of the effect of creel limit and population size on fishing mortality
    C - Plots of the effect of creel limit and population size on harvest
    S - Save creel data in FSIM format
    N - Get new input file
    X - Exit
```

The input file (CRLSRT.DAT) should be an ascending sorted list of the number of fish per fisherman in the absence of any creel limit. The number of fish per fisherman need not be an integer. If a party of fishermen contributes to an aggregate creel, then the aggregate catch of that party should be divided by the number in the party. The resulting fractional amount would then be repeated for each angler in the party.

The histogram routine (Option H) provides graphical representation of the estimated effect of a creel limit given the CFD from the input file (CRLSRT.DAT). The estimated reduction in F assumes that the size of the population is unchanged from that which existed during the period when the creel data were taken. It also assumes that each angler will catch the same number of fish (on average) and that all fish captured after the creel limit is reached will be released. The mortality of released fish may be varied to examine the influence of this variable on the reduction in fishing mortality that may be anticipated with a particular creel limit.

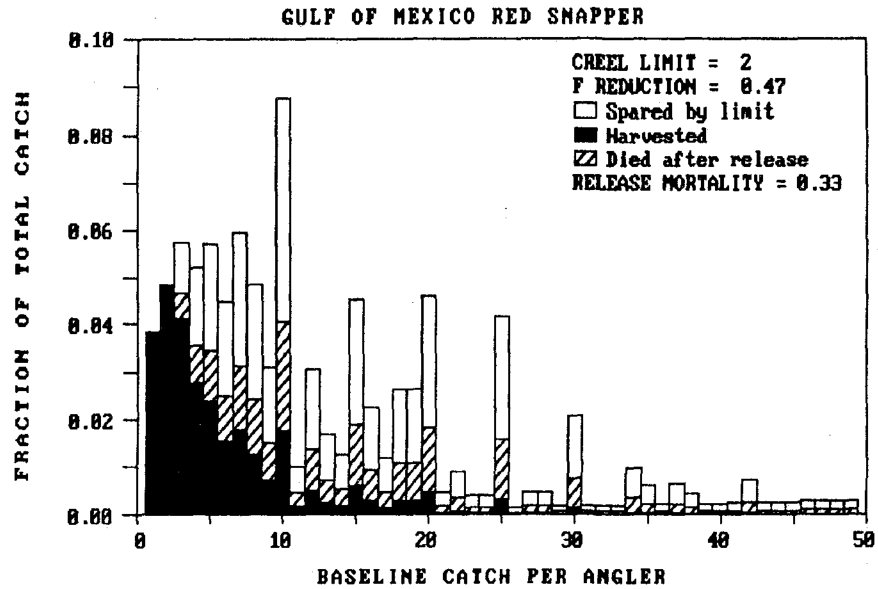


Figure 2. Example of the histogram depiction of the effect of a creel limit on fishing mortality based on an empirical CFD of catch per angler and specified release mortality.

Figure 2 illustrates the basic computation of the creel limit effect. The height of each bar in the histogram represents the catch per angler with no creel limit imposed, and it also is assumed to be the **catch** per angler after the creel limit is in effect. The solid bar represents that portion of the catch that is still harvested. The diagonally marked bars represent the number of fish that would die as the result of capture and release for the specified release mortality rate. The open bars represent fish that were caught, released, and survived the experience. The reduction in fishing mortality, F_{RED}, attendant the creel limit is estimated as

$$F_{RED} = 1 - \left(\sum_{I=1}^{NCELL} S_I\right) / \left(\sum_{I=1}^{NCELL} C_I\right)$$

where:

NCELL is the number of cells (observations) in the empirical CFD,
S_I = the estimated number of survivors in each cell,
C_I = the total estimated catch (previous harvest) in the cell.

Plots of the effect of creel limits and population (fishable stock) size on fishing mortality can be obtained by selecting the F option of the CRLANA main menu. To evaluate a range of creel limits, the program will request beginning and ending points, step interval, and the release mortality. Figure 3 provides an example of the resulting analysis.

The vertical dashed line in Figure 3 is at the baseline population size. The numeric label on each curve is the creel limit associated with the curve. The intersection of each of the curves with this line corresponds to the level of F reduction estimated by the histogram routine (which performs the analysis assuming the baseline population size).

The reduction in fishing mortality is influenced by both the size of the population and the selected creel limit. This obvious fact highlights the need for caution in applying a CFD of catch per angler obtained during one period of a fishery to another period when the population size is different.

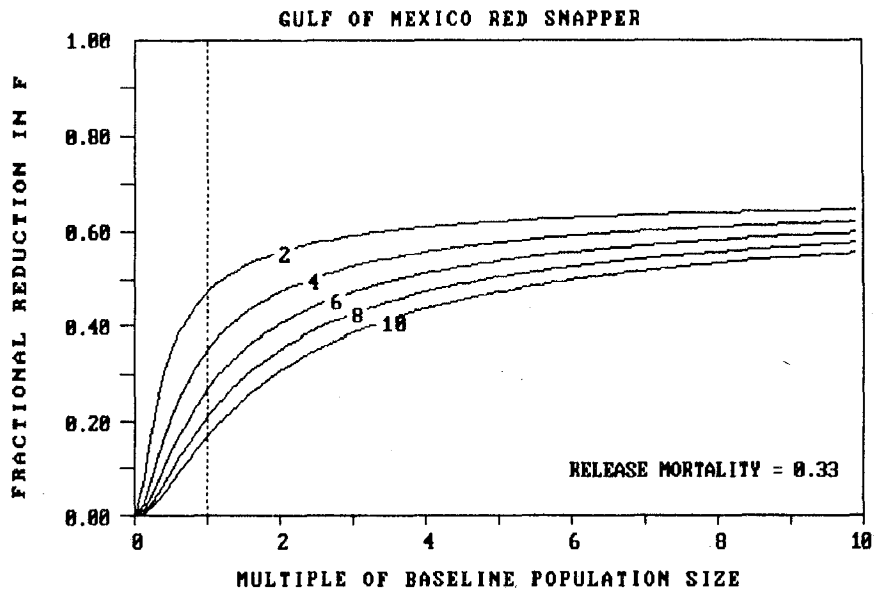


Figure 3. Sample plot of the estimated effect on fishing mortality of selected creel limits as a function of population size and release mortality.

A scaler variable, CRLCON, is used in FSIM to relate the empirical CFD to the size of the population. This variable is the reciprocal of the estimated size of the catchable stock at the time the CFD estimate was developed. FSIM multiplies the simulated catchable stock by this scaler to derive a population multiplier which relates the CFD to the model population.

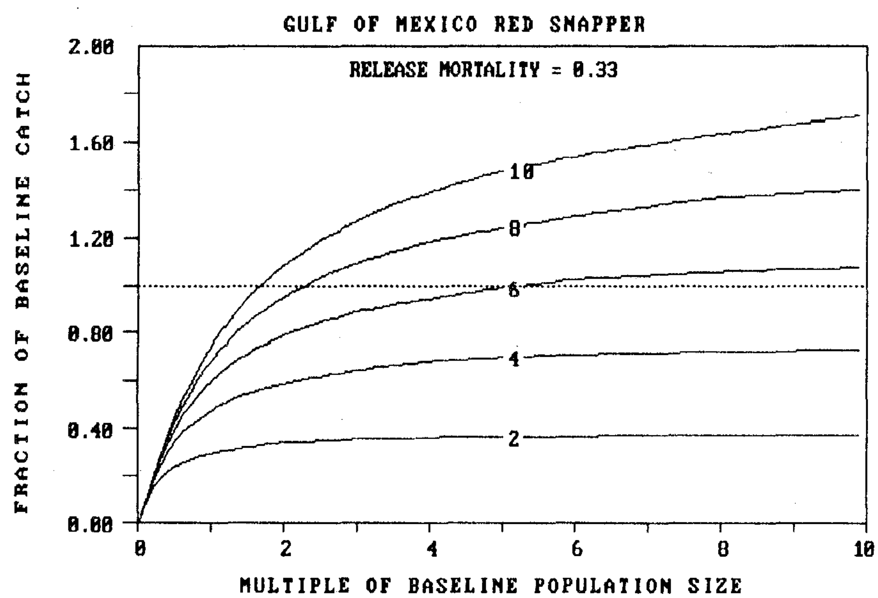


Figure 4. Sample plot of the estimated effect on harvest levels of selected creel limits as a function of population size and release mortality.

The effect of alternative creel limits on harvest as a function of population size can be examined by selecting the C option on the main menu. This option results in the same prompts as for the F option but produces a plot similar to Figure 4. The horizontal dashed line of Figure 5 is the catch (harvest) with no creel limit at the baseline population size; i.e., it is the estimated catch with no creel limit for the population at the level existing when the creel CFD was estimated. Here, catch increases rapidly with increasing population size but subsequently asymptotes to a level corresponding to each fisherman in the fishery catching a limit of fish.

These routines capture some of the essential features of the impact of creel limits on fishing mortality but do not address others. In particular, no attempt is made to address any effect of the creel limit on the number of participants in the fishery or their fishing habits. Any creel limit that will have a significant effect on fishing mortality can be expected to result in some changes in the perceptions and actions of some of the affected fishermen. Two opposing possibilities are often cited: 1) an increased motivation to catch the limit by some fishermen and 2) an increased conservation ethic which results in no retention by others. No attempt has made to include such phenomena in either FSIM or CRLANA.

Anticipated changes in the total effort caused by changes in the population of fishermen or by their fishing patterns may be accommodated by adjusting the vulnerabilities for gear 1 (anglers) in the management definition file for the year(s) where such changes are anticipated.

Another weakness of the algorithm to represent the creel limit effect is that it assumes that fishermen who participated in the fishery during the period represented by the empirical CFD but who did not catch fish will never catch fish regardless of how large the exploitable population becomes. This attribute may be important for some applications, particularly if the sample size for the CFD is small. However, in practice it is likely to be less important than some of the more imponderable aspects of possible changes of angler attitudes.

Selection of the S option from the main menu causes the CFD to be saved in a file formatted properly for input to FSIM. The input format for FSIM is illustrated in the example in the box on the next page.

The S option will save the CFD in this format for only the currently loaded data set. As a consequence. If the spatial dimension for the FSIM problem being investigated is 2, then CRLANA should be executed once for each area. The S option output files are then concatenated using the DOS COPY command; e.g.,

```
COPY crlarea1.dat+crlarea2.dat creel.dat
```

If the FSIM problem has only one spatial dimension (narea=1) then only the first block of creel data needs to be included in the input file. If no creel limits are involved in the FSIM problem, then the CREEL.DAT file may be omitted. However, a dummy filename must be supplied in the FSIM initialization sequence.

```
180        - number of records for area 1 (inshore)
 .1,  10   - lowest harvest per fisherman, number of observations of this harvest level
.15,  11   - next lowest harvest per fisherman, number of observations
.17,   5
   .
   .
   .
 50,   1   - highest harvest rate in area 1, observations at this level of harvest
270        - number of records for area 2 (offshore)
 .1, 10    - lowest harvest rate in area 2, number of observations of this harvest level
.15,  11   - next lowest harvest per fisherman, number of observations
.17,   5
   .
   .
   .
 55,   1   - highest harvest rate in area 2, observations at this level of harvest
eof        - end of file
```

FSIM CREEL.DAT INPUT FILE FORMAT

FANAL

FANAL (F ANALysis) provides a means to examine the simulated standing crops, estimate fishing mortality rates, and, if data for more than one sex is available, to output simulated sex ratios. All of the output variables are available in as many dimensions as possible given the input data set (which is constrained by the problem definition read from the first line of the biological definition file). FANAL is invoked by issuing the command:

```
C:>FANAL bio.dat
```

FANAL will then display its Setup menu. The filename for the biological definition file must be entered on the command line if it is named other than BIO.DAT. It is printed here only as a reminder of the definitions being used. The output file will default to the printer, and the input file to STOCK.DAT. The input file contains the state variables for those years where output was requested in the FSIM initialization sequence. This file consists of binary data which cannot be viewed or edited with word processors.

```
FANAL(1.0) /cpg Dec 88

BIOL. DATA FROM -> BIO.DAT
File for output (PRN)-> PRN
Input file (STOCK) -> STOCK
```

FANAL will display the years of available data and request the selection of the year to view. Once the user has specified the year of interest, FANAL asks the user which of the three available types of analysis is desired.

```
OUTPUT FILE IS -> PRN
INPUT FILE IS -> STOCK
BIO. DATA FROM -> BIO.DAT
DATASET - red snapper example
YEARS AVAILABLE = 1983 TO 1987

YEAR TO DISPLAY [<CR> to exit] ->1985   ...reading

TOUCH> S-Standing stocks F-Fishing rates R-Sex ratios N-New year
```

FANAL output selection menu.

To examine standing crops press the "S" key. FANAL will then provide the following output selection menu.

```
COMPILATION OF STANDING CROPS FOR 1985
Males, Females, sexes Combined or eXit (X) ->C
```

The actual series of prompts that are provided depend on the data which are available. The example above is provided if the problem involves separate sexes. A separate output table may be created for each sex or sexes combined. The above example specified sexes combined and produced the following sample output table, which displays the standing crops by age for each area and areas combined.

STANDING CROPS FOR YEAR = 1985 - SEXES COMBINED

INSHORE

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.10E+07	.10E+07	.10E+07	.10E+07	.98E+06	.97E+06	.95E+06	.91E+06	.87E+06	.84E+06	.80E+06	.78E+06
2	.12E+07	.11E+07	.98E+06	.89E+06	.80E+06	.76E+06	.71E+06	.63E+06	.56E+06	.52E+06	.49E+06	.47E+06
3	.11E+07	.99E+06	.90E+06	.84E+06	.77E+06	.73E+06	.68E+06	.61E+06	.56E+06	.52E+06	.49E+06	.47E+06
4	.47E+06	.44E+06	.41E+06	.38E+06	.36E+06	.34E+06	.32E+06	.29E+06	.27E+06	.25E+06	.24E+06	.23E+06
5	.20E+06	.19E+06	.18E+06	.17E+06	.16E+06	.15E+06	.14E+06	.13E+06	.13E+06	.12E+06	.11E+06	.11E+06
6	.46E+05	.44E+05	.41E+05	.40E+05	.38E+05	.36E+05	.34E+05	.32E+05	.30E+05	.29E+05	.28E+05	.26E+05
7	.73E+05	.70E+05	.66E+05	.64E+05	.61E+05	.59E+05	.56E+05	.53E+05	.50E+05	.48E+05	.46E+05	.44E+05
8	.19E+05	.19E+05	.18E+05	.17E+05	.17E+05	.16E+05	.15E+05	.14E+05	.14E+05	.13E+05	.13E+05	.12E+05
9	.11E+05	.11E+05	.10E+05	.10E+05	.97E+04	.93E+04	.89E+04	.84E+04	.80E+04	.77E+04	.74E+04	.71E+04
10	.76E+04	.73E+04	.70E+04	.68E+04	.65E+04	.62E+04	.60E+04	.57E+04	.54E+04	.52E+04	.50E+04	.48E+04
11	.38E+04	.36E+04	.35E+04	.34E+04	.33E+04	.31E+04	.30E+04	.28E+04	.27E+04	.26E+04	.25E+04	.24E+04
12	.26E+04	.25E+04	.24E+04	.23E+04	.22E+04	.21E+04	.20E+04	.19E+04	.18E+04	.18E+04	.17E+04	.16E+04
13	.68E+04	.65E+04	.63E+04	.61E+04	.59E+04	.56E+04	.54E+04	.51E+04	.48E+04	.46E+04	.45E+04	.43E+04
14	.23E+04	.22E+04	.21E+04	.21E+04	.20E+04	.19E+04	.18E+04	.17E+04	.16E+04	.16E+04	.15E+04	.15E+04
15	.31E+04	.29E+04	.28E+04	.27E+04	.26E+04	.25E+04	.24E+04	.23E+04	.22E+04	.21E+04	.20E+04	.19E+04

OFFSHORE

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.10E+07	.10E+07	.10E+07	.10E+07	.98E+06	.97E+06	.95E+06	.91E+06	.87E+06	.84E+06	.80E+06	.78E+06
2	.12E+07	.11E+07	.98E+06	.89E+06	.80E+06	.76E+06	.71E+06	.63E+06	.56E+06	.52E+06	.49E+06	.47E+06
3	.11E+07	.99E+06	.90E+06	.84E+06	.77E+06	.73E+06	.68E+06	.61E+06	.56E+06	.52E+06	.49E+06	.47E+06
4	.47E+06	.44E+06	.41E+06	.38E+06	.36E+06	.34E+06	.32E+06	.29E+06	.27E+06	.25E+06	.24E+06	.23E+06
5	.20E+06	.19E+06	.18E+06	.17E+06	.16E+06	.15E+06	.14E+06	.13E+06	.13E+06	.12E+06	.11E+06	.11E+06
6	.46E+05	.44E+05	.41E+05	.40E+05	.38E+05	.36E+05	.34E+05	.32E+05	.30E+05	.29E+05	.28E+05	.26E+05
7	.73E+05	.70E+05	.66E+05	.64E+05	.61E+05	.59E+05	.56E+05	.53E+05	.50E+05	.48E+05	.46E+05	.44E+05
8	.19E+05	.19E+05	.18E+05	.17E+05	.17E+05	.16E+05	.15E+05	.14E+05	.14E+05	.13E+05	.13E+05	.12E+05
9	.11E+05	.11E+05	.10E+05	.10E+05	.97E+04	.93E+04	.89E+04	.84E+04	.80E+04	.77E+04	.74E+04	.71E+04
10	.76E+04	.73E+04	.70E+04	.68E+04	.65E+04	.62E+04	.60E+04	.57E+04	.54E+04	.52E+04	.50E+04	.48E+04
11	.38E+04	.36E+04	.35E+04	.34E+04	.33E+04	.31E+04	.30E+04	.28E+04	.27E+04	.26E+04	.25E+04	.24E+04
12	.26E+04	.25E+04	.24E+04	.23E+04	.22E+04	.21E+04	.20E+04	.19E+04	.18E+04	.18E+04	.17E+04	.16E+04
13	.68E+04	.65E+04	.63E+04	.61E+04	.59E+04	.56E+04	.54E+04	.51E+04	.48E+04	.46E+04	.45E+04	.43E+04
14	.23E+04	.22E+04	.21E+04	.21E+04	.20E+04	.19E+04	.18E+04	.17E+04	.16E+04	.16E+04	.15E+04	.15E+04
15	.31E+04	.29E+04	.28E+04	.27E+04	.26E+04	.25E+04	.24E+04	.23E+04	.22E+04	.21E+04	.20E+04	.19E+04

AREAS COMBINED

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.21E+07	.21E+07	.20E+07	.20E+07	.20E+07	.19E+07	.19E+07	.18E+07	.17E+07	.17E+07	.16E+07	.16E+07
2	.24E+07	.22E+07	.20E+07	.18E+07	.16E+07	.15E+07	.14E+07	.13E+07	.11E+07	.10E+07	.98E+06	.94E+06
3	.22E+07	.20E+07	.18E+07	.17E+07	.15E+07	.15E+07	.14E+07	.12E+07	.11E+07	.10E+07	.98E+06	.93E+06
4	.94E+06	.87E+06	.81E+06	.77E+06	.72E+06	.68E+06	.64E+06	.59E+06	.54E+06	.51E+06	.48E+06	.46E+06
5	.40E+06	.37E+06	.35E+06	.34E+06	.32E+06	.30E+06	.29E+06	.27E+06	.25E+06	.24E+06	.23E+06	.22E+06
6	.92E+05	.87E+05	.83E+05	.79E+05	.76E+05	.72E+05	.68E+05	.64E+05	.61E+05	.58E+05	.55E+05	.53E+05
7	.15E+06	.14E+06	.13E+06	.13E+06	.12E+06	.12E+06	.11E+06	.11E+06	.10E+06	.95E+05	.92E+05	.88E+05
8	.39E+05	.37E+05	.36E+05	.34E+05	.33E+05	.32E+05	.30E+05	.29E+05	.27E+05	.26E+05	.25E+05	.24E+05
9	.23E+05	.22E+05	.21E+05	.20E+05	.19E+05	.19E+05	.18E+05	.17E+05	.16E+05	.15E+05	.15E+05	.14E+05
10	.15E+05	.15E+05	.14E+05	.14E+05	.13E+05	.12E+05	.12E+05	.11E+05	.11E+05	.10E+05	.10E+05	.96E+04
11	.76E+04	.73E+04	.70E+04	.68E+04	.65E+04	.62E+04	.60E+04	.57E+04	.54E+04	.52E+04	.50E+04	.48E+04
12	.52E+04	.50E+04	.48E+04	.46E+04	.45E+04	.42E+04	.41E+04	.39E+04	.37E+04	.35E+04	.34E+04	.33E+04
13	.14E+05	.13E+05	.13E+05	.12E+05	.12E+05	.11E+05	.11E+05	.10E+05	.96E+04	.93E+04	.89E+04	.86E+04
14	.46E+04	.44E+04	.43E+04	.41E+04	.40E+04	.38E+04	.36E+04	.35E+04	.33E+04	.31E+04	.30E+04	.29E+04
15	.61E+04	.59E+04	.56E+04	.55E+04	.53E+04	.50E+04	.48E+04	.46E+04	.43E+04	.42E+04	.40E+04	.39E+04

Sample FANAL standing crop output.

After completion of the standing crop table, LFR will return to the output selection menu. If the "F" key is depressed at that menu then the program will branch to the mortality output menu and, depending on the problem, it may prompt the user as follows

```
FISHING RATES AND SURVIVAL COMPUTATIONS FOR 1985

Males, Females, sexes Combined or eXit (X) ->C
Inshore, Offshore, areas Combined or eXit (C) ->C
```

The example selections produced the following table

FISHING MORTALITY MATRIX FOR 1985 AREAS COMBINED SEXES COMBINED

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	ANNUAL SURV.
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0198	0.0327	0.0229	0.0301	0.0080	0.0091	0.125	0.722
2	0.0907	0.0912	0.0830	0.0841	0.0456	0.0492	0.1013	0.0989	0.0543	0.0521	0.0193	0.0177	0.787	0.376
3	0.0747	0.0758	0.0612	0.0646	0.0432	0.0537	0.0851	0.0782	0.0536	0.0473	0.0314	0.0268	0.696	0.413
4	0.0572	0.0589	0.0430	0.0468	0.0400	0.0492	0.0673	0.0621	0.0463	0.0393	0.0327	0.0280	0.571	0.467
5	0.0433	0.0452	0.0302	0.0339	0.0354	0.0423	0.0526	0.0495	0.0381	0.0316	0.0299	0.0257	0.458	0.523
6	0.0378	0.0396	0.0259	0.0292	0.0320	0.0380	0.0462	0.0437	0.0340	0.0282	0.0271	0.0235	0.405	0.552
7	0.0325	0.0342	0.0218	0.0248	0.0288	0.0335	0.0401	0.0386	0.0296	0.0244	0.0242	0.0210	0.353	0.581
8	0.0269	0.0287	0.0180	0.0204	0.0275	0.0285	0.0341	0.0355	0.0247	0.0208	0.0200	0.0180	0.303	0.611
9	0.0249	0.0274	0.0160	0.0183	0.0322	0.0285	0.0337	0.0396	0.0233	0.0203	0.0194	0.0184	0.302	0.612
10	0.0250	0.0274	0.0160	0.0184	0.0315	0.0286	0.0335	0.0386	0.0236	0.0204	0.0197	0.0187	0.301	0.612
11	0.0250	0.0274	0.0160	0.0184	0.0315	0.0286	0.0335	0.0386	0.0236	0.0204	0.0197	0.0187	0.301	0.612
12	0.0250	0.0274	0.0160	0.0184	0.0315	0.0286	0.0335	0.0386	0.0236	0.0204	0.0197	0.0187	0.301	0.612
13	0.0250	0.0274	0.0160	0.0184	0.0315	0.0286	0.0335	0.0386	0.0236	0.0204	0.0197	0.0187	0.301	0.612
14	0.0250	0.0274	0.0160	0.0184	0.0315	0.0286	0.0335	0.0386	0.0236	0.0204	0.0197	---	---	---
15	0.0250	0.0274	0.0160	0.0184	0.0315	0.0286	0.0335	0.0386	0.0236	0.0204	0.0197	---	---	---

Sample output of FANAL mortality estimates.

If two sexes are available in the simulation results, the R option may be selected at the output selection menu. This selection will result in the following prompt

```
COMPILATION OF SEX RATIOS FOR 1985

proportion Males, Females or f/m Ratio or eXit (X) -> R
```

The example selection of the female-to-male ratio produced the following sample table

SEX RATIOS FOR YEAR = 1985 - FEMALE TO MALE RATIO

INSHORE

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
2	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
3	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
4	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
5	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
6	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
7	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
8	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
9	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
10	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
11	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
12	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
13	.12E+01	.12E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01
14	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01
15	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.14E+01	.14E+01	.14E+01	.14E+01	.14E+01	.14E+01

OFFSHORE

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
2	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
3	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
4	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
5	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
6	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
7	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
8	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
9	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
10	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
11	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
12	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
13	.12E+01	.12E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01
14	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01
15	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.14E+01	.14E+01	.14E+01	.14E+01	.14E+01	.14E+01

AREAS COMBINED

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
2	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
3	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01
4	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.10E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
5	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
6	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
7	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
8	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01	.11E+01
9	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
10	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
11	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
12	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01	.12E+01
13	.12E+01	.12E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01
14	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01
15	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.13E+01	.14E+01	.14E+01	.14E+01	.14E+01	.14E+01	.14E+01

Sample FANAL output of sex ratios.

LFR

This program provides the capability to interactively examine simulated length frequencies of the catch or population. It reads data from the file, **LENGTH.DAT**. A switch in the management definition file is used to specify whether or not the length information is to be saved in the current year of the simulation and whether or not to save the lengths of the catch or of the population. This program requires EGA support.

The filename for the length data may be entered on the command line. An example follows,

```
C:>LFR length.dat
```

If no filename is present on the command line, LFR will prompt the user for a filename. Once the filename is identified LFR will scan the file for valid data sets and will provide a list of the data sets available for analysis. The dataset selection menu in the box below illustrates the initial setup sequence that resulted from the command issued in the preceding box.

```
                LFR(1.0) /cpg Dec 88

Input file -> LENGTH.DAT
Species description -> Red snapper

                AVAILABLE DATA
1983(POP)  1984(LND)  1985(ALL)  1986(LND)  1987(POP)

YEAR [-1 EXITS] (1983 ) -> 1985<CR>

Population or Catch (P or C) -> C
Loading catch data for  1985
```

LFR dataset selection menu.

The line of the preceding example that displays the data available for plotting shows the year and the type of available data. The data type labels are:

POP Population length frequency data only (length output switch in the management definition file set to 1);

LND Length frequency data are available only for the simulated landings (length output switch in the management definition file set to 2);

ALL Length frequency data are available for both the simulated population and landings (length output switch in the management definition file set to 3).

The year prompt displays the default year in parentheses. In the example, the year 1985 was entered to override the default year (1983). Because both population and catch data were available in 1985, the program further asked which data set to plot.

Alternatively, a value of -1 could have been entered for the year selection to exit the program.

Once the data set has been loaded from the file into memory, the program will request the selection of the data to be included in the plot, as in the example below.

```
SELECTION OF DATA TO PLOT FOR 1985

Youngest age <1> 1     Oldest age <15> 15
First season <1> 1     Last season <12> 1
First area <1> 1       Last Area <2> 2
First sex <1> 1        Last sex <2> 2
First gear <1> 1       Last gear < 3> 3

              working
```

LFR data selection menu.

When the user has completed selection of the data to plot, the program will begin the task of assembling the length-frequency distributions. This step may take several minutes for large problems.

After the length-frequency distributions have been constructed, LFR will present a table of the characteristics of the current plot as in the following example.

```
              Current plot data

            Histogram type = 1
         XMIN = 0   XMAX = 50
         YMIN = 0   YMAX = 18
   X LABEL = LENGTH (INCHES)
   TITLE = SIMULATED LENGTHS OF LANDINGS

   C to change - anything else to continue <CR>
```

LFR plot option menu.

The variables involved are:

Histogram type (1 or 2) controls bar design. The examples in this text are type 2.
XMIN and XMAX are the minimum and maximum values along the X axis.
YMIN and YMAX are the minimum and maximum values along the Y axis.
X LABEL is the label for the X axis.
TITLE is the label printed at the top of the plot.

The values of any of these variables may be changed with the change option (C). If this option is selected, LFR will prompt for each value. A carriage return in response to the prompts will leave the current value unchanged. After the user has had an opportunity to change all of the values, the program will again display the preceding box (which displays the updated plot settings). The user may elect to again alter the data by depressing "C" on the keyboard or to plot the graph with a carriage return (or other character).

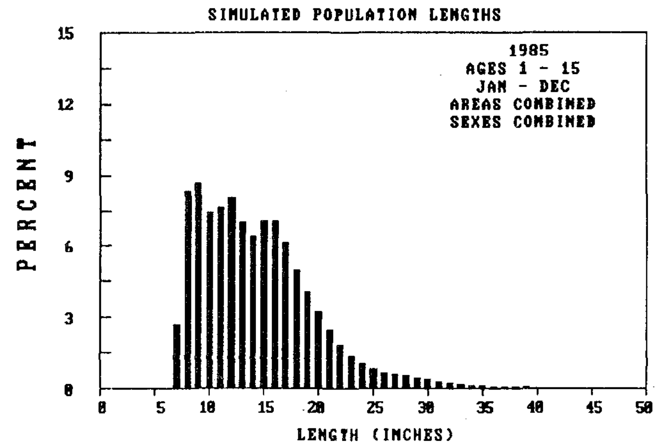


Figure 5. Sample plot of the length frequency of a simulated population of red snapper.

The selected length-frequency histogram will then be displayed on the screen for examination. An example is shown in Figure 5 which displays the simulated population length frequency using the Histogram type option = 2. The selected data set included all available ages, seasons, sexes, and areas for 1985, as detailed in the figure inset. This inset will be produced for all plots to specify what data have been plotted.

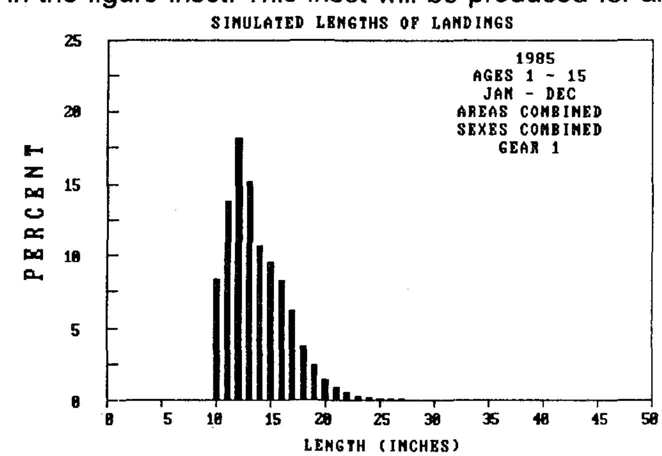


Figure 6. Sample plot of the simulated length frequency of the recreational catch (gear 1) of red snapper.

Once the plot has been displayed, it can be written to disk by depressing the "H" key on the keyboard (see the section on "Saving Plots" for more discussion.

Depression of any other key will erase the current plot. LFR will then ask the user if the current plot is to be redrawn. An affirmative response will result in the user being given the option to change the plot parameters.

A negative response will result in the user being asked if another plot for the current dataset is desired. The current dataset is the dataset for the year and type (population or catch) that is currently in memory. A positive response returns the user to the data selection menu.

A negative response returns the user to the dataset selection menu, where another dataset may be selected or program execution terminated.

LFR provides a convenient way to contrast the simulated length frequencies of landings by gears to each other and to those of the population. The examples presented in Figures 5-8, illustrate the results of sample simulations of the Gulf of Mexico red snapper fishery using three categories of gear. As noted before, Figure 5 presents the length frequency of the population. Figure 6 presents the simulated length frequency of the recreational landings. Figure 7 presents the simulated length frequency of the commercial landings with gears other than bottom longlines, and Figure 8 presents the same for the simulated bottom longline catch.

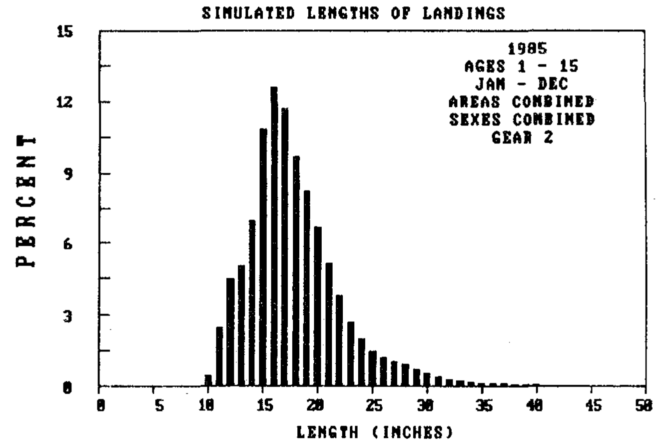


Figure 7. Sample plot of the simulated length frequency of the commercial catch of red snapper with gears other than bottom longlines (gear 2).

These plots are useful to establish the degree of correspondence between aspects of simulation results and observation. Actual length frequencies constructed from field data can be used to assess the relative consistency of the simulated data and empirical observations.

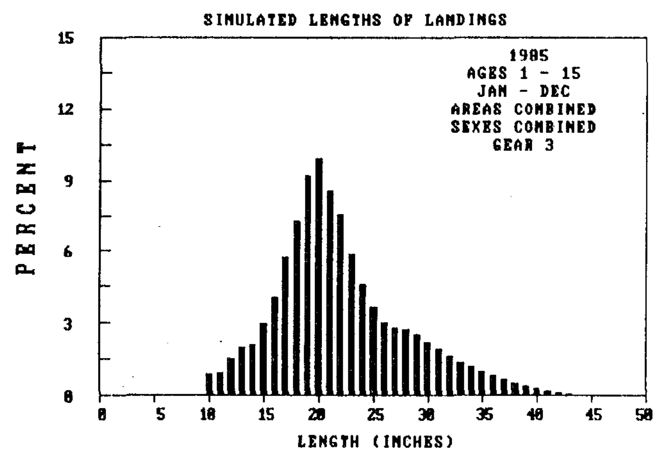


Figure 8. Sample plot of the simulated length frequency of the bottom long line catch (gear 3) of red snapper.

Poor correspondence between the two would be good evidence to suspect the simulation results, particularly if the empirical observations are believed to be robust estimators of the corresponding simulated data. Thus, in such cases, these plots can be helpful in detecting input errors or isolating important unknown parameters that require additional research or sensitivity study.

Alternatively, poor correspondence between simulated and observed data may highlight important problems in biological understanding incorporated in the model or inadequate field data. In such cases, the use of simulation procedures such, as those provided by FSIM can be very instructive in establishing both the types of information that are needed and their relative importance for the problem being investigated.

In the absence of the required information these same procedures can be used to study the implications of alternative assumptions on the robustness of adhering to recommended management or research activities in the face of uncertainty.

LFR provides a means to directly incorporate length-frequency concepts in the development of sampling protocols for biological investigations and monitoring of the impact of management actions.

MDUMP

MDUMP is used to create tabular output of the contents of the management definition file for selected years. It is invoked by issuing the command

```
C:>MDUMP
```

The program will respond

```
MDUMP(1.0)

bio.dat filename (bio.dat) -> bio.dat
 File to dump (manage.dat) -> manage.dat
       output file (PRN) -> prn
```

The output will only be produced for those years where the output switch has been turned on (=1). It will consist of two sections. The first produces a summary of the management options such a the following example.

```
DUMP OF MANAGEMENT DATA FROM FILE - manage.dat
YEAR =  1988      BASE FISHING MORTALITY =  1
INSHORE MINIMUM   =   10       MAXIMUM   99.9
RELEASE MORTALITY =  15 %
OFFSHORE MINIMUM =   15        MAXIMUM   99.9
RELEASE MORTALITY =  33 %

                     CREEL DATA
              CONSTANT          CREEL LIMIT
 INSHORE     0.275E-05               3
 OFFSHORE    0.500E-05               5

            QUOTA DATA
                     GEARS
     QUOTA        FIRST     LAST
     1000000        1         1
     1500000        2         3
```

The second section of the output provides a table of the partial F's by sex, gear, and area as defined by the products of the "Base F" and the vulnerabilities. A sample table is provided in the box below.

Males

Partial F's for GEAR # 1

INSHORE

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
0	.0591	.0591	.0561	.0561	.0279	.0279	.0653	.0653	.0325	.0325	.0077	.0077	0.497
1	.0591	.0591	.0561	.0561	.0279	.0279	.0653	.0653	.0325	.0325	.0077	.0077	0.497
2	.0691	.0691	.0657	.0657	.0326	.0326	.0764	.0764	.0380	.0380	.0090	.0090	0.582
3	.0365	.0365	.0346	.0346	.0172	.0172	.0403	.0403	.0200	.0200	.0048	.0048	0.307
4	.0170	.0170	.0161	.0161	.0080	.0080	.0187	.0187	.0093	.0093	.0022	.0022	0.143
5	.0065	.0065	.0062	.0062	.0031	.0031	.0072	.0072	.0036	.0036	.0009	.0009	0.055
6	.0043	.0043	.0041	.0041	.0020	.0020	.0047	.0047	.0024	.0024	.0006	.0006	0.036
7	.0028	.0028	.0026	.0026	.0013	.0013	.0031	.0031	.0015	.0015	.0004	.0004	0.023
8	.0025	.0025	.0024	.0024	.0012	.0012	.0027	.0027	.0014	.0014	.0003	.0003	0.021
9	.0017	.0017	.0016	.0016	.0008	.0008	.0019	.0019	.0009	.0009	.0002	.0002	0.014
10	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
11	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
12	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
13	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
14	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
15	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011

OFFSHORE

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
0	.0591	.0591	.0561	.0561	.0279	.0279	.0653	.0653	.0325	.0325	.0077	.0077	0.497
1	.0591	.0591	.0561	.0561	.0279	.0279	.0653	.0653	.0325	.0325	.0077	.0077	0.497
2	.0691	.0691	.0657	.0657	.0326	.0326	.0764	.0764	.0380	.0380	.0090	.0090	0.582
3	.0365	.0365	.0346	.0346	.0172	.0172	.0403	.0403	.0200	.0200	.0048	.0048	0.307
4	.0170	.0170	.0161	.0161	.0080	.0080	.0187	.0187	.0093	.0093	.0022	.0022	0.143
5	.0065	.0065	.0062	.0062	.0031	.0031	.0072	.0072	.0036	.0036	.0009	.0009	0.055
6	.0043	.0043	.0041	.0041	.0020	.0020	.0047	.0047	.0024	.0024	.0006	.0006	0.036
7	.0028	.0028	.0026	.0026	.0013	.0013	.0031	.0031	.0015	.0015	.0004	.0004	0.023
8	.0025	.0025	.0024	.0024	.0012	.0012	.0027	.0027	.0014	.0014	.0003	.0003	0.021
9	.0017	.0017	.0016	.0016	.0008	.0008	.0019	.0019	.0009	.0009	.0002	.0002	0.014
10	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
11	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
12	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
13	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
14	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011
15	.0013	.0013	.0012	.0012	.0006	.0006	.0014	.0014	.0007	.0007	.0002	.0002	0.011

A separate table will be produced for each sex, each area, each gear, and all gears combined. These tables represent the fishing mortality rates that would exist in the absence of any quotas, creel limits, or size effects. They are most useful for checking for errors in the input data.

The actual fishing mortality rates that result from the simulated management measures is an emergent property of the system. These rates may be examined through analysis of the changes in the state variables saved in STOCK.DAT using the program FANAL.

TABRES

TABRES is used to interactively select catch output for examination and analysis. If the problem under study involves both spatial dimensions, two sexes, several gears, and numerous age classes, the number of possible output variables can be cumbersome, particularly if only a few items are of interest. This program permits the user to select those tables of particular concern and to defer printing output of marginal interest. This capability significantly reduces the volume of output that could otherwise be unmanageable. The program is invoked by typing the following

```
C:>TABRES bio.dat
```

TABRES will then display its Setup menu. If the biological definition file is named other than BIO.DAT, then its filename must be entered on the command line. TABRES prints it in the setup menu only as a reminder of the definitions being used.

```
TABRES(1.0) /cpg Dec 88

BIOL. DATA FROM -> BIO.DAT
File for output (PRN)-> PRN
Input file (CATCH.DAT) -> CATCH.DAT
```

TABRES setup menu.

The output file will default to the printer, and the input file to CATCH.DAT. The input file contains the catches by gear and survivors for those years where output was requested in the FSIM initialization sequence. This file consists of binary data that cannot be viewed or edited with word processors.

TABRES will display the years of available data and request the selection of the year to view. Once the user has specified the year of interest, TABRES loads the data for that year into memory.

```
OUTPUT FILE IS -> PRN
INPUT FILE IS  -> CATCH.DAT
BIO. DATA FROM -> BIO.DAT
DATASET - red snapper
YEARS AVAILABLE =  1983  TO  1987

YEAR TO OUTPUT [<CR> to exit] ->1985   ...reading
```

TABRES year specification menu.

After loading the data, TABRES displays an output definition menu and prompts the user to specify which variables are to be included in the output file. The actual prompts that are issued depend on the dimensions of the problem as defined in the biological definition file. The following examples assume two spatial dimensions, two sexes and three gears. As elsewhere, default values are included in the prompt in parentheses. These values will be accepted in response to a carriage return <CR>.

The output definition menu illustrated in the box below presents a typical output request. The inshore/offshore/combined/all option selects the pattern for tabularizing by area. If either inshore or offshore is selected, only data for that area is included in the subtotals. If the "Combined" option is selected, then both areas are included in the subtotals. If the "All" option is selected, then tables for all of the other options on the line are produced. The following example specifies a table of catch by areas and gears combined.

Output selection for 1985

gears Separate or Combined (C) -> **C**

Inshore Offshore Combined All (C) -> **C**
Yield Number Survivors All (Y) -> **Y**

working

TABRES output selection menu.

The task specified in the preceding box produced the following sample table of the simulated yield in weight (in units of weight specified by the length-weight equation).

```
Year simulated =  1985   DATE OF RUN WAS 12-06-1988
Base fishing mortality =  1
INSHORE MINIMUM  =  0  MAXIMUM  99.9   RELEASE MORTALITY =  15 %
OFFSHORE MINIMUM =  0  MAXIMUM  99.9   RELEASE MORTALITY =  15 %
SCALE = millions

1985            ALL AREAS COMBINED - ALL GEARS COMBINED

YIELDS IN WEIGHT
```

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.002	0.016	0.027	0.019	0.025	0.007	0.008	0.106
2	0.140	0.135	0.118	0.116	0.063	0.069	0.137	0.127	0.069	0.066	0.026	0.025	1.091
3	0.245	0.239	0.184	0.190	0.127	0.158	0.237	0.206	0.140	0.121	0.083	0.071	2.002
4	0.155	0.154	0.108	0.115	0.098	0.119	0.154	0.136	0.100	0.082	0.069	0.059	1.349
5	0.080	0.081	0.053	0.059	0.061	0.072	0.086	0.078	0.059	0.048	0.046	0.039	0.761
6	0.025	0.025	0.016	0.018	0.019	0.022	0.026	0.024	0.018	0.015	0.014	0.012	0.233
7	0.046	0.047	0.029	0.033	0.037	0.042	0.049	0.045	0.034	0.027	0.027	0.023	0.441
8	0.013	0.013	0.008	0.009	0.012	0.012	0.014	0.014	0.010	0.008	0.007	0.007	0.128
9	0.008	0.009	0.005	0.006	0.010	0.008	0.010	0.011	0.006	0.005	0.005	0.004	0.087
10	0.006	0.007	0.004	0.004	0.007	0.006	0.007	0.008	0.005	0.004	0.004	0.003	0.067
11	0.004	0.004	0.002	0.002	0.004	0.004	0.004	0.004	0.003	0.002	0.002	0.002	0.037
12	0.003	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.028
13	0.008	0.008	0.005	0.005	0.009	0.008	0.009	0.010	0.006	0.005	0.005	0.004	0.081
14	0.003	0.003	0.002	0.002	0.003	0.003	0.003	0.004	0.002	0.002	0.002	0.002	0.032
15	0.005	0.005	0.003	0.003	0.005	0.004	0.005	0.005	0.003	0.003	0.002	0.002	0.045
TO	0.740	0.734	0.538	0.564	0.461	0.534	0.760	0.703	0.475	0.415	0.301	0.263	6.488

If the separate/combined prompt in the output selection menu is answered with **S**, then TABRES will issue an additional prompt requesting the specific gears to include. The most detailed output can be obtained by selecting **S** at the gear prompt, selecting the entire range of gears, and subsequently selecting the all option (**A**) for each of the remaining options. The following example specifies a table of inshore catch by number with subtotals by gear, using only gear 1.

```
Output selection for 1985

gears Separate or Combined (C) -> S
First gear (1) 1 Last gear ( 3) -> 1

Inshore Offshore Combined All (C) -> I
Yield Number Survivors All (Y) -> N

working
```

TABRES output selection menu.

The task specified in the preceding box produced the following sample table of the simulated numbers of fish caught in area 1 with gear 1 in 1985.

Year simulated = 1985 DATE OF RUN WAS 12-06-1988
Base fishing mortality = 1
INSHORE MINIMUM = 0 MAXIMUM 99.9 RELEASE MORTALITY = 15 %
OFFSHORE MINIMUM = 0 MAXIMUM 99.9 RELEASE MORTALITY = 15 %
SCALE = millions

INSHORE TOTALS - GEAR 1

YIELDS IN NUMBERS

AGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.002	0.016	0.025	0.017	0.021	0.005	0.006	0.093
2	0.079	0.071	0.061	0.055	0.025	0.024	0.051	0.045	0.021	0.019	0.004	0.004	0.462
3	0.038	0.035	0.030	0.028	0.013	0.012	0.026	0.024	0.011	0.010	0.002	0.002	0.230
4	0.008	0.007	0.006	0.006	0.003	0.003	0.006	0.005	0.002	0.002	0.001	0.000	0.049
5	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.008
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TO	0.127	0.115	0.099	0.091	0.042	0.042	0.100	0.101	0.051	0.053	0.013	0.013	0.846

FCAST

This program takes the simulated population fecundities and estimated first-year survival rates for a selected set of years and estimates the probability distributions for year class strengths. This is done by fitting a log-normal distribution to the estimated survival rates. The percentiles for year-class strength are then estimated as the product of the simulated fecundities and the percentiles for the survival rates from the fitted distribution.

This program is invoked by entering the command

```
C:>FCAST
```

FCAST will then prompt the user for the information indicated in the setup menu illustrated in the box to the right. The provision for two input files stems from the possibility that one file may contain a series of survival estimates from a run used to establish a set of initial conditions, and the second file might contain estimates from a subsequent run. The specification of any filename other than "NUL" for the second input file will cause FCAST to attempt to load that file into memory.

```
FCAST(1.0)/cpg Dec 88

File for output (PRN)-> PRN
Input file #1 (SO.DAT) -> SO.DAT
Input file #2 (NUL) -> NUL
```

FCAST setup menu.

```
         title
1977  0.250579  41.90280
1978  0.564850  40.71877
1979  0.207568  38.54158
1980  0.493320  36.48746
1981  0.585647  34.15026
1982  0.592587  32.06278
1983  0.259150  30.87014
1984  0.162979  30.67868
1985  0.198671  30.20064
1986  0.202903  29.57078
1987  0.0       28.43072
```

The sample box to the left illustrates the contents of the S0 data file. The first line is a title that originated in the FSIM initialization sequence. It may be modified with a text editor. Each of the rest of the lines in the file contain three items: year, survival estimate for the year, and the population fecundity estimate for the year. FCAST will read these data until the end of the file is reached.

Two such files can be concatenated so long as the years form a contiguous time series. The title line of the second file must be deleted in such cases.

FCAST uses all of the non-zero survival estimates in the file when it fits the lognormal distribution that will be used in probability forecasts.

The "survival" estimates here are actually only estimates of survival if the units of fecundity in the length-fecundity equation are eggs. In the example box, which was derived for red snapper, the fecundity units are in units of grams of ovarian tissue. Thus, actual survival is related to the estimated "survival" by a constant (which in this case would be the reciprocal of the number of eggs per gram of ovary). The value of the constant is of no real concern since, for the forecasting application described here, its value would cancel. (The "survival" estimates would be multiplied by the constant and the population fecundities would be divided by it.) However, such may not be the case with all possible uses of the egg-to-juvenile survival rate estimates.

Once FCAST has loaded the input data, it will prompt the user to specify the percentiles to tabulate and the years to include in the table of estimated probability distributions for year-class strengths, as in the box to the right.

It is sometimes instructive to have FCAST generate probability distribution estimates for year classes which have already occurred. This practice can assist interpretation of actual forecasts through study of the placement of the realized year-class strengths within the model-generated estimated probability distributions.

```
FCAST(1.0) /cpg Dec 88

OUTPUT FILE IS    -> PRN
INPUT FILE #1 IS -> SO.DAT
DATASET #1 - EXAMPLE

Percentiles to tabulate (5) ->  5
Years available for tabulation include 1977 to 1987

First year to tabulate 1977  ->  1977
Last year to tabulate 1987  ->  1987
```

FCAST output specification menu.

The sample FCAST run in the preceding box produced the following table of year-class probability estimates. The darker shaded values are the estimates closest to the realized values for the years that were observed.

INPUT FILE #1 IS -> SO.DAT
DATASET #1 - EXAMPLE

%tile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
0.05	5.6	5.4	5.1	4.8	4.5	4.2	4.1	4.1	4.0	3.9	3.8
0.10	6.7	6.5	6.2	5.8	5.5	5.1	4.9	4.9	4.8	4.7	4.5
0.15	7.6	7.4	7.0	6.6	6.2	5.8	5.6	5.6	5.5	5.4	5.2
0.20	8.4	8.2	7.7	7.3	6.9	6.4	6.2	6.2	6.1	5.9	5.7
0.25	9.2	8.9	8.5	8.0	7.5	7.0	6.8	6.7	6.6	6.5	6.2
0.30	9.9	9.7	9.1	8.7	8.1	7.6	7.3	7.3	7.2	7.0	6.7
0.35	10.7	10.4	9.8	9.3	8.7	8.2	7.9	7.8	7.7	7.5	7.2
0.40	11.4	11.1	10.5	10.0	9.3	8.8	8.4	8.4	8.2	8.1	7.8
0.45	12.2	11.9	11.2	10.6	10.0	9.4	9.0	8.9	8.8	8.6	8.3
0.50	13.0	12.7	12.0	11.4	10.6	10.0	9.6	9.6	9.4	9.2	8.9
0.55	13.9	13.5	12.8	12.1	11.4	10.7	10.3	10.2	10.0	9.8	9.4
0.60	14.9	14.5	13.7	13.0	12.1	11.4	11.0	10.9	10.7	10.5	10.1
0.65	15.9	15.5	14.7	13.9	13.0	12.2	11.7	11.7	11.5	11.2	10.8
0.70	17.1	16.6	15.8	14.9	14.0	13.1	12.6	12.5	12.3	12.1	11.6
0.75	18.5	18.0	17.0	16.1	15.1	14.2	13.6	13.6	13.3	13.1	12.6
0.80	20.2	19.6	18.6	17.6	16.5	15.5	14.9	14.8	14.6	14.3	13.7
0.85	22.4	21.7	20.6	19.5	18.2	17.1	16.5	16.4	16.1	15.8	15.2
0.90	25.4	24.7	23.4	22.1	20.7	19.4	18.7	18.6	18.3	17.9	17.2
0.95	30.7	29.8	28.2	26.7	25.0	23.5	22.6	22.4	22.1	21.6	20.8

Tables of this sort are often useful for presenting forecasts of possible recruitment benefits that may arise from management to increase the spawning stock. They reflect the observed levels of uncertainty in year-class survival derived during the analyses. The probability distributions are easily interpreted and present a more realistic appraisal of possible recruitment trends with alternative management actions.

FCAST uses projections of spawning population size that are based on observed year-class strengths for the first few years beyond the present because of the delay in females reaching reproductive maturity. However, after an interim period that will depend on the species, simulated year-class strengths will begin to impact the estimated spawning stock size. Because of this, the reliability of the estimates will deteriorate with distance into the future.

VIEWPLOT

This is a utility program to view saved graphics output, to add/edit figure captions, and to print them on a HP Laserjet printer. It requires EGA support.

SAVING GRAPHIC IMAGES - In order to use VIEWPLOT the graphics images must be saved in HP Laserjet format images. All of the LSIM modules that create graphic images can save the images in files of the proper format. In order to generate such a file follow the following steps.

A. Proceed with LSIM module execution until a graphics image is displayed on the screen.

B. Press the "H" key on the keyboard.

C. Enter a short prefix for the name of the file where the image will be stored, and press the carriage return.

The image will be saved in a file with a .PLT suffix. This suffix determines which files VIEWPLOT will list in its directory. Each of the files will be approximately 30K bytes in length.

RUNNING VIEWPLOT - To begin program execution type

```
C:<VIEWPLOT file.plt
```

If a valid filename is specified on the command line, VIEWPLOT will copy the image to the display. Otherwise Viewplot will search the current directory for files with the ".PLT" extension. VIEWPLOT will then display a directory of available image files that may be selected, as in the example below.

```
                 VIEWPLOT DIRECTORY (1.0)/cpg Dec 1988
 Direction keys to select file        Enter to read       Escape to exit

AJDEPTH.PLT  AJF&SZ.PLT  AJRED.PLT  AJSIZ.PLT   AMBER.PLT  GAGDPTH.PLT
LDALL.PLT    LDBLL.PLT   LDELE.PLT  LDHAND.PLT  RED.PLT
```

Options available at this point are:

1. Use the arrow keys to highlight a particular file.
2. Press a carriage return <CR> to display the file.
3. Depress the "P" key on the keyboard to send the file to the printer.
4. Depress the Escape key to exit to the operating system.

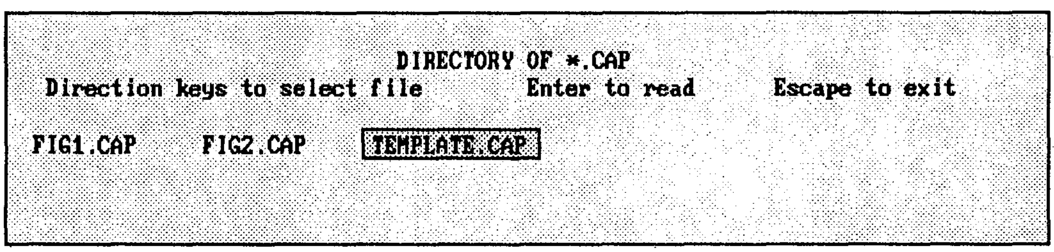
If the second option is selected, the image will be displayed and VIEWPLOT will await additional instructions. Options available at this point are:

1. Press a carriage return to create/edit the figure legend.
2. Depress the Escape key to return to the VIEWPLOT directory menu.

If the first option is selected, a rudimentary text editor is available for typing or editing a figure legend. While in the editor, the following functions are available.

Esc - Exits the edit, and asks whether to save the file.
Insert - Toggles between insert and typeover modes.
Home - Cursor to beginning of line.
End - Cursor to end of line.
Pgup - Cursor to beginning of text.
Pgdn - Cursor to end of text.
Ctrl Y - Deletes the current line.
Alt V - View the graph.
Alt R - Read caption from file.

If the Alt R function is activated, then VIEWPLOT will search the current directory for all files with a ".CAP" extension and display a file selection menu as in the following example.



Use the arrow keys to highlight the desired caption, then press a carriage return to load the caption. VIEWPLOT will then return to edit mode. If this option is selected, any preexisting caption is deleted and the ALT V option is disabled for the current plot.

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