FISH DIVISION
Oregon Department of Fish and Wildlife

MOCPOP 2.0: A Flexible System for Simulation of Age-Structured Populations and Stock-Related Functions
WHAT IS MOCPOP?

MOCPOP is a program for simulating annual variation in numbers, production and biomass of a population of organisms based on recruitment, mortality, and growth. Commonly used models of population dynamics (Vaughan et al. 1982), including stock-recruitment, logistic (surplus production), dynamic pool (yield), and Leslie matrix or combinations or portions of these models can be approximated with MOCPOP. MOCPOP tracks population size in numbers and biomass, and also calculates numbers of particular interest to harvest managers including yield, number of harvestable individuals, and an index of population size structure. MOCPOP also allows weighting of age-specific numbers, production, or biomass to project potential effects of a population.

This software was written to simplify use of the computer in modeling populations. It provides the flexibility to simulate a variety of populations and population processes with a minimum of experience with microcomputers and no knowledge of computer language or programming. MOCPOP is based on population models outlined by Taylor (1981) and Walters (1969), but is much more flexible in its consideration of reproduction and recruitment processes. Input population parameters and simulation results can also be more easily manipulated and inspected.

MOCPOP 2.0 uses pull-down menus off a single main menu to increase flexibility in moving around within the program. MOCPOP 2.0 also offers improved file handling and editing capabilities, more complete screening for inappropriate inputs, and additional options for inputs of population parameters.

This guide documents the operation of and calculations made by MOCPOP 2.0. Several examples are included to demonstrate the program's operation, but a broader discussion of modeling and model building can be found in other references such as Grant (1986).

HOW TO RUN MOCPOP 2.0

To run MOCPOP 2.0:

1. Boot machine with PC-DOS or MS-DOS.

2. Place diskette containing model in default drive.

3. Start the model (type MOCPOP20 after the > prompt and press Enter).

MOCPOP 2.0 will run much faster if you copy all associated files to your hard disk and execute from there.

MOCPOP 2.0 is written in compiled Microsoft QuickBASIC 4.0 to run on IBM and IBM-compatible machines. Graphics require an IBM color graphics adaptor or a functional equivalent. MOCPOP 2.0 will support monochrome graphics cards if the program is executed using the batch
file MP (type MP after the > prompt and press Enter) and if you own software using the file HGChBP.COM and that file is in your path.

HOW MOCPOP 2.0 WORKS

The program is executed from a main menu bar displayed across the top of the screen. Commands in the main menu (Name, Edit, Run, Predict, and Write) are typically executed in sequence to build and run a model, inspect results, and write results to a printer or file. The main menu also contains commands to get help, exit temporarily to DOS, and quit. A series of pull-down menus off the main menu bar list other options. Pop-up menus for each option may be displayed for even more detail. Commands are selected by typing designated capital letters (typically the first). The escape key may be pressed at any time to exit a pull-down or pop-up menu.

The name of the current model is displayed in the upper right corner of the screen in the main menu bar. After a model has been named, model parameters and starting values are displayed on the screen following the main menu bar. This information is contained in two screens that can be swapped by pressing the F1 key.

NAMING A MODEL

A name must be assigned to a model before it can be edited or run. You may create a new model by pressing N to select Name in the main menu bar, then C to select Create from the Name pull-down menu. You are prompted for a name for your model. Names may have up to eight characters, typed in upper or lower case with characters following DOS conventions. All input parameters, options, and start values for variables are initially set to 0 in a newly created model.

You may save up to 30 models for future use by selecting Save in the Name pull-down menu. You are prompted for a file name to which MOCPOP 2.0 adds the extension .K20. Instead of reentering inputs each time you use MOCPOP 2.0, you may load inputs saved previously and rerun a simulation, or you may edit previous inputs and run a new simulation. To load a saved model, select Load in the Name pull-down menu. MOCPOP 2.0 will check the diskette for files with the extension .K20, list these files, and prompt you to select one. The selection is made by using cursor control keys to highlight the desired model then pressing enter. Files created using the original MOCPOP (Beamesderfer 1988) cannot be accessed by MOCPOP 2.0.

Each time a model is run, inputs are stored automatically in a file named LASTRUN. This file may be recalled for reuse, but it is not necessary to reload this file before each run because the last file loaded is retained. Files may be erased by selecting Delete in the Name pull-down menu.
EDITING INPUTS

After a model is named, the Edit option in the main menu bar is used to change inputs and select processes that describe your population. Inputs are organized into eight categories that are listed in the Edit pull-down menu. Each category has a pop-up menu that displays current values for inputs.

A new value is entered by typing over all or part of an old value. Changes are logged by pressing Enter or one of the cursor control keys (Up, Down, Tab, End, Home) to move among the listed inputs. Remember to press Enter after typing over old values before escaping the Edit pop-up screen. Otherwise, your last change will not be logged. Inappropriate values will not be accepted, and you will have to enter a new value before you can continue. Commas in numbers are not accepted. Decimal fractions may or may not be preceded with a zero. Large ($>10^6$) or small ($<10^{-6}$) numbers should be entered in exponential format. For instance, 1,500,000 should be entered as 1.5E+06 and 0.0000015 should be entered as 1.5E-06. Additional details on each Edit pop-up screen follow.

Start Population

Selection of this Edit option displays a list of age-specific numbers of individuals in the population at the start of Year 1. Inputs are listed for all ages up to the maximum age listed in the Mortality pop-up screen.

Reproduction

Selection of this Edit option displays input parameters for an exponential length-fecundity equation (coefficient and exponent), the age at which females first mature, the proportion of the population over the age of maturity that is female, and the proportion of mature females that spawn in any year. You have two options for entering the spawning proportion:

1. Input for up to three groups.
2. Cumulative normal function of length.

Option 1 allows you to enter different numbers for the proportion for females spawning in any year for one to three age groups. After each entry you must supply the maximum age to which it applies. The minimum age is one greater than the previous entry except for the first entry where the minimum age is the age at which females first mature.

Option 2 sets the spawning proportion as a function of length adapted from that of Welch and McFarlane (In press). This function is based on a cumulative normal distribution function.

$$e = \frac{1}{\sqrt{2\pi}} e^{-\frac{(L_x - \mu)^2}{2\sigma^2}} \sum_{i=1}^{5} b_i \left(1 + p \frac{|L_x - \mu|}{\sigma} \right)^{1-1}$$
\[ p_{sX} = c \Phi \text{ for } L_X \leq \mu \]

\[ p_{sX} = c (1 - \Phi) \text{ for } L_X > \mu \]

where

- \( \Phi \) = cumulative normal distribution function dependent variable,
- \( \pi = 3.141593 \),
- \( e = 2.718282 \),
- \( L_X \) = age-specific length,
- \( \mu \) = mean length of sexual maturity,
- \( \sigma \) = variance about mean length of sexual maturity,
- \( b_1 = 0.31938153 \),
- \( b_2 = -0.356563782 \),
- \( b_3 = 1.781477937 \),
- \( b_4 = -1.821255978 \),
- \( b_5 = 1.330274429 \),
- \( p = 0.2316419 \),
- \( p_{sX} \) = age-specific proportion of females that spawn in any year, and
- \( c \) = spawning proportion equation coefficient corresponding to maximum proportion.

Recruitment

Selection of this Edit option displays choices for the mechanism of recruitment and associated parameters. Recruitment is defined as the number of age-1 individuals at the start of the year. Recruitment can be varied independently or as a function of parental stock size.

Nine recruitment options exist:

1. CONSTANT—Number entered for age 1.
2. BIG YEAR CLASSES—at fixed intervals, otherwise constant.
3. BIG YEAR CLASSES—at random intervals, otherwise constant.
4. RANDOM—Uniformly distributed.
5. RANDOM—Normally distributed.
6. STOCK RELATED—Proportional to reproductive potential.
7. STOCK RELATED—Beverton-Holt relationship.
8. STOCK RELATED—Ricker relationship.
9. STOCK RELATED—Cushing equation.

Recruitment Options 1-3 use the number of age-1 individuals entered in the starting population screen as an average condition. Recruitment Options 2-3 allow replacing this average recruitment with a severalfold
increase at fixed or random intervals. If Recruitment Option 2 or 3 is selected, you will be prompted for this multiplication factor. For Recruitment Option 2, you will also be prompted for the interval at which big year classes occur and the first year of a big year class. For Recruitment Option 3, you will be prompted for the average frequency with which big year classes occur. The probability of a big year class in any given year would thus be the inverse of this frequency.

Recruitment Options 4 and 5 select recruitment as random either with equal probability between a specified minimum and maximum (Option 4) or with varying probability distributed normally with a specified mean and standard deviation (Option 5).

Recruitment Options 6-9 select recruitment as a function of stock size and factor in parental stock size indirectly by calculating reproductive potential for each parental age class. Recruitment at age 1 is calculated as the product of this potential egg deposition, and an egg-to-age-1 survival rate calculated from an input on the Mortality pop-up screen (Input Option 4). In Recruitment Option 6, recruitment is thus calculated directly from reproductive potential. In Recruitment Options 7-9, a realized egg deposition is calculated from the potential egg deposition using the density-dependent relationship indicated. Age-1 numbers are then calculated as the product of this realized egg deposition and the egg-to-age-1 survival rate. All density-dependent mortality thus takes place at the egg and larval stages. There is no provision for density-dependent mortality occurring beyond age 1.

Density-dependent relationships between reproductive potential and realized egg deposition include those described by Beverton-Holt, Ricker, and Cushing.

The Beverton-Holt equation (Ricker 1975) is

\[ R = \frac{P}{1 - A(1 - P/P_r)} \]

where

- \( R \) = actual egg deposition,
- \( P \) = potential egg deposition,
- \( A \) = parameter describing the shape of the curve. If you select this equation, you will be prompted for \( A \), and
- \( P_r \) = replacement egg deposition at equilibrium.

The Ricker equation (Ricker 1975) is

\[ R = Pe^{\alpha(1 - P/P_r)} \]

where

- \( e \) = 2.718282,
- \( \alpha \) = parameter describing the shape of the curve,
- \( P \) = potential egg deposition, and
- \( P_r \) = replacement egg deposition at equilibrium.
You will be prompted for "$P_r$" and "a" if you select this option. See Ricker (1975) for a discussion of these functions and methods for estimating parameters.

The Cushing equation (Kimura et al. 1984) is

$$ R = E_{max} \left( \frac{P}{P_{max}} \right)^c $$

where

- $P$ = population size,
- $E_{max}$ = maximum egg deposition,
- $P_{max}$ = population size at $E_{max}$, and
- $c$ = a constant describing strength of relationship.

If you select this option, you will be prompted for "$E_{max}$," "$P_{max}$," and "c."

**Growth**

Selection of this Edit option displays parameters related to calculations of length and weight at age including parameters for a von Bertalanffy age-length equation ($L_\infty, k, t_0$), and an exponential length-weight equation (coefficient and exponent).

**Mortality**

Selection of this Edit option displays inputs for maximum age and natural mortality rate. A maximum age of up to 100 may be entered. If the population has no age structure, enter a maximum age of 1.

You have the following options for egg-to-age-1 mortality rate:

1. **CONSTANT.**
2. **RANDOM**—Uniformly distributed.
3. **RANDOM**—Normal.

You will be prompted for numbers appropriate for the option you select. Egg-to-age-1 mortality rate is used by the model only when stock-related recruitment options were specified. Recruitment Options 1-5 (constant, big year classes, or random) over-ride the calculation of age-1 number from egg number.

You are also prompted for a series of natural mortalities for ages 1 and above. Enter the conditional annual rate. The following options are provided:

1. Set for up to three age groups.
2. Linear function of age.

Option 1 allows you to enter different rates for one to three age groups. After each entry you must supply the maximum age to which it applies. The minimum age is one greater than the previous entry except for the first entry where the minimum age is 1.

Option 2 allows you to vary rate as a linear function of age using the equation

\[ n_x = \alpha n + (\beta n)(x) \]

where

\( n_x \) = age-specific conditional natural mortality rate,
\( \alpha n \) = rate-age equation intercept parameter,
\( \beta n \) = rate-age equation slope parameter, and
\( x \) = age.

Option 3 sets natural mortality rate for all ages greater than 0 to a constant predicted from a regression on parameters in the age-length equation and temperature (Pauly 1980)

\[ M = 10^{[-0.0066 - 0.279 \log_{10}(L_w) + 0.6543 \log_{10}(k) + 0.4634 \log_{10}(T)]} \]

\[ n_x = 1 - e^{-M} \]

where

\( M \) = instantaneous rate of annual natural mortality,
\( L_w \) = von Bertalanffy equation length at infinity based on total length in cm,
\( k \) = von Bertalanffy equation parameter based on total length in cm,
\( T \) = mean annual water temperature in °C,
\( n_x \) = conditional natural mortality rate, and
\( e \) = 2.718282.

Length-weight equation parameters input for this option are used only in calculation of mortality rate and are independent of those input for growth.

**Exploitation**

Selection of this Edit option displays inputs for exploitation rate. Exploitation rates may be input for one or two fisheries. Rates for two fisheries are added for a total rate. Rates input or calculated from inputs are limited to the range 0 to 1 when the model is run. Rates may be input directly or based on effort and catchability (q). The following options are provided:

1. Set for up to three size groups.

2. \( f(\text{effort} \& \text{catchability})=q \) set for up to three groups.
3. $f(\text{effort & catchability}) - q$ a normal function of size.

Upon selection of Option 1, you are prompted for the minimum and maximum exploitable sizes, and the annual rate of exploitation. Size classes must not overlap.

Options 2 and 3 prompt for input of fishing effort and inputs for catchability. An assumption that spatial and temporal variations in fishing effort and stock catchability can be approximated by an average catchability is implicit in the use of these options. Option 2 prompts for direct input of catchability for one to three groups and corresponding minimum and maximum sizes. Exploitation rate is calculated as

$$m_x = 1 - e^{-fq}$$

where

$m_x =$ exploitation (harvest mortality rate),
$f = $ fishing effort,
$e = 2.718282$, and
$q = $ catchability.

Option 3 prompts for parameters in a normal function of catchability versus size:

$$q = (aq) e^{-\left(bq - L_x\right)^2/(2)(cg)^2}$$

where

$aq =$ catchability-size equation parameter corresponding to maximum catchability,
$bq =$ catchability-size equation parameter corresponding to size of maximum catchability,
$cg =$ catchability-size equation parameter corresponding to size increment in 1 SD from the size of maximum catchability,
$e =$ 2.718282, and
$L_x =$ age-specific length.

Weight Factor

Selection of this Edit option displays a list of age-specific weighting factors that can be used to project the effect of the population on another component of the system (the weighted effect). Values are listed for all ages up to the maximum age listed in the Mortality pop-up screen. You are also prompted for the expression of population size or growth that is to be weighted. Choices include number, biomass, and production.

Size Index

Selection of this Edit option lists sizes used in calculating an index of population size structure analogous to proportional stock.
density (PSD; Anderson 1980). The index is calculated as the number of individuals within one pair of minimum and maximum sizes (the numerator) divided by the number within a second pair of minimum and maximum sizes (the denominator).

RUNNING THE MODEL

Using the Run option in the main menu, you have the options of running a new simulation starting at Year 1 (New in the Run pull-down menu) or of extending the current simulation for more years (Continue in the Run pull-down menu). You may thus structure the population based on one set of inputs, edit the inputs, and examine the corresponding effect on the population without having to enter the results of the first simulation as a new starting condition. After specifying New or Continue, you will be prompted for the number of years to run or extend the simulation. A maximum of 300 years may be run.

Processing of inputs is based on a series of difference equations. Given a number of individuals at the start of the year, the sequence of events is reproduction, exploitation, and death from natural causes.

The age-specific numbers of individuals at the start of the first year of the simulation are an input. Age-specific numbers of individuals \( N_x \) after the first year are calculated by the equation

\[
N_{x+1,t+1} = (N_{x,t})(S_x)
\]

where

\( t = \text{year}, \) and
\( S_x = \text{age-specific annual survival rate}. \)

Age-specific annual survival \( (S_x) \) is calculated as

\[
S_x = 1 - (m_x + n_x - (m_x)(n_x))
\]

where

\( m_x = \text{exploitation (harvest mortality rate)}, \) and
\( n_x = \text{conditional natural mortality rate}. \)

Biomass present in each age class \( (B_x) \) is estimated as

\[
B_{x,t} = (N_{x,t})(W_x)
\]

where

\( W_x = \text{age-specific weight (units same as those supplied in length-weight equation)}. \)

Age-specific weights are calculated with age-length and length-weight equations using input parameters

\[
L_x = L_m(1 - e^{-k(x - t0)}) \text{ and}
\]

-12-
\[ w_x = (\alpha_w) (L_x^B_w) \]

where

\( L_x \) = length at age,
\( L_\infty \) = von Bertalanffy equation length at infinity,
\( k \) = von Bertalanffy equation parameter,
\( t_0 \) = von Bertalanffy equation parameter,
\( \alpha_w \) = length-weight equation coefficient, and
\( B_w \) = length-weight equation exponent.

Reproductive potential of each age class \( (P_x) \) at or above the age of female maturity is estimated by

\[ P_{x,t} = (N_{x,t}) (F_x) (p_f^e) (p_s^e) \]

where

\( F_x \) = age-specific fecundity of females,
\( p_f^e \) = proportion of population that is female, and
\( p_s^e \) = age-specific proportion of females that spawn in any year.

Fecundity \( (F_x) \) is estimated by

\[ F_x = (\alpha_f) (L_x^B_f) \]

where

\( \alpha_f \) = length-fecundity equation coefficient, and
\( B_f \) = length-fecundity equation exponent.

The net reproductive potential of all ages in any given year is

\[ P = \sum (P_x). \]

This is the number upon which stock-related recruitment functions, discussed under EDITING INPUTS, Recruitment, operate to calculate recruitment at age 1 \( (N_1) \).

All animals are harvested at one time. All mortality occurs following spawning. Harvest in number (catch) and weight (yield) from an age class are calculated by

\[ H_x = (N_x) (m_x) \] and
\[ Y_x = (N_x) (m_x) (W_x) \]

where

\( H_x \) = age-specific numbers of individuals removed by exploitation, and
\( Y_x \) = age-specific weight of individuals removed by exploitation.

Annual production of any age class \( (PD_{x,t}) \) is calculated by
\[ PD_{x,t} = \frac{(N_{x+1,t} + N_x,t)}{2} \left(\log W_{x+1} - \log W_x\right). \]

The weighted effect of any age class \((E_x)\) is calculated by

\[ E_x = \frac{N_x}{W_x} \]

where

\(W_x\) = age-specific weighting factor.

**INSPECTING MODEL PREDICTIONS**

Simulation results in the form of tables, summary statistics, or graphs may be displayed using the Predict option in the main menu. Selecting this option displays a pull-down menu containing six choices. Details on these options follow.

**Reproduction by Age**

Selection of this option displays a pop-up screen that contains a table of information similar to the following:

<table>
<thead>
<tr>
<th>Age</th>
<th>Leng</th>
<th>Wgt</th>
<th>Num</th>
<th>Fecund</th>
<th>P Fem</th>
<th>P Spn</th>
<th>Per Fish</th>
<th>Eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76</td>
<td>4</td>
<td>10000</td>
<td>76</td>
<td>0.50</td>
<td>1.00</td>
<td>38</td>
<td>0.3803E+06</td>
</tr>
<tr>
<td>2</td>
<td>137</td>
<td>28</td>
<td>5000</td>
<td>137</td>
<td>0.50</td>
<td>1.00</td>
<td>69</td>
<td>0.3432E+06</td>
</tr>
<tr>
<td>3</td>
<td>191</td>
<td>79</td>
<td>2500</td>
<td>191</td>
<td>0.50</td>
<td>1.00</td>
<td>95</td>
<td>0.2386E+06</td>
</tr>
<tr>
<td>4</td>
<td>238</td>
<td>160</td>
<td>1250</td>
<td>238</td>
<td>0.50</td>
<td>1.00</td>
<td>119</td>
<td>0.1487E+06</td>
</tr>
<tr>
<td>5</td>
<td>279</td>
<td>266</td>
<td>900</td>
<td>279</td>
<td>0.50</td>
<td>1.00</td>
<td>140</td>
<td>0.1256E+06</td>
</tr>
<tr>
<td>6</td>
<td>315</td>
<td>392</td>
<td>648</td>
<td>315</td>
<td>0.50</td>
<td>1.00</td>
<td>158</td>
<td>0.1021E+06</td>
</tr>
<tr>
<td>7</td>
<td>347</td>
<td>532</td>
<td>467</td>
<td>347</td>
<td>0.50</td>
<td>1.00</td>
<td>173</td>
<td>0.0891E+05</td>
</tr>
<tr>
<td>8</td>
<td>375</td>
<td>680</td>
<td>336</td>
<td>375</td>
<td>0.50</td>
<td>1.00</td>
<td>187</td>
<td>0.6291E+05</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>21100.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Potential | 1482316 |
| Realized  | 1482316 |

where

- Leng = length in units from age-length equation \((L_x)\),
- Wgt = weight in units from length-weight equation \((W_x)\),
- Num = number of individuals in population \((N_x)\),
- Fecund = fecundity of females in age class \((F_x)\),
- P Fem = proportion of population that is female \((pf)\),
- P Spn = proportion of females that spawn in any year \((p_{Sx})\),
- Per Fish = fecundity per individual in population \([\{F_x\}\{pf\}\{p_{Sx}\}]\), and
- Eggs = reproductive potential in age class \((P)\).

Potential egg deposition is total eggs produced by all age classes. Realized egg deposition is the potential deposition modified by the effects of the stock-recruitment function.
Population by Age

Selection of this option displays a pop-up screen that contains a table of information similar to the following:

<table>
<thead>
<tr>
<th>Age</th>
<th>Leng</th>
<th>Wgt</th>
<th>Start</th>
<th>Fshg</th>
<th>Ntrl</th>
<th>Surv</th>
<th>Biomass</th>
<th>Prod</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>148232E+01</td>
<td>0.000</td>
<td>1.000</td>
<td>0.000</td>
<td>1.000</td>
<td>42089</td>
<td>169926</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>76</td>
<td>4</td>
<td>10000</td>
<td>0.000</td>
<td>0.500</td>
<td>0.500</td>
<td>138368</td>
<td>177032</td>
</tr>
<tr>
<td>2</td>
<td>137</td>
<td>28</td>
<td>5000</td>
<td>0.000</td>
<td>0.500</td>
<td>0.500</td>
<td>198136</td>
<td>139752</td>
</tr>
<tr>
<td>3</td>
<td>191</td>
<td>79</td>
<td>2500</td>
<td>0.000</td>
<td>0.500</td>
<td>0.500</td>
<td>199929</td>
<td>111938</td>
</tr>
<tr>
<td>4</td>
<td>238</td>
<td>160</td>
<td>1250</td>
<td>0.100</td>
<td>0.200</td>
<td>0.720</td>
<td>239571</td>
<td>958002</td>
</tr>
<tr>
<td>5</td>
<td>279</td>
<td>266</td>
<td>900</td>
<td>0.100</td>
<td>0.200</td>
<td>0.720</td>
<td>254256</td>
<td>76673</td>
</tr>
<tr>
<td>6</td>
<td>315</td>
<td>392</td>
<td>648</td>
<td>0.100</td>
<td>0.200</td>
<td>0.720</td>
<td>248372</td>
<td>58493</td>
</tr>
<tr>
<td>7</td>
<td>347</td>
<td>532</td>
<td>467</td>
<td>0.100</td>
<td>0.200</td>
<td>0.720</td>
<td>228542</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>375</td>
<td>680</td>
<td>336</td>
<td>0.100</td>
<td>0.200</td>
<td>0.000</td>
<td>15493E+02</td>
<td>829616</td>
</tr>
</tbody>
</table>

TOTAL 21100

where

- Age = 0 refers to reproductive potential,
- Leng = length in units from age-length equation ($L_x$),
- Wgt = weight in units from length-weight equation ($W_x$),
- Start = number of individuals at the start of the year ($N_{x,t}$),
- Fshg = exploitation or harvest mortality rate ($m_x$),
- Ntrl = conditional natural mortality rate ($n_x$),
- Surv = age-specific annual survival rate ($S_x$),
- New = number of individuals surviving to the start of the next year from the previous age class ($N_{x,t+1}$),
- Biomass = weight of all individuals at the start of the year ($B_{x,t}$), and
- Prod = production in biomass including individuals that die ($PD_x$).

Fishery by Age

Selection of this option displays a pop-up screen that contains a table of information similar to the following:

<table>
<thead>
<tr>
<th>AGE-SPECIFIC HARVEST, YIELD, AND EFFECT INFORMATION IN YEAR 8</th>
<th>Age</th>
<th>Leng</th>
<th>Wgt</th>
<th>Start</th>
<th>Expl</th>
<th>Catch</th>
<th>Yield</th>
<th>Wt Var</th>
<th>Factor</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76</td>
<td>4</td>
<td>10000</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0E+00</td>
<td>1.00</td>
<td>10000</td>
</tr>
<tr>
<td>2</td>
<td>137</td>
<td>28</td>
<td>5000</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
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<tr>
<td>5</td>
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<td>266</td>
<td>900</td>
<td>0.100</td>
<td>0.90</td>
<td>2396E+01</td>
<td>900</td>
<td>0.00</td>
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<td>6</td>
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<td>392</td>
<td>648</td>
<td>0.100</td>
<td>0.65</td>
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<td></td>
</tr>
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<td>7</td>
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<td>0.100</td>
<td>0.47</td>
<td>2484E+01</td>
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<td>680</td>
<td>336</td>
<td>0.100</td>
<td>0.34</td>
<td>2285E+01</td>
<td>336</td>
<td>0.00</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL 21100

360 1171E+02 10000
where

\[
\begin{align*}
\text{Leng} &= \text{length in units from age-length equation } (L_X), \\
\text{Wgt} &= \text{weight in units from length-weight equation } (W_X), \\
\text{Start} &= \text{number of individuals at the start of the year } (N_X,t), \\
\text{Explo} &= \text{exploitation or harvest mortality rate } (m_X), \\
\text{Catch} &= \text{harvest in numbers } (H_X), \\
\text{Yield} &= \text{harvest in weight } (Y_X), \\
\text{Wt Var} &= \text{variable weighted by Factor to calculate Effect,} \\
\text{Factor} &= \text{age-specific weighting factor } (W_{FX}), \text{ and} \\
\text{Effect} &= \text{age-specific weighted effect } (E_X).
\end{align*}
\]

By Year

Selection of this option displays a pop-up screen that contains a table of information similar to the following:

<table>
<thead>
<tr>
<th>Year</th>
<th>Num</th>
<th>Biom</th>
<th>Repro</th>
<th>Recruit</th>
<th>Catch</th>
<th>Yield</th>
<th>Harnum</th>
<th>Prod</th>
<th>Effect</th>
<th>PSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1OE+03</td>
<td>4E+04</td>
<td>38E+04</td>
<td>1OE+03</td>
<td>0E+00</td>
<td>0E+00</td>
<td>0</td>
<td>2E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1OE+03</td>
<td>2E+05</td>
<td>72E+04</td>
<td>1OE+03</td>
<td>0E+00</td>
<td>0E+00</td>
<td>0</td>
<td>4E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1OE+03</td>
<td>4E+05</td>
<td>96E+04</td>
<td>1OE+03</td>
<td>0E+00</td>
<td>0E+00</td>
<td>0</td>
<td>5E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1OE+03</td>
<td>6E+05</td>
<td>11E+05</td>
<td>1OE+03</td>
<td>13E+01</td>
<td>2OE+03</td>
<td>1250</td>
<td>6E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>2OE+03</td>
<td>8E+05</td>
<td>12E+05</td>
<td>1OE+03</td>
<td>22E+01</td>
<td>44E+03</td>
<td>2150</td>
<td>7E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>2OE+03</td>
<td>1E+06</td>
<td>13E+05</td>
<td>1OE+03</td>
<td>28E+01</td>
<td>69E+03</td>
<td>2798</td>
<td>8E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>2OE+03</td>
<td>1E+06</td>
<td>14E+05</td>
<td>1OE+03</td>
<td>33E+01</td>
<td>94E+03</td>
<td>3265</td>
<td>8E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>2OE+03</td>
<td>2E+06</td>
<td>15E+05</td>
<td>1OE+03</td>
<td>36E+01</td>
<td>12E+04</td>
<td>3600</td>
<td>8E+05</td>
<td>1OE+03</td>
<td>0</td>
</tr>
</tbody>
</table>

where

\[
\begin{align*}
\text{Num} &= \text{total number of individuals in population } (\Sigma N_X), \\
\text{Biom} &= \text{total weight of all individuals in population } (\Sigma B_X), \\
\text{Repro} &= \text{realized egg deposition of all ages } (R), \\
\text{Recruit} &= \text{number of age 1 individuals } (N_{1}), \\
\text{Catch} &= \text{total numbers of individuals harvested } (\Sigma H_X), \\
\text{Yield} &= \text{total weight of individuals harvested } (\Sigma Y_X), \\
\text{Harnum} &= \text{number of individuals in the harvestable size range (should be proportional to catch per unit effort in the fishery),} \\
\text{Prod} &= \text{total production of biomass } (\Sigma PD_X), \\
\text{Effect} &= \text{total effect of population weighted by age, and} \\
\text{PSD} &= \text{size structure index (relative numbers of individuals in 2 size classes).}
\end{align*}
\]

Summary Statistics

Summary statistics include mean, standard deviation, minimum, and maximum for annual summary variables selected from a list. The same variables displayed in the By Year selection from the Predict pull-down

---
menu may be selected. Select a variable by highlighting with cursor control keys then pressing enter. Statistics are calculated over a range of years ending with the last year of the simulation. You also have the option of beginning at a year greater than 1 if you wish to allow a population to reach some equilibrium.

Graph

You may plot yearly totals versus time, yearly totals versus each other, age-specific results in the last year of the simulation versus age, or age-specific results versus each other. You are prompted to select age-specific or year-specific results. Variables that can be plotted for each option are displayed once you make your selection. You select variables for X and Y axes by highlighting with cursor control keys and pressing Enter. X-axis variables are automatically sorted from minimum to maximum. Plotable variables and definitions correspond with those listed in tables. The plot is automatically scaled so that the plot fills the Y-axis. You may print graphs by pressing P after the plot is drawn on the screen. (This print graph option was programmed for an IBM graphics printer and may not work on other printers.)

PRINTING OR SAVING MODEL PREDICTIONS

Selection of the Write option in the main menu bar allows you to send simulation results to a file or to your printer. These results are then available for other applications such as plotting with graphics software or for later review. If you select File, you will be prompted to select age-specific or year-specific results. You are also prompted for a name for the file in which results are saved. You may enter a name up to eight characters long or accept the default name. MOCPOP 2.0 will add the extension .DAT to the name you select. The default name is BYAGE for age-specific results. All age-specific variables included in tables listed in Predict By Age pop-up tables will be written to the file, and the first line in the file will contain variable names. If you are saving year-specific results, the default name is BYYEAR. Variables listed in the Predict By Year pop-up table will be written to the file and the first line in the file will contain variable names.

The Print option prints a summary of model inputs similar to that displayed under the main menu bar, all age-specific numbers such as those listed in Predict by Age pop-up tables, and all year-specific numbers such as those presented in the Predict By Year pop-up table.
EXAMPLE APPLICATIONS

Problem 1—Yield

Estimate yield at 10% exploitation for a population with the following characteristics:

1. Recruitment constant at 10,000 age-1 individuals.
2. von Bertalanffy age-length (mm) equation coefficients:
   \( L_\infty = 571; \, k = 0.132; \, t_0 = -0.093. \)
3. Length (mm)—weight (gm) equation coefficients:
   intercept = 0.0000042; slope = 3.19.
4. Maximum age, 8.
5. Natural mortality: age 1 through age 3, 50% per year; age 4 through age 8, 20% per year.
6. Harvestable size range, 200–400 mm.

Start MOCPOP 2.0. MOCPOP 2.0 first displays two introductory pages and the help screen. Press any key for each to advance to a screen that is blank, except for the menu bar across the top. Press N to select Name, then C to select Create, then type in a name for the model you are creating ("YIELD"). The following screen should appear.
Pressing Enter will then display Page 1 of the default input parameters in the newly created model.

Name  Edit  Run  Predict  Write  Help  DDS  Quit  <YIELD>

REPRODUCTION  Age F Mat 1  % F 50  % F Spawning Annually 100  For ages to 1
Leng-Fecundity  Int 1  Slope 1

RECRUITMENT  Fixed at 1

GROWTH  Age-Leng eqn  Lm 1  K 1  T0 1
Leng-Wgt eqn  a 1  b 1

PSD  Num min 1  max 1  Denom min 1  max 1

MORTALITY  Egg to age 1  Constant at 0
1  For ages to 1

EXPLOITATION  Fishery #1 1 of sizes 1 to 1

F1 Other summary screen...

Press B to display the Edit pull-down menu so that you can enter the appropriate numbers for your population.

Name  Edit  Run  Predict  Write  Help  DDS  Quit  <YIELD>

REPRODUCTI  Start population  % F 50  Reproduction  Annually 100  For ages to 1
Repro
Growth
RECRUITEME  Mortality
Exploitation
GROWTH  Weight factor  1  K 1  T0 1
1  b 1
size index

PSD  1  Denom min 1  max 1

MORTALITY  Egg to age 1  Constant at 1
1  For ages to 1

EXPLOITATION  Fishery #1 1 of sizes 1 to 1

F1 Other summary screen...
Press S to pop up the Start Population edit screen then overtype the 1 displayed for maximum age with 8. Overtypw the 1 displayed for age 1 with 10000. Press Enter to log the change. Press Escape to return to the Edit pull-down menu. Editing the recruitment screen is not necessary because recruitment is set to the fixed option by the default of 1.

Press G to pop up the Growth edit screen, then overtype new parameters for the von Bertalanffy and length-weight equations. Use the tab or down arrow keys to move among entries. Remember to press Enter to log your last entry before pressing Escape to return to the Edit pull-down menu.
Press M to pop up the Mortality edit screen. Note that maximum age is
displayed here as well as on the Start Population edit screen. Skip
entries related to egg-to-age-1 natural mortality as they are not used
when recruitment is fixed. Change the number of groups for ages 1 to
max from 1 to 2 then press Enter. Note the screen changes to display
space for two groups. Type ages, rates, and sizes as shown in the
following screen. Press Escape to return to the Edit pull-down menu.

<table>
<thead>
<tr>
<th>Name</th>
<th>Edit</th>
<th>Run</th>
<th>Predict</th>
<th>Write</th>
<th>Help</th>
<th>DOS</th>
<th>Quit</th>
<th>&lt;YIELD&gt;</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

MORTALITY (NATURAL)

Maximum age = 8

Egg to Age 1

1 = CONSTANT
2 = RANDOM - Uniformly distributed constant = 1
3 = RANDOM - Normal

Ages 1 to max

1 = Set for up to 3 age groups option = 1
2 = Linear function of age # of groups = 2
3 = Pauly regression vs growth & temp for ages to 3 = .5

for ages to 8 = .2

Press E to pop up the Exploitation edit screen and type sizes and rates
as shown in the following screen.

<table>
<thead>
<tr>
<th>Name</th>
<th>Edit</th>
<th>Run</th>
<th>Predict</th>
<th>Write</th>
<th>Help</th>
<th>DOS</th>
<th>Quit</th>
<th>&lt;YIELD&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPLOITATION (RATE)

Number of fisheries (2 max) = 1

Fishery #1

option = 1
# of groups = 1
sizes 200 to 400 = .1

Options 1 = Set for up to 3 size groups
2 = f(effort & catchability) - q set for up to 3 groups
3 = f(effort & catchability) - q a normal function of size
You are now ready to run the simulation. Press Escape again to exit the Edit pull-down menu. Press R to display the Run pull-down menu. Press N to indicate a new simulation, then type 8 for years to run. The following screen is displayed at this point. Press Enter to start the simulation.

When the simulation is completed, the Predict pull-down menu will be displayed automatically. You will find the answer to this yield problem under the Fishery by Age option. Yield for this example is 117,057 qm. The example output tables shown on Pages 14-16 correspond to this simulation.
Before quitting, save the current inputs in a file by selecting Name in the main menu bar, selecting Save in the Name pull-down menu, and entering YIELD at the pop-up screen prompt.

Problem 2---Uncertainty

Estimate the range over which a population may vary as a result of variable recruitment. Use inputs as in Problem 1 (Page 18, except set recruitment to include big year classes that occur every four years on the average and are three times greater than normal.

Start MOCPOP 2.0 and load the model YIELD created in problem 1. Select Name in the main menu bar, select Load from the Name pull-down menu, and use the cursor movement keys to highlight YIELD. The following screen should be displayed. Press Enter to load the model.
Change the recruitment option from 1 to 3 and indicate the relative frequency and size of big year classes. You must press Enter after overtyping the recruitment option to display inputs associated with the big year class option.

Option = 3

1 = CONSTANT - number entered for age 1
2 = BIG YEAR CLASSES - At fixed intervals, otherwise constant
3 = BIG YEAR CLASSES - At random intervals, otherwise constant
4 = RANDOM - Uniformly distributed
5 = RANDOM - Normally distributed
6 = STOCK RELATED - Proportional to reproductive potential
7 = STOCK RELATED - Beverton-Holt relationship
8 = STOCK RELATED - Ricker relationship
9 = STOCK RELATED - Cushing equation

Avg Frequency of Big Year Classes = 4
Size of Big Year Classes (times Average) = 3

Run the simulation for 100 years by escaping from the Edit pull-down menu, selecting Run, selecting New, and entering 100.
After the run is complete, you might wish to plot numbers versus years to examine the pattern of variation. Select the Graph option in the Predict pull-down menu and use the cursor control keys to highlight the choices Year-specific for plot type, Year for the X-axis, and Num for the Y-axis. Press Enter after highlighting each choice to proceed to the next option.

A figure similar to the following will appear. Figures will vary because the years when big year classes occur are randomly selected.

You see that number of individuals started low and increased as a population containing all age classes was built. After that, the population fluctuated as big year classes occurred and moved through the population.
You may also use the Summary Statistics option in the Predict pull-down menu to calculate the mean, standard deviation, and range over which population numbers varied. In this example, we start with Year 9 to avoid including years before all age classes were represented in the population. Remember to save model inputs for future use before ending the current session.

![Image of MOCPOP software interface](image)

**Problem 3--Response Time**

Estimate how quickly a population will recover after a reduction of 50%. Assume a Beverton-Holt stock-recruitment relationship of low to moderate resilience \( A = 0.2 \) [see Ricker (1975), page 292]. Assume no age structure, weights and lengths as in Problems 1 and 2, fecundity equal to length, and a sex ratio of 1:1 with all females spawning.

This situation approximates a simple stock-recruitment-type model, but instead of calculating a progeny stock size directly from parental stock size, MOCPOP 2.0 works by calculating a reproductive potential for parental stock, then multiplying that potential by an egg-to-adult survival rate. You must supply reproductive potential at equilibrium \( A \) in the Beverton-Holt equation and egg-to-adult (age 1) mortality to run this simulation. You can use MOCPOP 2.0 to simplify calculation of these numbers by first running a one-year simulation to calculate reproductive potential, then solving for the mortality rate that will give you the starting stock size you supplied.
Start MOCPop 2.0 and load the model used in Problem 2 (UNCERT). Use the Edit pull-down options to double check that reproduction inputs are as follows:

![REPRODUCTION Menu]

Length-Fecundity Parameters ($f = \alpha L^b$):
\[ \alpha = 1 \]
\[ b = 1 \]

Age of Female Maturation
\[ = 1 \]

Proportion of Population > Age 1 That is Female
\[ = 0.5 \]

Proportion of Females Spawning Yearly:
Option 1: Input for up to 3 groups
Option 2: Sigmoid function of length

# of groups = 1
for ages to 8 = 1

Next, fix recruitment at 10000 and set maximum age to 1.

![RECRUITMENT Menu]

Option = 1

1 = CONSTANT - number entered for age 1
2 = BIG YEAR CLASSES - at fixed intervals, otherwise constant
3 = BIG YEAR CLASSES - at random intervals, otherwise constant
4 = RANDOM - uniformly distributed
5 = RANDOM - normally distributed
6 = STOCK RELATED - proportional to reproductive potential
7 = STOCK RELATED - Bevorton-Holt relationship
8 = STOCK RELATED - Ricker relationship
9 = STOCK RELATED - Cushing equation
For the present, you may ignore inputs for mortality rate as these are not needed in the one-year simulation. Run a new simulation for one year and inspect the age-specific reproduction information screen. The reproductive potential of the population you input is 380,308.
Now run a new simulation to determine how long it will take for the population to recover from a 50% reduction. First reduce starting population size to 5000.

Next, indicate that recruitment is based on a Beverton-Holt equation and supply parameters.
Lastly, edit mortality inputs and input the egg mortality rate.

<table>
<thead>
<tr>
<th>Name</th>
<th>Edit</th>
<th>Run</th>
<th>Predict</th>
<th>Write</th>
<th>Help</th>
<th>DOS</th>
<th>Quit</th>
<th>&lt;UNCERT&gt;</th>
</tr>
</thead>
</table>

**MORTALITY (NATURAL)**

- **Maximum age** = 1
- **Egg to Age 1** = 1
  - **1 = CONSTANT**
  - **2 = RANDOM - Uniformly distributed** constant = .973796
  - **3 = RANDOM - Normal**
- **Ages 1 to max** option = 1
  - **1 = Set for up to 3 age groups**
  - **2 = Linear function of age** # of groups = 1
  - **3 = Pauly regression vs growth & temp** for ages to 1 = .5

This rate is calculated as

\[ \text{Rate} = 1 - \frac{10000}{380308} = 0.973796 \]

You are also prompted for natural and harvest mortality rates on the Mortality edit screen, but these numbers are not used in our simulation because no fish live past age 1. Age 1 mortality is automatically set to 100% by MOCPop 2.0 regardless of what you enter here because 1 is the maximum age.

You are now ready to run the simulation. Do so by escaping from edit screens, selecting Run and New, and entering 50 years. When the simulation is complete, plot numbers versus years. You see approximately 25 years are required for the population to recover to equilibrium levels.
COPIES AND HUGS

A copy of MOCPOP 2.0 may be obtained by sending a diskette and self-addressed mailer with stamp to the author. MOCPOP 2.0 may be copied and distributed freely; no person or organization is authorized to charge any fee or price for MOCPOP 2.0. MOCPOP 2.0 includes the following files:

1. MOCPOP20.EXE: Executable program file.
2. MP20EDIT.OBJ: Program module called by main file.
3. MP20MISC.OBJ: Program module called by main file.
4. MP20TEST.MPK: File containing example input data.
5. MP.BAT: Batch file for running program with monochrome graphics card (see Page 1).

MOCPOP 2.0 is distributed without warranty. If you find a bug, I will attempt to repair it in future versions if you notify me in writing.

ACKNOWLEDGEMENTS

I thank B.E. Rieman and H.A. Schaller for thoughtful review of this program and W.A. Burck and A.A. Nigro for helpful comments on the documentation. This work was supported by funds from the Bonneville Power Administration (Contract DE-AI79-868P63584).

REFERENCES


