ESTIMATES OF SUSTAINABLE EXPLOITATION RATES FOR COLUMBIA RIVER LANDLOCKED WHITE STURGEON: EVALUATING THE IMPORTANCE OF A MAXIMUM SIZE LIMIT

Technical Report 88-4

Adolphe O. Debrot
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COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
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ABSTRACT

Life history computer simulations, along with available parameter estimates, were used to evaluate sustainable exploitation rates for landlocked white sturgeon, *Acipenser transmontanus,* of the Columbia River. The results of the simulations show that the long life span and high fecundity of sturgeon mean that a relatively few mature fish (a few percent of the fishable population) may support the fishery. The results suggest that 35% annual exploitation rates for fish older than 12 years are not unrealistic under the current six-foot (182.9 cm) maximum legal size limit (6FSL). Without the 6FSL, sustainable exploitation rates varied between 9% and 25% depending on the assumed levels of gear size-selection for fish larger than 182.9 cm. Gear size-selection estimates suggest that these large fish have high catchability in comparison to smaller fish. The 6SFL is important in maintaining a commercially exploitable population.

INTRODUCTION

The anadromous white sturgeon, *Acipenser transmontanus,* is intensively fished in the Columbia River basin. It is a native species known to reach weights of up to 680 kg (Galbreath 1979). White sturgeon are long lived, commonly exceeding 40 years of age. Reproductive maturity usually occurs at sizes between 167.6 - 182.9 cm.

The Columbia River white sturgeon were first heavily fished at the turn of the century. After a decade of high catches, the fishery collapsed and only began recovery in the 1970s (Galbreath 1985). Recent regulations have consisted of area closures near hydroelectric dams, seasonal closures, and a 91.4 - 182.9 cm legal size range. Over the years, upriver stocks have become isolated behind numerous dams. Compared to fish with ocean access, landlocked sturgeon tend to grow more slowly (Galbreath 1979; Malm 1981) and are exposed to high levels of industrial and agricultural toxins (Bosley and Gately 1981). In addition, changes in seasonal discharge patterns due to hydropower development may cause pathology in sturgeon gonads (Khoroshko 1972) and important changes in sturgeon behavior.

The sturgeon stocks of concern in this study are those between the Bonneville and McNary dams of the Columbia River, an area also known as Zone 6 (Figure 1). These stocks support a large tribal commercial fishery and a nontribal sport fishery. In

contrast to the stock below Bonneville Dam, which is not landlocked, these stocks are exposed to fishing year-round. After low catches for many years, annual landings increased tenfold between 1980 and 1987 to a total catch of about 16,000 fish. Rapid expansion of the fishery, declining catch per unit of effort since 1985, and—more recently—depressed catches have concerned management agencies. In an effort to reduce exploitation rates, tribal commercial seasons have been shortened and the sport fishery's minimum size limit was increased from 91.4 cm to 101.6 cm.

Little is known about sturgeon biology, sustainable exploitation rates, potential yields, or long-term effects of different management options for sturgeon (Galbreath 1985). Of particular concern have been questions raised by fishermen about the need for the six-foot (182.9 cm) size limit (6FSL) currently used for brood-stock protection (King 1987).

In this report, a previously developed model (Fox 1973) was modified and used to: 1) estimate equilibrium exploitation rates (EERs) for sturgeon; 2) determine the sensitivity of sturgeon EERs to uncertainty in several life history parameters; and 3) evaluate the importance of the 6FSL.

METHODS

Simulation Model

The simulation model used was the Generalized Exploited Population Simulator (GXPOPS) of Fox (1973), as modified by Restrepo et al. (1986). The model is a single-stock, multi-age-class model with options for growth and recruitment curves and for the simulation of catch histories. The model was further modified to compute yield separately for multiple fisheries and to allow age-specific selection factors.

EERs were defined as the rates of exploitation that maintain the population at constant size and that were simply a function of the mortality, growth, and fecundity schedules chosen. The model assumed no density dependence. It was also assumed that the parameter estimates used were derived from populations well below carrying capacity.

In the model, the number of age-0 recruits (i.e., eggs) at the end of simulation month j ($R_{0,j}$) was calculated as:

$$R_{0,j} = \sum_{i=m}^{\lambda} (FF) Fec_i N_{i,j}$$

where FF is the fraction of mature females in the adult population; Fec_i is the fecundity of females of age i; $N_{i,j}$ is the population size of age i fish at the beginning of month j; m is the age of maturation; and λ is the assumed maximum age for sturgeon. Recruitment was set to occur once per simulation year.

The population was subsequently decremented monthly by a natural and a fishing mortality schedule. The population size of a given set of recruits i at month j+1 was expressed as:

$$N_{i,j+1} = N_{i,j} e^{-Z_{i,j}}$$

with

$$Z_{i,j} = M_{i,j} + \sum_{k=1}^{nf} F_{i,j,k} S_{i,j,k} (FMULT)$$

where $M_{i,j}$ is the instantaneous monthly natural mortality rate; nf is the number of fisheries; $F_{i,j,k}$ is the input instantaneous monthly fishing mortality rate for fishery k; $S_{i,j,k}$ is a selectivity coefficient for fishery k; and FMULT is a scalar multiplier of all input values of $F_{i,j,k}$. FMULT simply allows for easy changes of the level of fishing mortality without having to enter a new fishing mortality matrix. Annual yield in numbers by fishery k (Y_k) was calculated as:

$$Y_k = \sum_{i=1}^{\lambda} \sum_{j=1}^{12} F_{i,j,k} S_{i,j,k} N_{i,j} (1 - e^{-Z_{i,j}}) Z^{-1}$$

Exploitation rates were expressed as the fraction of the population, age 12 and older, that was harvested by the end of each year.

Parameter Estimates

Maximum Age

The oldest fish ever taken from Zone 6 was an 82-year-old fish of 350.5-cm total length (Galbreath 1979). For sensitivity analysis, we assumed a middle value of 80 years for the maximum life span, with lower and upper bounds of 70 and 90 years, respectively.

Natural Mortality

Natural mortality estimates reported for white sturgeon ages 4 --30 (Semakula and Larkin 1968; Kohlhorst 1980; Cochnauer 1983) were expressed as annual instantaneous rates (Figure 2). The estimates are not strictly natural mortality but may represent "non-catch" mortality, including catch-release mortality for non-legal fish.

In sturgeon, as in most fishes, natural mortality appears to be lowest for adult fish (Cochnauer 1983). For white sturgeon over 15 years of age, natural mortality is about 5% per year. For fish age 16 and older, a natural mortality rate range of 5 ± 2.5% was assumed.

For fish between 4 and 15 years of age (mid-age fish), available mortality estimates are more divergent and range as high as 27% per year (Cochnauer 1983).

For sensitivity analysis, the lower, middle, and upper values chosen were 6%, 16.5%, and 27%, respectively.

Juvenile sturgeon mortality estimates were not available for fish ages 1 - 3 years. However, losses before hatching may be as high as 73% (Khoroshko 1972). Considering other likely sources of mortality for young fish, it was assumed that 73% egg loss at spawning also represents the minimum mortality for the first year. The middle value of mortality in the first year was then arbitrarily chosen as twice the instantaneous rate of egg loss at spawning ($1 - 0.27^2 = 92.71\%$), while the upper value was 3 times egg loss at spawning ($1 - 0.27^3 = 98.03\%$). For ages 2 and 3, values were obtained by linear interpolation from the chosen 1-year-old annual instantaneous mortality level to the corresponding 4-year-old mortality level.

While juvenile mortality estimates were admittedly arbitrarily chosen, the resultant mortality schedules probably represent meaningful ranges of uncertainty regarding mortality. The lower extreme for natural mortality corresponds to 2.5% survival to maturity, while the upper extreme corresponds to 0.000276%. The middle schedule used corresponds to a 0.0295% survival to maturity.

Lower, middle and upper mortality schedules for juveniles, mid-age, and old fish were combined to give three main mortality schedules (lower, middle, and upper schedules) for simulation (Figure 3). For use in the model, which has a monthly time step, these rates were assumed to be divided evenly across months.

Growth

Data on growth of large sturgeon are scarce; however, it appears that sturgeon growth is asymptotic (Semakula and Larkin 1968; Coon et al. 1977). For these simulations a von Bertalanffy growth curve was fit to data collected by Malm (1981) for the Bonneville-pool stock of Zone 6 (Figure 4) using a nonlinear fitting routine (Saila et al. 1988). An average fork length of 361 cm is predicted at the age of 80 years using Malm's (1981) data set. This corresponds closely to the largest fish recorded for the populations of interest (Galbreath 1979). No lower and upper bounds were specified for growth parameters.

Annual Egg Production

It is well established that in the Columbia River, few white sturgeon mature at sizes less than 167.6 cm long. Average size of maturation likely ranges between

167.6 cm and 182.9 cm (King 1987) and was set at 173.7 cm for simulation. This corresponds to an age of 23 years. For sensitivity analysis, upper and lower ages of maturation were 25 years (185.8 cm) and 22 years (167.7 cm), respectively.

Fecundity at size data were obtained from the Washington Department of Fisheries (G. Kreitman, Washington Department of Fisheries, personal communication 1988). An exponential curve was fit to the data using a non-linear routine (Saila et al. 1988). The length-fecundity curve (Figure 5) and the von Bertalanffy length-age curve together defined fecundity at age for simulation.

Limited sampling suggests that larger fish are more often female, but a sex ratio of 1:1 was assumed for these simulations. Intervals between spawning in white sturgeon may lie between 4 (Roussow 1957) and 10 years (Cochnauer 1983). These values were chosen as the respective lower and upper extremes. A seven-year interval was assumed as the middle and most likely value. Fecundity was divided by the interval between spawning to give annual average egg production per female. No lower or upper bounds were specified for either fecundity or sex ratio.

Size At Age Specific Fishery Impacts

Catch size-structure was used to estimate size at age specific impacts (i.e., relative size selection) in the current fisheries. Catch data from the years 1981-1987 (King and Kreitman 1987) indicate that the sport fishery takes largely the younger and more abundant 91.4 - 121.9 cm fish, while the tribal commercial catch is predominantly 121.9 - 152.4 cm fish (Figure 6).

Limited sampling from 1981 to 1986 suggests an annual sport catch of about 5,000, with no established trend over time (King 1987). In contrast, tribal commercial landings increased from about 1,500 annually in the early 1980s to 11,100 in 1987. Catch size-structure and relative fishery catches were combined to yield two simulation scenarios. For the "mid-1980s" type fishery, where tribal catch was greatest, the sport/tribal catch ratio was set at 1:2.2. Fish 121.9 - 152.4 cm predominated because of the greater magnitude of the tribal commercial fishery (Figure 7). For the reconstructed "early 1980s"-type fishery, the corresponding catch ratio was set at 5:1.5, and 91.4 - 121.9 cm fish predominated because of the greater relative catch of the sport fishery (Figure 7).

Simulations

It was assumed that the lower and upper bounds chosen for each parameter approximated the range of likely values. In the simulations done for each parameter set specified, FMULT was varied until the equilibrium F for constant population size (change $\leq$ 1%/100 years) was found. This was then translated into an EER estimate for the parameter set.

The 91.4 cm lower legal limit was simulated by having recruitment to the fishery occur at the beginning of the 12^{th} year of age (fork length = 89.2 cm by the growth curve used). The 6FSL was simulated by terminating availability to the fishery at the end of the 24^{th} year of age (fork length = 188.7 cm).

EERs were estimated both with and without the 6FSL for the three main mortality schedules (lower, middle, and upper schedules, respectively). Sensitivity was then examined for selected portions of the overall mortality schedule, assuming all other parameters at midpoint values. Sensitivity to spawning frequency, age of maturation, and maximum age were also examined.

All of the above simulations were done assuming a selection factor of 1 (i.e., equal combined-fishery size at age selection). Availability of catch size-structure data, however, allowed estimation of age and fishery-specific selection factors. Input size-specific F-values were always constant for the three size-classes. Then, age-specific selection factors (S_i) were input, and FMULT for the combined fishery was varied until the simulated population reached equilibrium. The parameters S_i and FMULT were varied iteratively until equilibrium conditions yielded a catch size-structure approximating the observed structure.

Once age-specific selection factors were determined, EERs, assuming size selection in the combined fishery, were compared to the values that assumed no size selection. No estimates of age or fishery selection could be determined for fish larger than 182.9 cm, because of the lack of corresponding catch size-structure data under the current 6FSL. For simulations without the 6FSL, selection for all fish above the 6FSL was assumed to be equal to that of fish in the 152.4 - 182.9 cm range. In order to express the resulting age-specific selection factors separately for both the sport and commercial fisheries, the selection factors were scaled by the observed fishery-specific catches.

RESULTS

EERs were very sensitive to changes in the overall mortality schedule. Under the low, middle, and high mortality schedules, EERs with the 6FSL were, respectively, 57%, 35%, and 6% annual removal of fish age 12 and older (Table 1). Without the 6FSL, EERs were, respectively, 1/2, 1/4, and 1/6 lower. Under both the low and middle mortality schedules, brood fish (ages 23-80) represented a very small fraction (less than 2%) of the fishable population (Table 2). The 6FSL thus served to protect a small but very productive segment of the population.

Sensitivity of EER was greatest for the specified range of juvenile mortality. Leaving all other parameters at midpoint values while varying only juvenile mortality, lower and upper EER bounds differed by 27% (Table 3). EER was next most sensitive to the assumed range of natural mortality for ages 4 - 15 years, differing by less than 16% between lower and upper bounds. It was least sensitive to the assumed range in natural mortality for fishes older than 15, differing by less than 6% between lower and upper bounds. EER was also surprisingly insensitive to assumed ranges of uncertainty in spawning frequency, the age of maturation, and maximum life span, differing no more than 4% between lower and upper bounds for each of these parameters.

Estimates of age-specific impacts suggest that for both fisheries, large fish are preferentially targeted (Table 4). Catch size-structure simulated with the estimated selection factors closely mimicked observed catch size-structure for the combined Zone 6 fisheries (Table 5). While 121.9 - 152.4 cm fish may predominate in the catch (mid-1980s scenario), the 152.4 - 182.9 cm fish experience fishing mortality rates 3.5 - 4 times higher (Table 4). Also, in recent years older fish (within the legal size range) have been harvested at a higher rate than in the early 1980s (Table 4).

EERs, assuming size selection, were very similar to those assuming no size selection in cases with the 6FSL (Table 6). In contrast, without the 6FSL, EERs were greatly reduced by assuming high selection for large fish. Under the early 1980s selectivity scenario, EER was 20%, instead of the 25% obtained when assuming no size selection. Under the mid-1980s scenario, where the selectivity contrast between small and large fish was highest, EER was only 9%.

DISCUSSION

Fisheries are typically managed for some variant of maximum sustainable yield (MSY). With no information on Zone 6 carrying capacity and population sizes, estimation of MSY for Zone 6 was not possible. MSY-based models are inappropriate for managing potentially depleted populations, because of the assumption of equilibrium (Prager et al. 1987). In most management cases, yield-per-recruit analysis is insufficient since it does not account for effects of harvest on population egg production. In this report, we instead estimated EERs. These represent the exploitation rates needed to maintain a stock at existing levels given what is known about mortality and egg production by the population. This approach provides a tool with which to evaluate long-term effects of different management actions.

Sensitivity analysis was done for parameters that are either difficult or expensive to estimate, or for which multiple estimates defined a range of current uncertainty. EER estimates for sturgeon were found to depend critically on the assumed overall rates of natural mortality. It was not possible to narrowly define EERs, because of the great degree of uncertainty in mortality rates. However, the middle mortality schedule used suggests that 35% annual exploitation may not be unrealistic. Without the 6FSL, EERs may differ between 9% and 25% depending on assumed selection factor for fish above the 6FSL. The results suggest that high fecundity and long life spans in adult sturgeon can translate into high levels of stock productivity.

Egg-to-juvenile survival rates (from egg to age 4 in these simulations) are important determinants of stock productivity. Great uncertainty as to the magnitude of these rates are a major obstacle to determining long-term sustainable exploitation rates for sturgeon. Narrowing the uncertainty to within a factor of 10 would constitute a major improvement. While egg-to-juvenile survival estimates for marine species are especially hard to obtain, they may be easier to obtain for Zone 6 sturgeon because of the confined nature of the populations. The stocks of interest are practically closed populations. In conjunction with juvenile population size, associated estimates of egg production could provide the data to derive egg-to-juvenile survival estimates. Egg production of the sturgeon population could be estimated if research is directed to determine sex ratios, spawning frequencies, fecundities, and population size of mature fish. This approach could also yield useful mortality estimates.

Sensitivity analysis was not done for growth parameters, sex ratio or fecundity. With current ongoing studies, well-defined growth rates, and fecundity and sex ratios should soon be available for the sturgeon of interest. Errors in growth parameters may

affect the estimated EERs by altering the fecundity schedule and the fraction of brood stock harvested. However, the simulations for spawning frequency varied annual population egg production by a factor of 2.5 and had little effect on EERs. Therefore, equivalent variation in fecundity or sex ratio will yield similar results.

For sport and commercial fisheries, the simulations suggested high selection for large fish in the legal size range. The estimated selection factors are based on observed catch size-structure and assume equilibrium conditions. However, increasing catches from Zone 6 since the mid-1970s make it unlikely that the population has been at equilibrium. Observed catch size-structure data likely contained a higher fraction of juvenile fish than under equilibrium conditions, causing underestimation of actual size selection.

The catch size-structure data shows that the commercial fishery targets large fish at a higher rate than the sport fishery. A recent shift in combined fishery at age specific impact toward older fish is due to the increasing catch of the commercial fishery. However, simulations showed that because of the current 6FSL, this shift can be expected to have little effect on actual EERs.

EER estimates assuming size selection were very similar to those assuming no size selection in cases with the 6FSL. This is because fishing occurs primarily on an immature component of the population. Neither the age structure of the mature fish nor the number of annually resulting recruits are substantially effected by the selection pattern of the fisheries. In contrast, EERs without the 6FSL were greatly reduced by assuming high selection for large fish.

In conclusion, these simulations suggest several benefits to maintaining a 6FSL. Long life span and high fecundity of the sturgeon is such that a relatively small number of brood fish may support a major fishery. Conversely, harvest of a few large fish could translate into heavy overexploitation. Without the 6FSL, fish larger than 182.9 cm would be targeted both by the commercial and sport fisheries because of their caviar, food, and trophy value. High selection for large fish could easily decimate the brood stock of the small, landlocked populations and drastically reduce sustainable exploitation rates. Current uncertainty regarding sustainable exploitation rates also means that it may be possible to "accidentally" overharvest the species, in which case recovery of the stocks could take decades. Protecting brood stock by means of the 6FSL will reduce the possibility of overfishing and provide greater stock resilience should overfishing occur.

Table 1. White sturgeon equilibrium exploitation rates for the three main mortality schedules assuming all other parameters at midpoint values.

	6FSL	No 6FSL
Low Mortality	56.8%	46.9%
Middle Mortality	35.2%	25.3%
High Mortality	5.5%	3.3%

Table 2. White sturgeon equilibrium population age structure under the three main mortality schedules.

	6FSL	No 6FSL
Low Mortality Schedule		
% of Population		
Age 12-24	99.98%	99.98%
Age 25-40	0.01%	0.02%
Age 41-80	0.01%	0.00%
Brood Fish[a]	0.02%	0.05%
Middle Mortality Schedule		
% of Population		
Age 12-24	99.47%	99.40%
Age 25-40	0.31%	0.60%
Age 41-80	0.22%	0.00%
Brood Fish[a]	0.66%	1.26%
High Mortality Schedule		
% of Population		
Age 12-24	83.82%	83.30%
Age 25-40	11.69%	14.06%
Age 41-80	4.48%	2.64%
Brood Fish[a]	19.3%	21.0%

a. Brood fish constitute all fish (male and female) ages 23-80.

Table 3 Sensitivity analysis of equilibrium exploitation rates for white sturgeon. The exploitation rate ranges shown were obtained by varying each parameter between its lower and upper bound while maintaining all other parameters at mid-point values. Average differences shown are between lower and upper equilibrium rates.

	Juvenile M	Age 4-15 M	Age 16-80 M	Spawn Freq.	Age Mature	Max. Age
6FSL	22.1% - 48.4%	28.2% - 43.6%	32.8% - 41.0%	34.8% - 39.2%	36.1% - 37.1%	36.1% - 36.9%
No 6FSL	12.2% - 39.5%	17.5% - 33.6%	24.7% - 27.5%	24.2% - 26.1%	23.6% - 27.6%	25.8% - 26.5%
Average Difference	26.8%	15.7%	5.5%	3.2%	2.5%	0.8%

Table 4. Estimates of relative size selection factors for sport and commercial Zone 6 white sturgeon fisheries under two scenarios. Size-classes 1, 2, and 3 are 91.4 - 121.9 cm, 121.9 - 152.4 cm, and 152.4 - 182.9 cm, respectively.

	Mid-1980s Scenario			Early 1980s Scenario		
	1	2	3	1	2	3
Relative Size-Class Selection Factors:						
Sport	0.111	0.136	0.695	0.446	0.535	2.572
Commercial	0.036	0.864	2.834	0.020	0.465	1.428
Total	0.147	1.000	3.529	0.466	1.000	4.000

Table 5. Observed and simulated white sturgeon equilibrium catch size-structure for combined Zone 6 sturgeon fisheries under two scenarios. Size-classes 1, 2, and 3 are 91.4 - 121.9 cm, 121.9 - 152.4 cm, and 152.4 - 182.9 cm, respectively.

	Mid-1980s Scenario			Early 1980s Scenario		
	1	2	3	1	2	3
Observed Catch Distribution:	27.5%	60.5%	11.9%	53.3%	37.7%	9.0%
Simulated Catch Distribution:	26.2%	61.6%	12.2%	54.4%	36.0%	9.6%

Table 6. Estimates of white sturgeon equilibrium exploitation rates for three selectivity scenarios, assuming all other parameters at midpoint values.

	6FSL	No 6FSL
No Size Selection	35.2%	25.3%
Mid-1980s Selection	35.9%	8.8%
Early 1980s Selection	35.8%	20.0%

Figure 1. Map of the Columbia River and the Zone 6 management area.

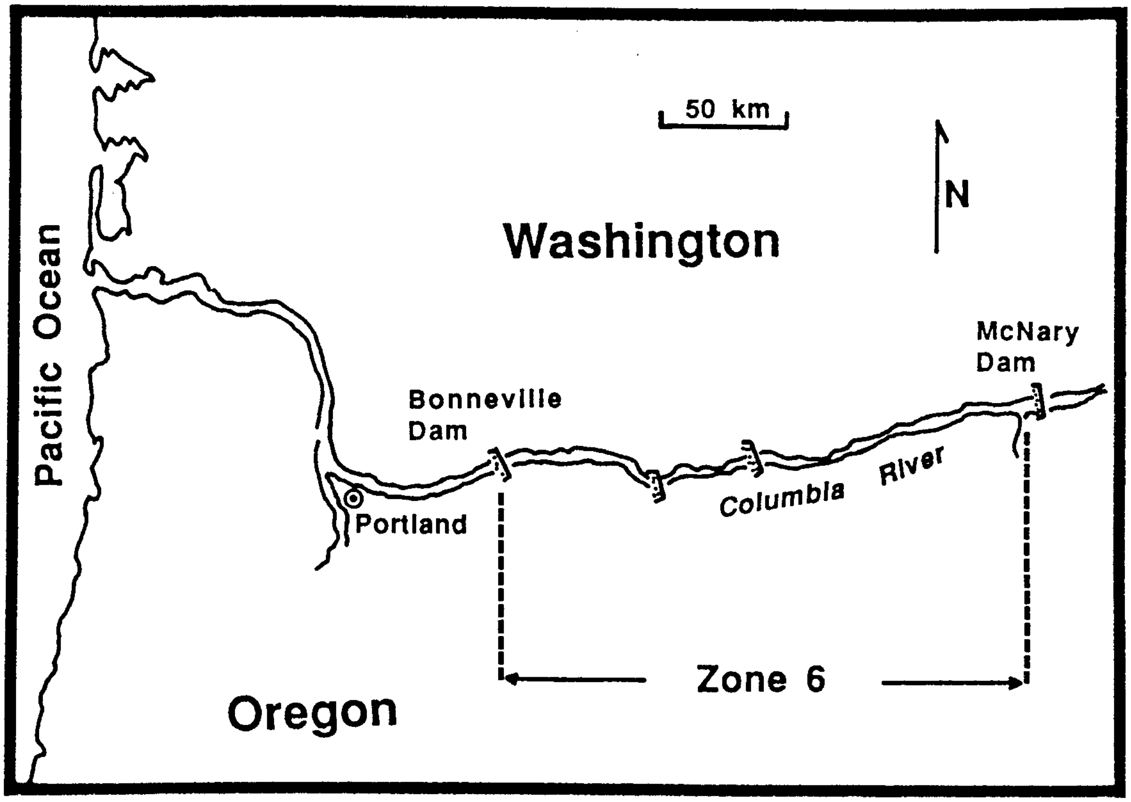


Figure 2. Annual instantaneous rate estimates of natural mortality for white sturgeon.

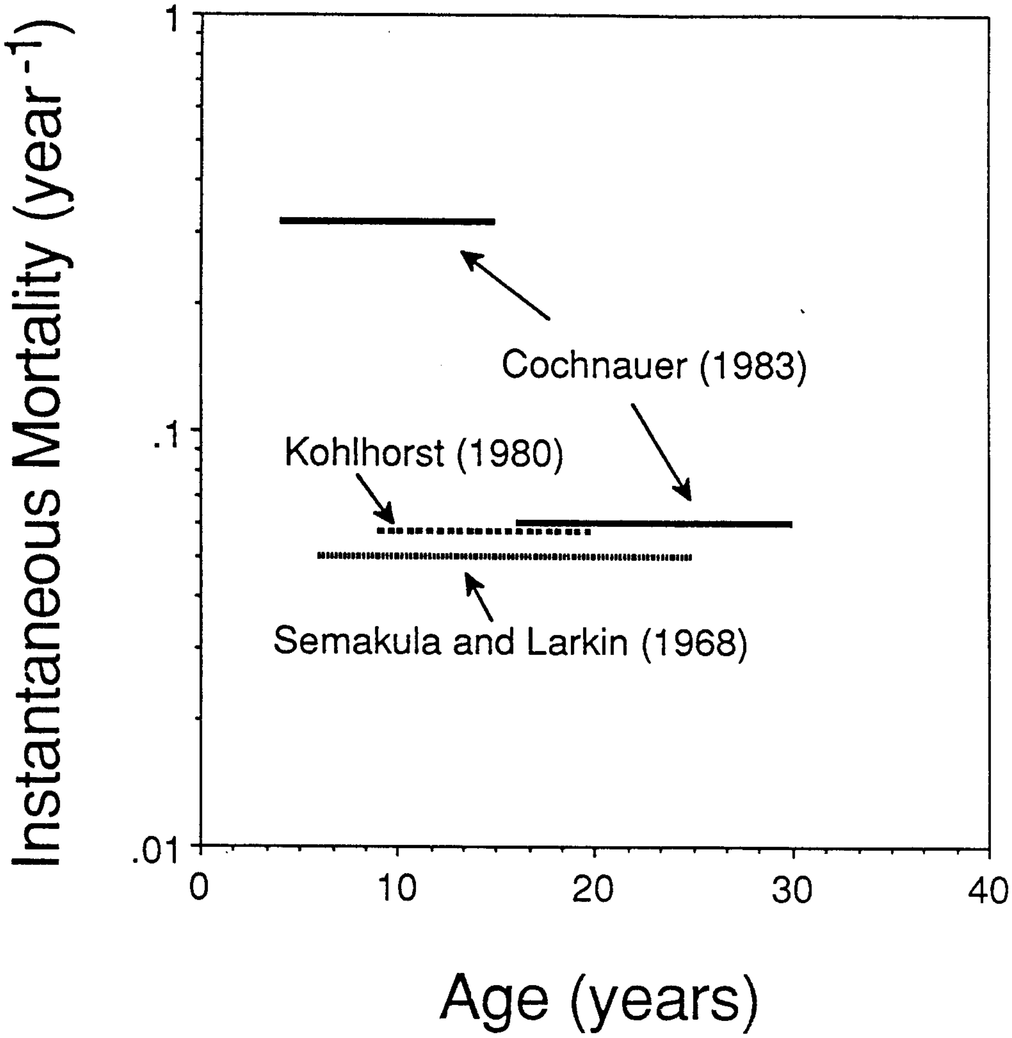


Figure 3. Annual instantaneous mortality schedules used for white sturgeon simulations.

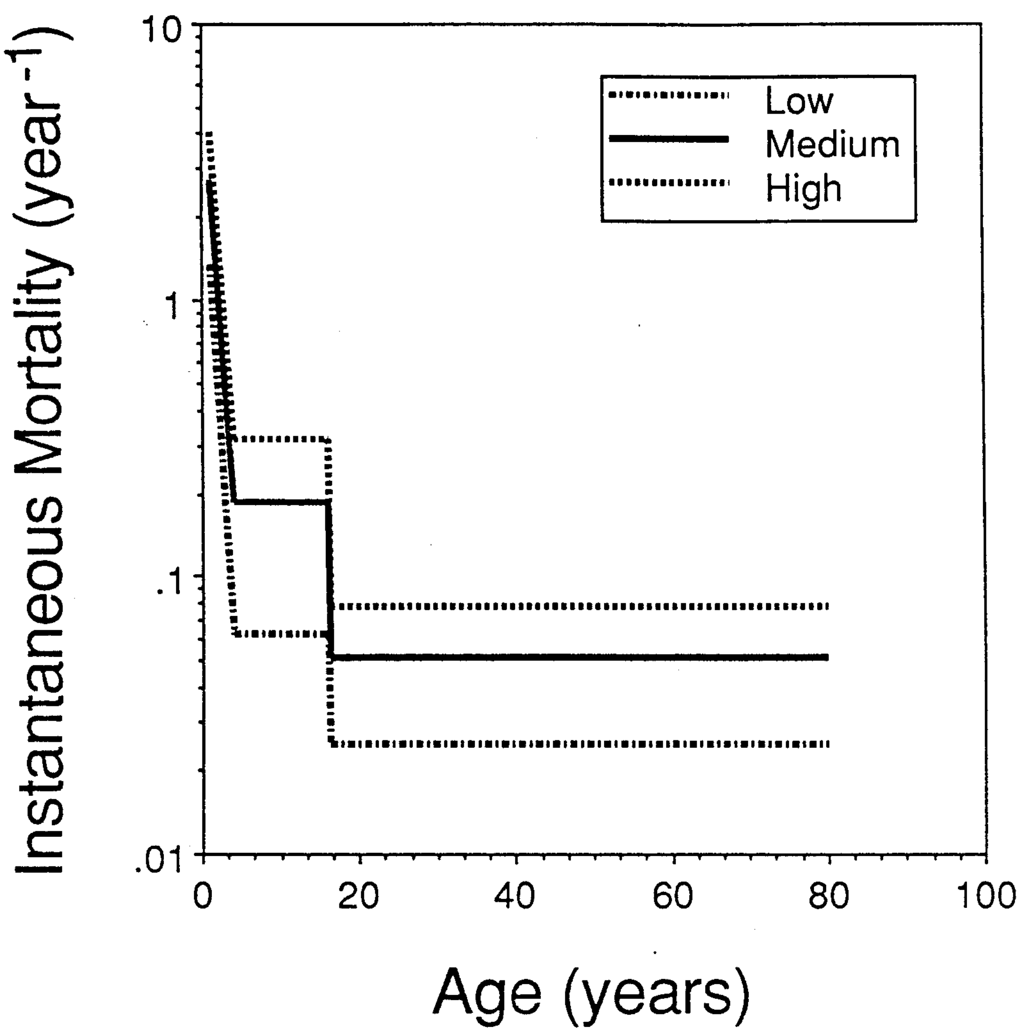


Figure 4. Von Bertalanffy growth curve fit to length-at-age data for white sturgeon from the Bonneville pool of the Columbia River. Data from Malm (1981).

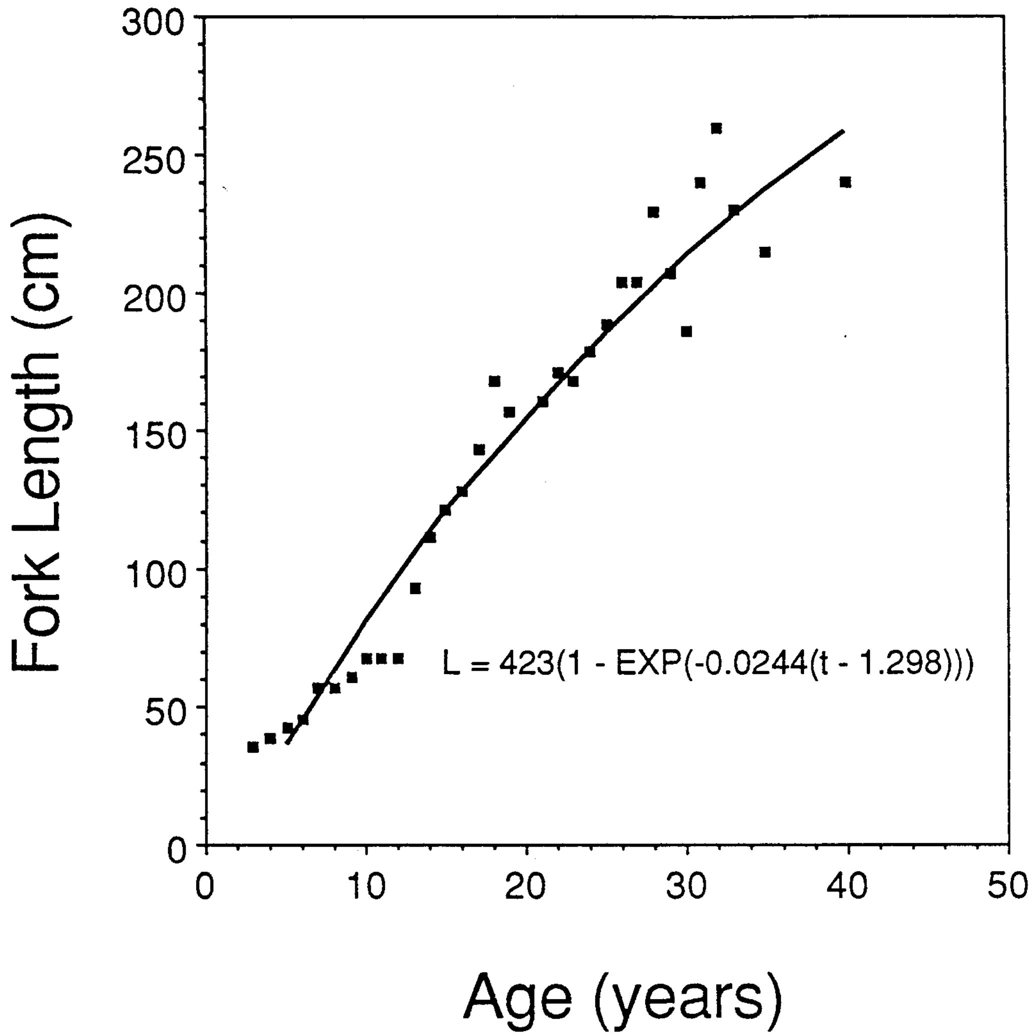


Figure 5. A length-fecundity curve fit to Columbia River white sturgeon fecundity-at-length data (Washington Department of Fisheries, unpublished data).

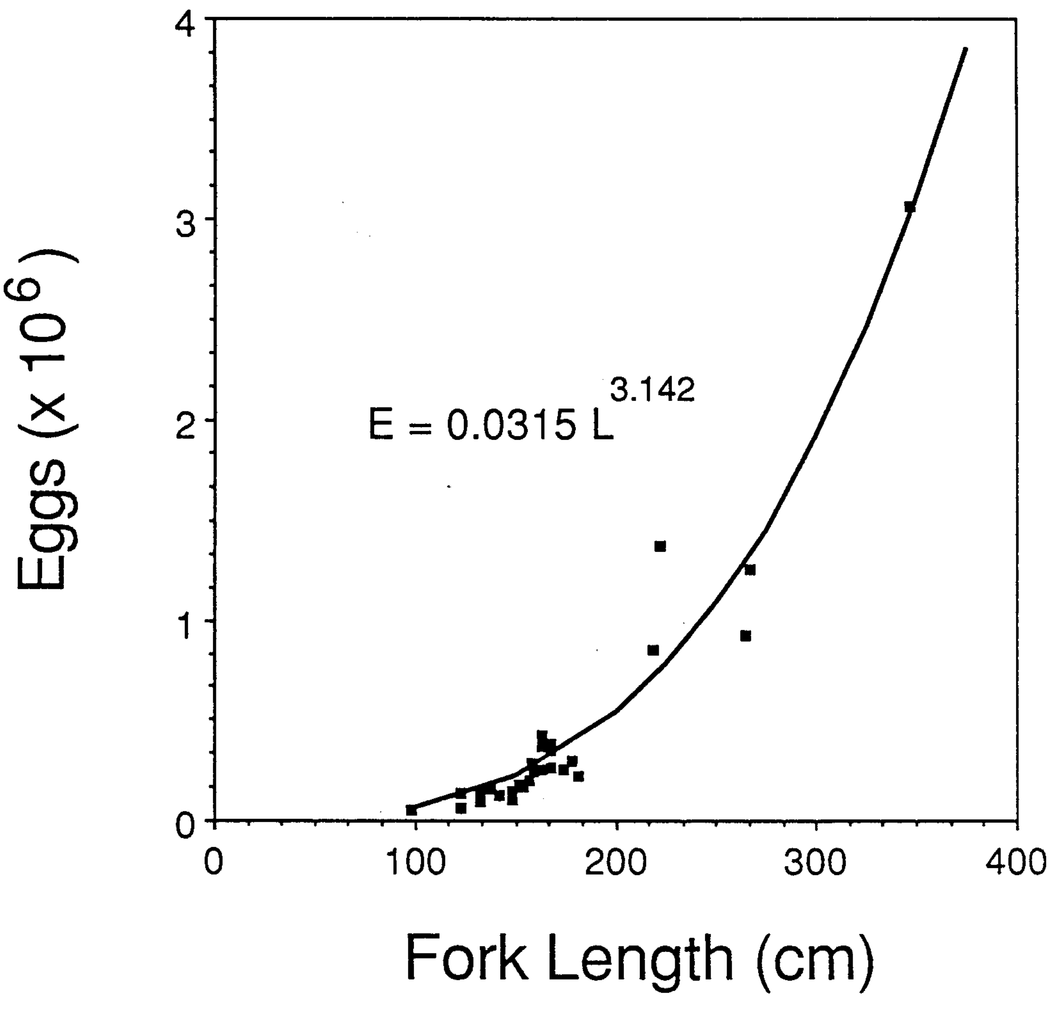


Figure 6. White sturgeon catch size-structure for the Columbia River Zone 6 fisheries. Data from King and Kreitman (1987).

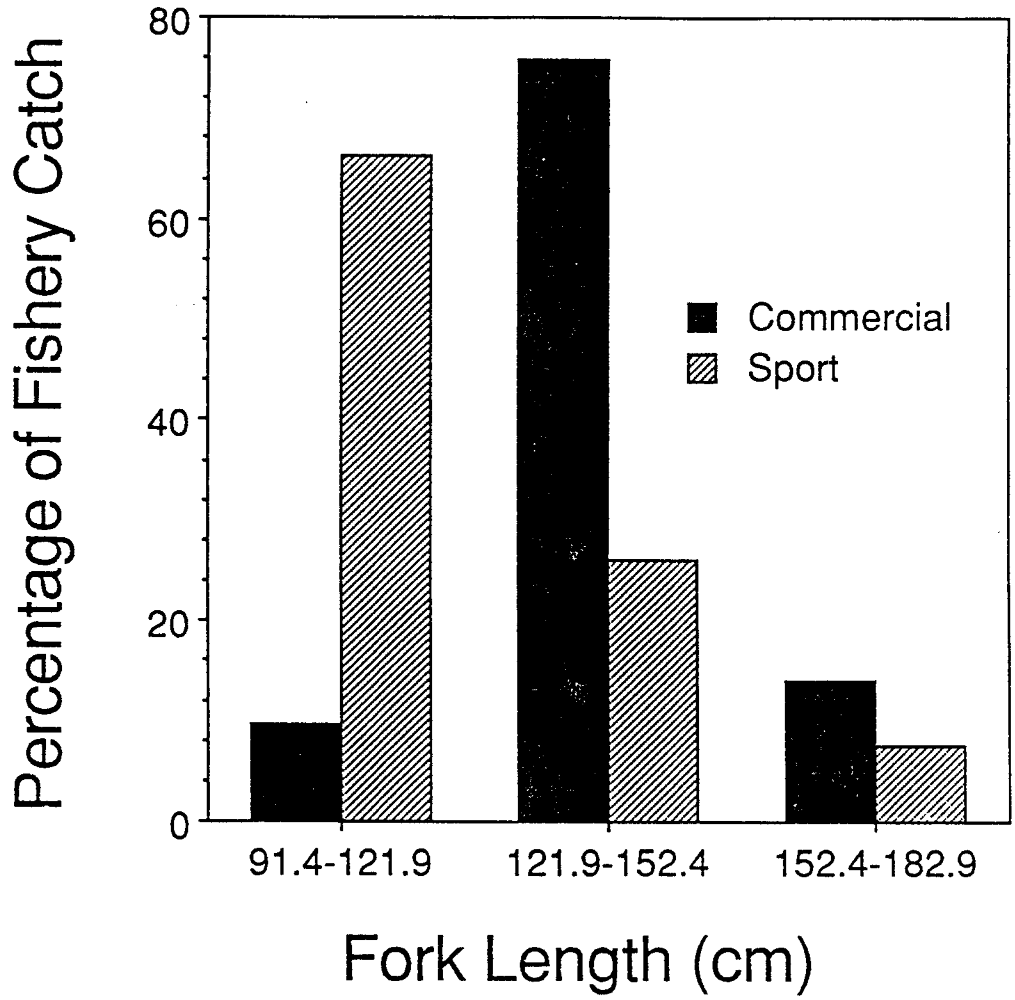
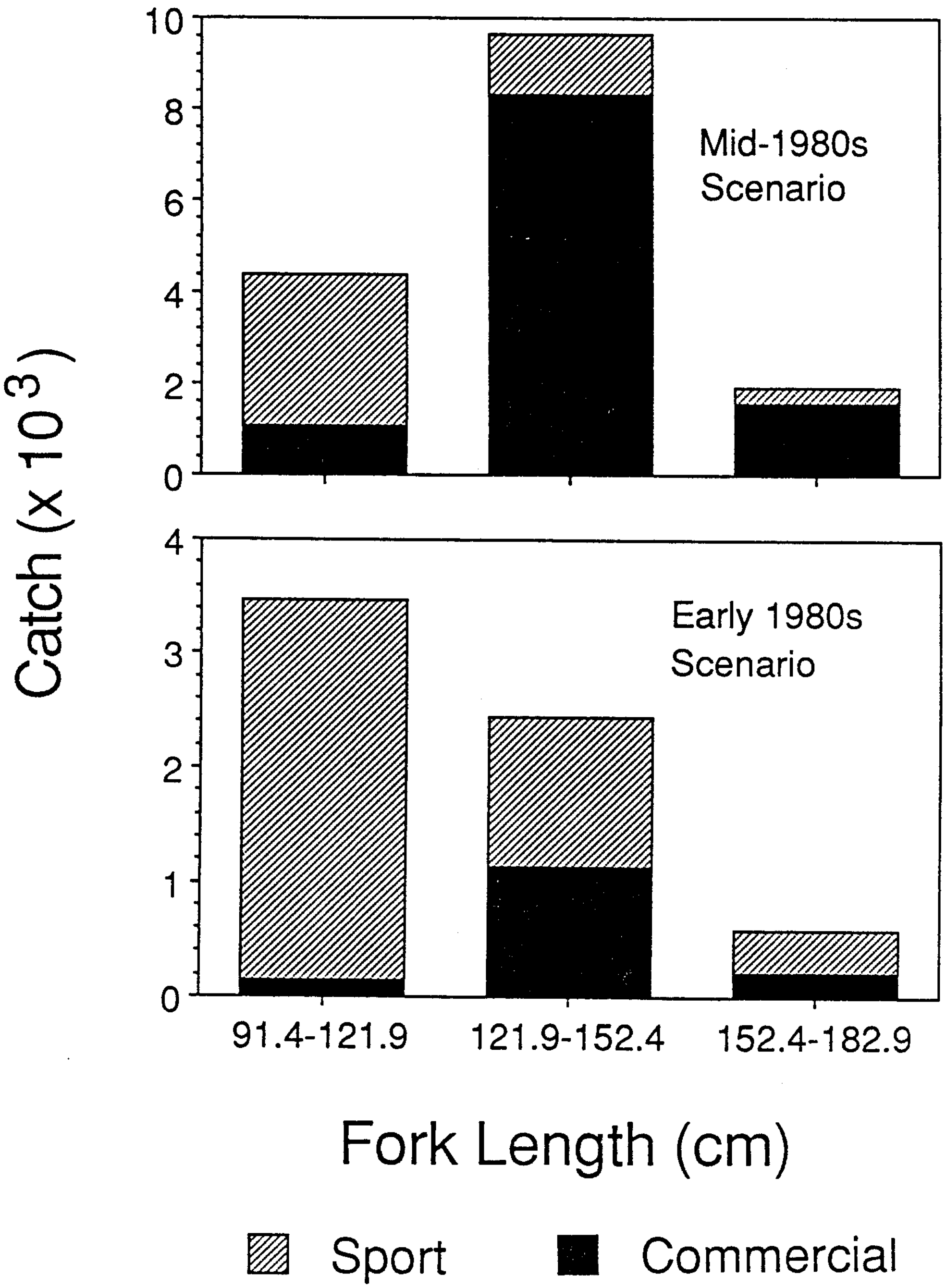


Figure 7. White sturgeon catches for the Columbia River Zone 6 fisheries for the early and mid-1980s scenarios.



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APPENDIX A: Model Program in Quick Basic Code

```
'REM GXPOPX IN QUICK BASIC
'Version AUG. 25, 1988, modified by Al Debrot.
'Program translated into MicroSoft Quick Basic Version 4.0.
'Also changed to separately accumulate yields for up to 5
'fisheries.
'................................input
PRINT
FILES "*.DAT"
INPUT "ENTER INPUTNAME (LEAVE OFF .DAT EXTENSION)", Filename$
Filename$ = Filename$ + ".DAT"
OPEN Filename$ FOR INPUT AS #1
INPUT #1, TITLE$
INPUT #1, SFR
INPUT #1, NY, ABREV, LI, LF, GRO, NRE, NFMT, NPCF
INPUT #1, NYC, MFR, MSB, MSE, MY, XKC, PCF, A1, A2, NUMF
INPUT #1, MAA, MBB, MCC, MDD, MEE

INPUT #1, A11, A21, A22, A23, A33
INPUT #1, B21, B22, B23

INPUT #1, F11, F22, F33
INPUT #1, G11, G22, G33

REM $DYNAMIC
DIM P(NYC + 1, 12), XM(NYC, 12)
DIM A(NUMF, NYC, 12), F(NUMF, NYC, 12)
DIM AN(NYC, 12), LNG(NYC * 12 + 1)
DIM YN(NUMF, NYC, 12), XOMEG(4), YW(NUMF, NYC, 12), W(NYC * 12 + 1), FM(NYC), FMF(NYC),
E(NYC)
DIM AYWI(NUMF, NYC), BYWI(NUMF, NYC), CYWI(NUMF, NYC)
DIM AYNI(NUMF, NYC), BYNI(NUMF, NYC), CYNI(NUMF, NYC)
DIM AFPJ(NUMF, 12), BFPJ(NUMF, 12), CFPJ(NUMF, 12), AFANJ(NUMF, 12), BFANJ(NUMF, 12),
CFANJ(NUMF, 12)
DIM APJ(12), BPJ(12), CPJ(12), AANJ(12), BANJ(12), CANJ(12)
DIM BANI(NYC), CANI(NYC),AANI(NYC),AFANI(NYC),BFANI(NYC),CFANI(NYC)
DIM AYWJ(NUMF, 12), BYWJ(NUMF, 12), CYWJ(NUMF, 12), AYNJ(NUMF, 12), BYNJ(NUMF, 12),
CYNJ(NUMF, 12)
DIM FMULT(NFMT), FT(NUMF, NYC, 12), ZLY(NYC), SXR(12)
DIM FTX(NYC, 12), FTI(NYC, 12), FTZ(NYC, 12), FXM(NYC, 12)
DIM AFANA(NUMF), BFANA(NUMF), CFANA(NUMF)
DIM FORM$(10)
DIM AYWA(NUMF), BYWA(NUMF), CYWA(NUMF), AYNA(NUMF), BYNA(NUMF), CYNA(NUMF)
DIM BP AS INTEGER
DIM DP AS INTEGER
FORM$(1) = "####.######"
FORM$(2) = "########.######"
FORM$(3) = "###"
FORM$(4) = "####"
FORM$(5) = "##########"
FORM$(6) = "######"
FORM$(7) = "#######.####"
```

```
FORM$(8) = "#.####^^^^"
CLS
PRINT
PRINT
PRINT
PRINT " PROGRAM GXPOPS"
PRINT "Compiled in:"
PRINT " Microsoft (R) Quick BASIC Version 4.0"
PRINT

'............ input starting population size
FOR I = 1 TO NYC
  INPUT #1, P(I, 1)
NEXT I

'.............calc natural mortality

  FOR J = 1 TO 12
    XM(1, J) = MAA / 11
    XM(2, J) = MBB / 12
    XM(3, J) = MCC / 12
  NEXT J

FOR I = 4 TO 15
FOR J = 1 TO 12
    XM(I, J) = MDD / 12
  NEXT J
NEXT I

FOR I = 16 TO NYC
  FOR J = 1 TO 12
    XM(I, J) = MEE / 12
  NEXT J
NEXT I

'...............fill availability matrix

FOR L = 1 TO NUMF
FOR I = 1 TO 11
  FOR J = 1 TO 12
    A(L, I, J) = A11
  NEXT J
NEXT I
NEXT L

    FOR L = 1 TO NUMF
FOR I = 12 TO 15
  FOR J = 1 TO 12
    A(1, I, J) = A21
    A(2, I, J) = B21
  NEXT J
NEXT I
NEXT L
```

```
  FOR L = 1 TO NUMF
   FOR I = 16 TO 20
 FOR J = 1 TO 12
   A(1, I, J) = A22
   A(2, I, J) = B22
 NEXT J
NEXT I
NEXT L
  FOR L = 1 TO NUMF
FOR I = 21 TO 24
 FOR J = 1 TO 12
   A(1, I, J) = A23
   A(2, I, J) = B23
 NEXT J
NEXT I
NEXT L

FOR L = 1 TO NUMF
FOR I = 25 TO NYC
 FOR J = 1 TO 12
   A(L, I, J) = A33
 NEXT J
NEXT I
NEXT L

'................calc  fishing  mortality  matrix

FOR L = 1 TO NUMF
FOR I = 1 TO 11
 FOR J = 1 TO 12
   F(1, I, J) = F11 / 12
   F(2, I, J) = G11 / 12
 NEXT J
 NEXT I
 NEXT L

FOR L = 1 TO NUMF
FOR I = 12 TO 24
 FOR J = 1 TO 12
   F(1, I, J) = F22 / 12
   F(2, I, J) = G22 / 12
 NEXT J
 NEXT I
 NEXT L

FOR L = 1 TO NUMF
FOR I = 25 TO NYC
 FOR J = 1 TO 12
   F(1, I, J) = F33 / 12
   F(2, I, J) = G33 / 12
 NEXT J
 NEXT I
 NEXT L
```

```
'.........................NOT  INPUT................
FOR L = 1 TO NUMF
FOR I = 1 TO NYC
 FOR J = 1 TO 12
   FT(L, I, J) = F(L, I, J)
 NEXT J
NEXT I
NEXT L

'..............input  fmult  matrix
FOR I = 1 TO NFMT
INPUT #1, FMULT(I)
NEXT I

'......................NOT  DATA.............................

'.... egg  production

FOR I = 1 TO NYC
  E(I) = .0000315 * 1000 * (422.8 * (1 - EXP(-.0244 * ((I + .5) - 1.298)))) ^ 3.142
  E(I) = (1 / SFR) * E(I)
NEXT I

'..................input  mature  male  fraction
FOR I = 1 TO NYC
 FM(I) = .5
NEXT I


'................input  mature  female  fraction
FOR I = 1 TO NYC
 FMF(I) = .5
NEXT I

GRO = 1
IF GRO = 0 THEN
'.............input  von  Bertalanffy  parameters
 INPUT #1, WINF, XKV, T0
 XOMEG(1) = 1!
 XOMEG(2) = -3!
 XOMEG(3) = 3!
 XOMEG(4) = -1!
ELSE

 '.......................NOT  INPUT  DATA...................

 '.... weight  at  age

 NWT = 12 * NYC + 1
 FOR I = 1 TO NWT
 IF I < 17 THEN
 W(I) = 0
 ELSE
  LNG(I) = 422.8 * (1 - EXP(-.0244 * (((I) / 12 + (1 / 24)) - 1.298)))
```

```
 W(I) = .0000227 * .1 * (LNG(I)) ^ 3.277
 END IF
 NEXT I

END IF
CLOSE #1

'...........................output  input
CLS
PRINT
INPUT "ENTER OUTPUTNAME (LEAVE OFF .OUT EXTENSION)", Filename$
NameFile$ = Filename$ + ".OUT"
OPEN NameFile$ FOR OUTPUT AS #2
PRINT #2, SPC(45); TITLE$
PRINT #2,
PRINT #2, SPC(31); "PRODUCED BY THE GENERALIZED EXPLOITED POPULATION SIMULATOR"
PRINT #2,
PRINT #2, SPC(44); "PROGRAMMED BY WILLIAM W. FOX, JR."
PRINT #2,
PRINT #2, "NUMBER OF YEAR-CLASSES ="; USING FORM$(3); NYC
PRINT #2,
PRINT #2, "AGE (MO.) AT FIRST RECRUITMENT ="; USING FORM$(4); MFR
PRINT #2,
PRINT #2, "MONTH SPAWNING BEGINS ="; USING FORM$(3); MSB
PRINT #2,
PRINT #2, "MONTH SPAWNING ENDS ="; USING FORM$(3); MSE
PRINT #2,
PRINT #2, "YEAR OF FIRST MATURITY ="; USING FORM$(3); MY
PRINT #2,
PRINT #2, "RATE OF CONTACT ="; USING FORM$(2); XKC
PRINT #2,
PRINT #2, "RECRUITMENT REGULATION OPTION ="; USING FORM$(3); NRE
PRINT #2,
PRINT #2, "RECRUITMENT REGULATION PARAMETERS  A1 ="; USING FORM$(2); A1
PRINT #2, "      A2 ="; USING FORM$(2); A2
PRINT #2,
PRINT #2,
PRINT #2, " INITIAL POPULATION AGE STRUCTURE"
PRINT #2,

'............ print  starting  population  size
A = 0
FOR I = 1 TO NYC
A = A + 1
IF A < 6 THEN
  PRINT #2, P(I, 1);
 ELSE
  PRINT #2, P(I, 1)
  A = 0
  END IF
 NEXT I
PRINT #2,
PRINT #2, "  NATURAL MORTALITY MATRIX (TWO ROWS PER YEAR-CLASSES, COLS. = MO)"
PRINT #2,
```

```
'..............print  natural  mortality
A = 0

FOR I = 1 TO NYC
 FOR J = 1 TO 12
  A = A + 1
  IF A < 6 THEN
   PRINT #2, USING FORM$(1); XM(I, J);
  ELSE
   PRINT #2, USING FORM$(1); XM(I, J)
  A = 0
  END IF
 NEXT J
NEXT I

PRINT #2,
PRINT #2, "AVAILABILITY MATRIX (TWO ROWS PER YEAR-CLASSES, COLS. = MO.)"
PRINT #2,

'...............print  availability  matrix

A = 0
FOR L = 1 TO NUMF
PRINT #2,
FOR I = 1 TO NYC
 FOR J = 1 TO 12
 A = A + 1
 IF A < 6 THEN
  PRINT #2, USING FORM$(1); A(L, I, J);
 ELSE
  PRINT #2, USING FORM$(1); A(L, I, J)
  A = 0
 END IF
 NEXT J
NEXT I
NEXT L

PRINT #2,
PRINT #2, "FISHING MORTALITY MATRIX (2 ROWS PER YEAR-CLASSES, COLS.= MO.)"
PRINT #2,
'..............print  fishing  mortality  matrix
A = 0
FOR L = 1 TO NUMF
PRINT #2,
   FOR I = 1 TO NYC
    FOR J = 1 TO 12
   A = A + 1
   IF A < 6 THEN
    PRINT #2, USING FORM$(1); F(L, I, J);
   ELSE
    PRINT #2, USING FORM$(1); F(L, I, J)
   A = 0
   END IF
```

```
  NEXT J
  NEXT I
NEXT L

PRINT #2,
PRINT #2, " FISHING MORTALITY MULTIPLIERS"
PRINT #2,
'.................print fmult matrix
FOR I = 1 TO NFMT
  PRINT #2, USING FORM$(1); FMULT(I)
NEXT I

PRINT #2,
PRINT #2, " EGGS PER INDIVIDUAL"
PRINT #2,
'..................print egg production
FOR I = 1 TO NYC
  PRINT #2, I; SPC(5); USING FORM$(5); E(I)
NEXT I

PRINT #2,
PRINT #2, " MALE MATURITY FRACTION"
PRINT #2,
'.....................print mature male fraction
FOR I = 1 TO NYC
  PRINT #2, I; SPC(5); USING FORM$(1); FM(I)
NEXT I

PRINT #2,
PRINT #2, " FEMALE MATURITY FRACTION"
PRINT #2,
'.............print mature female fraction
FOR I = 1 TO NYC
  PRINT #2, I; SPC(5); USING FORM$(1); FMF(I)
NEXT I

IF GRO = 0 THEN
'.............print von Bertalanffy parameters

PRINT #2,
PRINT #2, "VON BERTALANFFY GROWTH FUNCTION PARAMETERS"

PRINT #2,
PRINT #2, "W(INF) ="; WINF, "K ="; XKV, "TO ="; T0
ELSE

PRINT #2,
PRINT #2, "WEIGHT AT BEGINNING OF MONTH"
 ' ...................print weight at age
 A = 0
 FOR I = 1 TO NWT
   A = A + 1
   IF A < 6 THEN
    PRINT #2, USING FORM$(2); W(I);
```

```
   ELSE
    PRINT #2, USING FORM$(2); W(I)
    A = 0
    END IF
  NEXT I
END IF

'..................converting  starting  pop  structure  end  of  1st
'...............month  to  structure  end  of  month  before  month  1
FOR I = 1 TO NYC
  FOR L = 1 TO NUMF
   FTI(I, 12) = FTI(I, 12) + A(L, I, 12) * F(L, I, 12)
   NEXT L
NEXT I

FOR I = 1 TO NYC
  P(I, 12) = P(I + 1, 1) * EXP(XM(I, 12) + FMULT(1) * FTI(I, 12))
NEXT I

MIS = 0
MYX=MY
NYCX=NYC

IF MSB + MSE - 2 > 0 THEN GOTO 46
  MYX = MY - 1
  NYCX = NYC - 1
  MIS = 1

'..................MAIN  LOOP
46 FOR NF = 1 TO NFMT

FOR L = 1 TO NUMF
FOR I = 1 TO NYC
  FOR J = 1 TO 12
   F(L, I, J) = FT(L, I, J) * FMULT(NF)
   NEXT J
  NEXT I
NEXT L

IF NF - 1 <= 0 THEN GOTO 35
   '.................calc  Z  last  year

FOR I = 1 TO NYC
 FOR L = 1 TO NUMF
   FTX(I, 12) = FTX(I, 12) + A(L, I, 12) * FT(L, I, 12)
   NEXT L
NEXT I

 FOR I = 1 TO NYC
   ZLY(I) = XM(I, 12) + FTX(I, 12) * FMULT(NF - 1)
 NEXT I

35FOR I = 1 TO NYC
 FOR L = 1 TO NUMF
```

```
  FTZ(I, 12) = FTZ(I, 12) + A(L, I, 12) * F(L, I, 12)
 NEXT L
NEXT I

FOR K = 1 TO NY
    LOCATE 7
    PRINT "YEAR = "; K

'.........................calculate  larval  production

LARVAE = 0!
 FOR IL = MYX TO NYCX
   JL = IL + MIS
  LARVAE = LARVAE + FMF(JL) * E(JL) * P(IL, 12) * EXP(-(XM(IL, 12) + FTZ(IL, 12))) * PCF
 NEXT IL

PCF = 0!
P(1, 1) = LARVAE

FOR J = 2 TO MFR
AT = J - 1
B% = (J / 12) + 1
JJ = (J + 12) - (12 * B%)

IF JJ - 1 <= 0 THEN
  IP = B% - 1
  JP = 12
ELSE
  IP = B%
  JP = JJ - 1
END IF

    IF NRE - 1 < 0 THEN
       '...........................choose  Beverton  and  Holt
         '.......................................recruitment
  P(B%, JJ) = 1! / (A1 + (A2 / P(IP, JP)))
    ELSE

       '...........................choose  Ricker  recruitment
38 P(B%, JJ) = LARVAE * EXP(-A1 * AT - A2 * LARVAE)
END IF
NEXT J

SXRS = 0!

FOR I = 1 TO NYC
  FOR J = 1 TO 12

   FXM(I, J) = 0!

  NEXT J
NEXT I

FOR I = 1 TO NYC
```

```
FOR J = 1 TO 12
 FOR L = 1 TO NUMF

 FXM(I, J) = FXM(I, J) + A(L, I, J) * F(L, I, J)

NEXT L
 NEXT J
NEXT I

FOR J = 1 TO 12
 FOR I = 1 TO NYC
 Z = XM(I, J) + FXM(I, J)

 IF J - 1 <= 0 THEN
  BP = I - 1
  DP = 12
 ELSE
  BP = I
  DP = J - 1
 END IF

 72 IF 12 * (I - 1) + J - MFR < 0 THEN GOTO 6
 IF 12 * (I - 1) + J - MFR = 0 THEN GOTO 7

 73 IF J - 1 < 1 AND K - 1 < 1 AND NF - 1 > 0 THEN
  P(I, 1) = P(BP, 12) * EXP(-ZLY(BP))
 ELSE
  P(I, J) = P(BP, DP) * EXP(-(XM(BP, DP) + FXM(BP, DP)))
 END IF
 7 AN(I, J) = P(I, J) / Z * (1! - EXP(-Z))
  FOR L = 1 TO NUMF
   YN(L, I, J) = A(L, I, J) * F(L, I, J) * AN(I, J)
  NEXT L
IF GRO - 1 < 0 THEN
'........................choosing von Bertalanffy growth
   T = 12 * (I - 1) + J - 1
  VSUM = 0!

  FOR IV = 1 TO 4
   VN = IV - 1
  5 VSUM = VSUM + XOMEG(IV) * EXP(-VN * XKV * (T - T0)) / (Z + VN * XKV) * (1! - EXP(-(Z +
  VN * XKV)))
  NEXT IV
   '......................yield in weight
  FOR L = 1 TO NUMF
  YW(L, I, J) = A(L, I, J) * F(L, I, J) * P(I, J) * WINF * VSUM
  NEXT L
ELSE

   '......................choosing linear incremental growth
   '.....................and calculating yield in weight
 JW = 12 * (I - 1) + J
   '.....................yield in weight
 FOR L = 1 TO NUMF
```

```
    YW(L, I, J) = YN(L, I, J) * (W(JW) + (W(JW + 1) - W(JW)) * (1! / Z - 1! / (EXP(Z) - 1!)))
   NEXT L
6     END IF

  NEXT I

XMA = 0!
XFE = 0!
  FOR RS = MY TO NYC
   XMA = XMA + FM(RS) * AN(RS, J)
   XFE = XFE + FMF(RS) * AN(RS, J)
  NEXT RS
SXR(J) = XMA / XFE
IF (J - MSB) < 0 GOTO 9
IF J - MSE >= 1 GOTO 9
  ANM = 0!
IF NPCF > 0 THEN
  PCF = 1!
ELSE
  FOR IC = MY TO NYC
    ANM = ANM + FM(IC) * AN(IC, J)
  NEXT IC
PCF = 1! - (1! - PCF) * EXP(-XKC * ANM)
END IF
890 SSP = PCF * 100!
XSM = MSE - MSB + 1
SXRS = SXRS + SXR(J) / XSM
9     NEXT J

FOR L = 1 TO NUMF
    '......................initialize  yield  sums
  FOR J = 1 TO 12
  AYWJ(L, J) = 0!
  AYNJ(L, J) = 0!
  APJ(J) = 0!
  AFPJ(L, J) = 0!
  AANJ(J) = 0!
  AFANJ(L, J) = 0!

   BYWJ(L, J) = 0!
   BYNJ(L, J) = 0!
   BPJ(J) = 0!
   BFPJ(L, J) = 0!
   BANJ(J) = 0!
   BFANJ(L, J) = 0!

   CYWJ(L, J) = 0!
   CYNJ(L, J) = 0!
   CPJ(J) = 0!
   CFPJ(L, J) = 0!
   CANJ(J) = 0!
   CFANJ(L, J) = 0!
  NEXT J
```

```
 FOR I = 1 TO NYC
  AYWI(L, I) = 0!
  AYNI(L, I) = 0!
  AANI(I) = 0!
  AFANI(I) = 0!

  BYWI(L, I) = 0!
  BYNI(L, I) = 0!
  BANI(I) = 0!
  BFANI(I) = 0!

  CYWI(L, I) = 0!
  CYNI(L, I) = 0!
  CANI(I) = 0!
  CFANI(I) = 0!
  NEXT I

AYWA(L) = 0!
AYNA(L) = 0!
AANA = 0!
AFANA(L) = 0!

BYWA(L) = 0!
BYNA(L) = 0!
BANA = 0!
BFANA(L) = 0!

CYWA(L) = 0!
CYNA(L) = 0!
CANA = 0!
CFANA(L) = 0!

      '......................summing yields over age-class, months
FOR J = 1 TO 12
   FOR I = 12 TO 15

   IF 12 * I - 12 + J - MFR < 0 THEN
   XRMU = 0!
     ELSE
   XRMU = 1!
   END IF

  ATEMPW = YW(L, I, J)
  ATEMPN = YN(L, I, J)
  ATEMPP = P(I, J)
  ATEMPA = A(L, I, J)
  ATEMPAN = AN(I, J)
  AYWJ(L, J) = AYWJ(L, J) + ATEMPW
  AYNJ(L, J) = AYNJ(L, J) + ATEMPN
  APJ(J) = APJ(J) + ATEMPP * XRMU
  AFPJ(L, J) = AFPJ(L, J) + ATEMPP * ATEMPA
  AANJ(J) = AANJ(J) + ATEMPAN * XRMU
  AFANJ(L, J) = AFANJ(L, J) + ATEMPAN * ATEMPA
  AYWI(L, I) = AYWI(L, I) + ATEMPW
```

```
AYNI(L, I) = AYNI(L, I) + ATEMPN
AANI(I) = AANI(I) + ATEMPAN / 12!
AFANI(I) = AFANI(I) + ATEMPAN * ATEMPA / 12!
NEXT I
AYWA(L) = AYWA(L) + AYWJ(L, J)
AYNA(L) = AYNA(L) + AYNJ(L, J)
AANA = AANA + AANJ(J) / 12!
AFANA(L) = AFANA(L) + AFANJ(L, J) / 12!

FOR I = 16 TO 20

IF 12 * I - 12 + J - MFR < 0 THEN
XRMU = 0!
ELSE
XRMU = 1!
END IF

BTEMPW = YW(L, I, J)
BTEMPN = YN(L, I, J)
BTEMPP = P(I, J)
BTEMPA = A(L, I, J)
BTEMPAN = AN(I, J)
BYWJ(L, J) = BYWJ(L, J) + BTEMPW
BYNJ(L, J) = BYNJ(L, J) + BTEMPN
BPJ(J) = BPJ(J) + BTEMPP * XRMU
BFPJ(L, J) = BFPJ(L, J) + BTEMPP * BTEMPA
BANJ(J) = BANJ(J) + BTEMPAN * XRMU
BFANJ(L, J) = BFANJ(L, J) + BTEMPAN * BTEMPA
BYWI(L, I) = BYWI(L, I) + BTEMPW
BYNI(L, I) = BYNI(L, I) + BTEMPN
BANI(I) = BANI(I) + BTEMPAN / 12!
BFANI(I) = BFANI(I) + BTEMPAN * BTEMPA / 12!
NEXT I
BYWA(L) = BYWA(L) + BYWJ(L, J)
BYNA(L) = BYNA(L) + BYNJ(L, J)
BANA = BANA + BANJ(J) / 12!
BFANA(L) = BFANA(L) + BFANJ(L, J) / 12!

FOR I = 21 TO 24

IF 12 * I - 12 + J - MFR < 0 THEN
XRMU = 0!
ELSE
XRMU = 1!
END IF

CTEMPW = YW(L, I, J)
CTEMPN = YN(L, I, J)
CTEMPP = P(I, J)
CTEMPA = A(L, I, J)
CTEMPAN = AN(I, J)
CYWJ(L, J) = CYWJ(L, J) + CTEMPW
CYNJ(L, J) = CYNJ(L, J) + CTEMPN
CPJ(J) = CPJ(J) + CTEMPP * XRMU
```

```
      CFPJ(L, J) = CFPJ(L, J) + CTEMPP * CTEMPA
      CANJ(J) = CANJ(J) + CTEMPAN * XRMU
      CFANJ(L, J) = CFANJ(L, J) + CTEMPAN * CTEMPA
      CYWI(L, I) = CYWI(L, I) + CTEMPW
      CYNI(L, I) = CYNI(L, I) + CTEMPN
      CANI(I) = CANI(I) + CTEMPAN / 12!
      CFANI(I) = CFANI(I) + CTEMPAN * CTEMPA / 12!
  NEXT I
  CYWA(L) = CYWA(L) + CYWJ(L, J)
  CYNA(L) = CYNA(L) + CYNJ(L, J)
  CANA = CANA + CANJ(J) / 12!
  CFANA(L) = CFANA(L) + CFANJ(L, J) / 12!

  NEXT J

        '.......................printing  results
    PRINT #2,
    ABREV = 2
IF (K - 1) > 0 GOTO 28
IF NF - 1 < 1 GOTO 43
41  PRINT  #2,
GOTO 28
43     A = 0
PRINT #2, SPC(21); "YEAR-CLASSES AT START OF YEAR"; SPC(30); "FISHABLE"
PRINT #2, SPC(80); "TOTAL"; SPC(10); "AVG."; SPC(11); "AVG."; SPC(11); "YIELD"; SPC(12);
"YIELD"
PRINT #2, "YR.";
FOR I = LI TO LF
  A = A + 1
  IF A < 6 THEN
  PRINT #2, SPC(6); USING FORM$(6); I;
  ELSE
  PRINT #2, SPC(6); USING FORM$(6); I
  A = 0
  END IF
NEXT I
PRINT #2, SPC(80); "POPL."; SPC(10); "POPL."; SPC(10); "POPL."; SPC(10); "NUMBERS"; SPC(10);
"WEIGHT"

28FOR L = 1 TO NUMF
   A = 0
   PRINT #2, USING FORM$(3); K;
   FOR I = LI TO LF
    PRINT #2, SPC(2); USING FORM$(8); P(I, 1);
   NEXT I
    PRINT #2, SPC(5);
    PRINT #2, USING FORM$(8); APJ(1);
    PRINT #2, SPC(5);
    PRINT #2, USING FORM$(8); AANA;
    PRINT #2, SPC(5);
    PRINT #2, USING FORM$(8); AFANA(L);
    PRINT #2, SPC(5);
    PRINT #2, USING FORM$(8); AYNA(L);
    PRINT #2, SPC(5);
```

```
   PRINT #2, USING FORM$(8); AYWA(L)
   GOTO 99
   PRINT #2, SPC(5); "SPAWNING SUCCESS (PCT.) ="; USING FORM$(1); SSP;
   PRINT #2, SPC(10); "MEAN SPAWNING SEX RATIO ="; USING FORM$(2); SXRS
99   NEXT L
IF K = NY THEN
 CLS
 PRINT
 NameFile$ = Filename$ + ".POP"
 OPEN NameFile$ FOR OUTPUT AS #3

 FOR L = 1 TO NUMF
    FOR I = 1 TO NYC
       PRINT #3, I; ; P(I, 1)
    NEXT I
   PRINT #3, USING FORM$(8); APJ(1), BPJ(1), CPJ(1)
   PRINT #3, USING FORM$(8); AANA, BANA, CANA
   PRINT #3, USING FORM$(8); AFANA(L), BFANA(L), CFANA(L)
   PRINT #3, USING FORM$(8); AYNA(L), BYNA(L), CYNA(L)
   PRINT #3, USING FORM$(8); AYWA(L), BYWA(L), CYWA(L)
 NEXT L
 CLOSE #3
 ELSE
 END IF
NEXT K
NEXT NF
CLOSE #2
END
```

APPENDIX B: Sample Structure for Model Input Data

```
***  RUN mid mortality schedule  ***
7
5 2 8 13 1 1 1 1
80 2 1 1 23 1 1 0 0 2
2.69  1.8533  1.0167  0.18  0.051
0 0.125 0.83 3 3
0.125  0.85  3
0  0.18  0.18
0  0.18  0.18
000  277678  90228  34293  24907  18089  13138  9542  5245  5420  3147  2448
1311  874  350  874  524  437  524  262  1048  262  524  350  175  175  175  87  175  87
87  87  175  0  87  0  0  0  0  87  87  87  175  0  87  0  0  0  0  87
87  87  175  0  87  0  0  0  0  87  87  87  175  0  87  0  0  0  0  87
87  87  175  0  87  0  0  0  0  87
0.119
0.5
0.5
```