Alaska Department of Fish and Game
Division of Game
Federal Aid in Wildlife Restoration
Research Final Report

INTERPRETATION OF BEAR HARVEST DATA

by
Sterling D. Miller and
SuzAnne M. Miller
Projects W-23-1
Study 4.18
October 1988

STATE OF ALASKA
Steve Cowper, Governor

DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner

DIVISION OF GAME
W. Lewis Pamplin, Jr., Director
Donald E. McKnight, Planning Chief

Additional copies of this report, or reports on other species covered in this series may be obtained from:

Publications Technician
ADF&G, Game Division
P.O. Box 3-2000
Juneau, AK 99802
(907) 465-4190

PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperator: None

Project No. W-22-6

Project Title: Big Game Investigations

Job No. 4.18R

Job Title: Interpretation of Bear Harvest Data

Period Covered: 1 July 1987-30 June 1988

SUMMARY

The relationship between trend in bear populations and composition of bear harvest data was examined using a deterministic simulation model and, as reported elsewhere (Miller 1988), through examination of harvest data from a declining brown bear population in Game Management Unit (GMU) 13.

Four scenarios were examined in the simulation studies. In the first one, a population was allowed to grow under a regime of light exploitation. In the other 3 scenarios, an increasing population was overharvested (population declines of 1.6-2.6%/year) under circumstances where different age and sex classes had different relative vulnerabilities to hunters but where males were always more vulnerable than females. In all three of the overharvest scenarios, the percentage of females in the harvest initially increased and then stabilized, mean age of harvested males declined and then stabilized, and little change in the mean age of harvested females occurred. We concluded that harvest age or sex composition will tend to stabilize in situations where relative vulnerabilities by sex or age remain unchanged, regardless of whether the population is increasing or decreasing. Changes in these values result from changes in the relative vulnerability by sex and age; within a period of less than 1 life-span following such a change, these statistics will stabilize. Managers should not interpret stability in these harvest statistics as indicating a lack of trend in the population.

A regression of the percentage of males in each age class has been proposed as a method of estimating harvest rate of bears (Fraser et al. 1982). This approach was applied to the 3 overharvest scenarios examined in the simulation studies, and it correctly estimated harvest rate in some cases. When harvest rates stabilized (i.e., generally about 10 years after a change when the age structure had stabilized to the new vulnerabilities), this approach was unable to detect continued decline in the simulated populations.

The deterministic model used to conduct these simulation exercises was also used to estimate sustainable rates of harvest in the brown bear population in GMU 13 (Miller 1988) and the black bear populations in GMU 13 and the Kenai Peninsula. Reproductive data were based on telemetry studies (Miller 1987, Schwartz and Franzmann 1988) and varied between the 2 areas; population structure and relative vulnerabilities to hunting and natural mortality were held constant in each area. According to model calculations, the estimated sustainable harvest rate for each area was the exploitation rate plus the population growth rate. With no natural mortality until age 15, a black bear population with GMU-13 reproductive characteristics could sustain an annual mortality (bears >1.0) of about 15.3%, compared with about 20.9% for those in the Kenai Peninsula. With conservative estimates of natural mortality rates, the black bear population in GMU 13 (>1.0) was estimated to be able to sustain exploitation rates of about 11.2%, compared with about 16.3% for Kenai black bears. These estimates were converted to sustainable exploitation rates for the whole population, using the assumption that 16% of the population were cubs (<1.0 year-old) that survived to age 1. In GMU 13 this resulted in an estimate that the total population could sustain 13.1% compared to 18.2% on the Kenai Peninsula. Both estimates refer to populations with low levels of natural mortality. Further refinement of the model and input parameters may alter these estimates somewhat.

Key words: Alaska, brown bear, *Ursus arctos*, black bear, *Ursus americanus*, harvest data interpretation, population modeling, sustainable harvest levels.

CONTENTS

Summary. i
List of Tables iv
List of Figures. iv
Background and Objectives. 1
Methods. 2
Results and Discussion 3
Using the LOTUS Model to Help Understand the Relationship of Harvest Data and Population Trend . 5
Scenario 1 5
Scenario 2 6
Scenario 3 7
Scenario 4 7
Using the LOTUS Model to Estimate Sustainable Harvest Rates 10
Scenario 5 (GMU 13 black bears). 11
Scenario 6 (Kenai Peninsula black bears) 11
Conversions. 12
Application. 13
Conclusions 13
Literature Cited 14
Table. 16
Figures. 17
Appendix. Documentation for LOTUS Model 57

LIST OF TABLES

Table 1. Summary of input from 4 exploitation scenarios discussed in text.

LIST OF FIGURES

Figure 1. Input parameters for scenario 1, a rapidly growing population with low harvest and natural mortality.

Figure 2. Brown bear population growth rate under scenario 1.

Figure 3. Mean age in kill and in population of brown bear females under scenario 1.

Figure 4. Mean age in kill and in population of brown bear males under scenario 1.

Figure 5. Percent females in kill and in population of brown bear females under scenario 1.

Figure 6. Input parameters for scenario 2 in which the growing population from scenario 1 is subjected to heavy hunting pressure.

Figure 7. Brown bear population growth rate under scenario 2.

Figure 8. Mean age in kill and in population of brown bear females under scenario 2.

Figure 9. Mean age in kill and in population of brown bear males under scenario 2.

Figure 10. Percent females in kill and in population of brown bear females under scenario 1.

Figure 11. Input parameters for scenario 3 which is like scenario 2 except that older animals are progressively more vulnerable than younger animals.

Figure 12. Brown bear population growth rate under scenario 3.

Figure 13. Mean age in kill and in population of brown bear females under scenario 3.

Figure 14. Mean age in kill and in population of brown bear males under scenario 3.

Figure 15. Percent females in kill and in population of brown bear females under scenario 3.

Figure 16. Input parameters for scenario 4 which is like scenario 2 (young animals more vulnerable than older ones) with the addition that older males become progressively more vulnerable.

Figure 17. Brown bear population growth rate under scenario 4.

Figure 18. Mean age in kill and in population of brown bear females under scenario 4.

Figure 19. Mean age in kill and in population of brown bear males under scenario 4.

Figure 20. Percent females in kill and in population or brown bear females under scenario 4.

Figure 21. Population composition in year 3 of scenario 4.

Figure 22. Harvest composition in year 3 of scenario 4. Arrow indicates last age class where number of males harvested exceed number of females harvested.

Figure 23. Population composition in year 5 of scenario 4.

Figure 24. Harvest composition in year 5 of scenario 4. Arrow indicates last age class where number of males harvested exceed number of females harvested.

Figure 25. Population composition in year 10 of scenario 4.

Figure 26. Harvest composition in year 10 of scenario 4. Arrow indicates last age class where number of males harvested exceed number of females harvested.

Figure 27. Regression of percent males harvested on age class in year 3 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 28. Regression of percent males harvested on age class in year 5 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 29. Regression of percent males harvested on age class in year 7 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 30. Regression of percent males harvested on age class in year 10 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 31. Regression of percent males harvested on age class in year 15 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 32. Regression of percent males harvested on age class in year 40 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 33. Regression of percent males harvested on age class in year 3 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 34. Regression of percent males harvested on age class in year 5 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 35. Regression of percent males harvested on age class in year 15 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 36. Regression of percent males harvested on age class in year 20 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. 1982). Regression values provided in Table 1.

Figure 37. Input parameters for scenario 5, estimation of sustainable harvest level of GMU 13 black bears.

BACKGROUND AND OBJECTIVES

Background and objectives were outlined by Miller and Miller (1986):

> Better understanding of bear population dynamics is important for interpretation of harvest data and for development of methods for directly assessing the status of living populations. The use of simulation models to mimic the dynamics of the possible responses of a population of animals to a variety of introduced variables is a well-established, relatively inexpensive, and occasionally misused tool of modern game managers who seek to better understand these dynamics (Pojar 1981).

The most thorough examination of the relationship between bear harvest data and population trend was conducted by Harris (1984):

> Age-structure of harvested populations displayed 3 patterns with increasing harvest pressure: (i) sex ratios favored females, (ii) male age declined, and (iii) female age increased slightly. Although clearly evident in unexploited populations that were subsequently overharvested to extinction, differences in age structures between populations above and below the sustained yield curve were virtually undetectable. Harvest age-structures exhibited high yearly variability and a substantial lag-time in their response to changing harvest rates.... Decisions about harvesting small populations of grizzlies must be viewed conservatively, because harvest data contain inherent uncertainty. Managers must work in the context of risk rather than irrefutable quantitative evidence.

Tait (1983) developed a stochastic model designed to estimate various parameters of grizzly bear populations based on composition of hunter harvests. The estimated parameters include survivorship rate, recruitment rate, harvest rates of each sex, and population size. Tait's approach has worked well on Monte Carlo simulations, but his model was not written in a format that allows it to be tested on real harvest data. Tait has assisted our efforts in converting this model to a format that permits this testing (Miller and Miller 1987).

We anticipate that the process of improving our ability to infer population status from data on sex and age composition of bear harvests will be both long and slow. Information collected from other states suggests that some (i.e., notably

Michigan, Idaho, Minnesota, and California) have active programs designed to better understand the relationship between bear harvest data and population trend; other states are concentrating their efforts on (1) increasing the proportion of their bear harvests that is sexed and aged and (2) getting a longer time series of harvest composition data.

In Alaska harvested brown bears have been sexed and aged since 1970, and we have a longer history and larger sample sizes of data to work with than most other regions. Difficulties in interpretation of these data and concerns over the cost of collecting it, however, have led to abandonment of tooth aging for black bears in many areas of Alaska. Some also question the need to obtain cementum ages for brown bears in areas with small harvests. Improved understanding of the relationship between data on composition of bears harvested in Alaska and trends in the population from which they were taken is the general objective of this study. The specific immediate objectives are as follows:

1. To identify or construct a bear population simulation model or models useful to bear managers for improving understanding of the relative importance of various reproductive parameters, harvest rates, and bear vulnerabilities in regard to population growth rates and sustainable harvest rates and to examine the utility of sex and age composition data derived from harvest records in making conventional interpretations of bear population status.

2. To evaluate Tait's harvest data model (Tait 1983) and, to the extent practical, to adapt it as a management tool for use in interpretation of bear harvest data in Alaska.

METHODS

We used several computer simulation models developed by others and ourselves to investigate the relationship of harvest data and population trend; however, we primarily used a deterministic model based on LOTUS 1-2-3 that we developed. In this model, survivorship rates were assigned to each age and sex class of animals for each of 2 types of mortality (i.e., natural and exploitative). Males of age i in year x first experienced "natural" mortality and the remaining males then experienced "exploitative" mortality to yield the number of males present in year i+1, and the same was done for females. Age classes included in the model are 2-30 years for brown bears and 1-29 years for black bears; bears younger than this are not included because (1) they cannot legally be hunted, (2) they are not independent of their mothers, and (3) population trend is very sensitive to mortality rates assumed for these subadult bears. Instead of making assumptions about these rates, our model calculated recruitment into the first independent age class (i.e., yearlings for black bears, 2-year-olds for brown bears). This procedure incorporated subadult mortality rates into the reproductive rate parameters, which are the model inputs used to calculate number of animals recruited into yearling and 2-year-old cohorts. This model is set up to run for 40 years; however, in <1 life-span for bears, this model will produce a stable age distribution. Results of altering any of the input parameters can be viewed using graphs built into the model. Calculations are straightforward; for example, the exploitation rate is calculated as

> 100* [number killed in year(i)]/number of animals present in that year, and annual population growth rate displayed in 1grow40.pic is

> 100*[number present in year(i+1) - number present in year(i)]/number present in year(i).

Another graph (%change.pic) displays percent change from initial conditions as

> 100*[number present in year(x) - number present in year(0)]/number present in year(0).

Documentation for this model is provided in the Appendix.

RESULTS AND DISCUSSION

Objective 2 has not been accomplished, although some progress was made during this reporting period on converting Tait's (1983) model to a version that could be tested and used on Game Division's computers. In order for Objective 2 to be accomplished, this conversion will have to be accorded a higher priority within Game Division.

Progress was made on Objective 1. As reported by Miller and Miller (1987), the Generalized Animal Population Projection System (GAPPS) (Harris et al. 1986) was obtained in a version compatible with the computer software available to Game Division staff. Stochastic approaches like GAPPS, however, may not be the most instructive way to better understand the relationship between bear population trend and harvest data, because many different results are possible with the same set of input parameters. Using the same parameters, a simlulated population could be increasing in one run and decreasing in a second run. The nature of stochastic models makes it difficult to determine whether the observed impact of a parameter change on the modeled population resulted from that change or by chance. Stochastic models probably reflect the way populations of real animals function better than deterministic models; but in some cases, deterministic models may allow users to more easily understand the relationships being examined.

A deterministic model for polar bears (Ursus maritimus), ANURSUS, with optional stochastic features was developed by Taylor et al. (1987a). The stochastic features are included after standard-error values are included for the inputted parameter rates. We ran a test simulation with this model during the reporting period. Versions of ANURSUS that are adapted for black bears and brown bears are currently being developed (M. Taylor, pers. commun.). No documentation for any version of ANURSUS is yet available, but such documentation is currently being written (M. Taylor, pers. commun.). The full utility of ANURSUS cannot be adequately evaluated until this documentation is available.

The relative importance of different reproductive and mortality factors on growth rates of polar bears was examined using ANURSUS (Taylor et al. 1987b). These authors concluded that the single-most significant parameter was survivorship of adult females; similar conclusions for brown bear were reached by Knight and Eberhardt (1984, 1985).

One objective of this and a related project (Miller 1988) was to examine the relationship of an independently documented downward trend in a brown bear population to harvest data derived from that population. In Alaska's Game Management Unit (GMU) 13, capture-recapture techniques were used to document a decline in brown bear density, and harvest data from that area were correlated with the decline (Miller 1988). The sex ratio of bears harvested in the fall seasons, as well as the number of subadults harvested, best reflected the declining population (Miller 1988). In his simulations, Harris (1984) also noted that the sex ratio in harvest best reflected altered population status. Mean age of harvested males also declined, and the number of subadults harvested increased (Miller 1988).

Development of procedures to estimate sustainable harvest rates was another objective of this study. The LOTUS model we developed was used to estimate sustainable harvest rates and numbers for the brown bear population in GMU 13 (Miller 1988). In that analysis, the number of bears harvested was found to exceed the sustainable level of harvest that was estimated using the LOTUS model (Miller 1988). In this report similar procedures are followed to estimate sustainable harvest rates for black bear populations in the Kenai Peninsula and GMU 13.

Using the LOTUS Model to Help Understand the Relationship of Harvest Data and Population Trend

We developed a deterministic model during this reporting period to help understand the relationship between bear population trend and composition of harvest data. The input matrix for this model is illustrated in Fig. 1, and the documentation is provided in the Appendix.

Care should be taken in using this model to understand the dynamics of real populations. The model is a very simple one, with no density-dependent mechanisms or other types of feedback. One could, for example, kill off all the males, and the females would continue to produce offspring. In particular, the absence of natural mortality in some of the following scenarios means that calculated "exploitation rates" do not reflect what would occur in a real bear population.

With these cautions clearly in mind, however, the model can be a useful tool in helping managers of real bear populations to understand what causes or is unlikely to cause certain kinds of changes in the sex and age composition of bear harvest data. Four scenarios are used here to provide illustrations of how this model can be used for this purpose. Reproductive rates and natural mortality rates were the same in all four of these scenarios; parameters are provided in Fig. 1. Reproductive rates used were those documented for GMU 13 (Miller 1988), and natural mortality was set at zero until age 15 (Fig. 1). Output parameters for each of the 4 scenarios are summarized in Table 1.

Fraser et al. (1982) outlined a method for estimating the exploitation rate based on a regression of percent males on age class in harvest. A recent review of this approach pointed out some basic problems (Harris and Metzgar 1987). The LOTUS spreadsheet model was used to further inspect the behavior of the method proposed by Fraser; regressions of percent males on age class during years 3, 5, 7, 10, 15, 20, and 40 of each simulation were calculated. These regressions were not weighted by sample size as recommended by Fraser et al. (1982).

Scenario 1:

The objective of this scenario was to produce an increasing population of bears that could, in subsequent scenarios, be overharvested in various ways. This was accomplished by taking a stable population of 817 bears (>2.0 years old), which was derived from an estimate of sustainable harvest levels in GMU 13 (Miller 1988), and allowing it to grow with 10% exploitation of each age class of males and 5% exploitation of each age class of females (Fig. 1). The population of 817 was derived with hunting survivorships of 89% for males of all ages and 92.5% for females.

This population grew at a final rate of 2.86%/year, reaching 2,228 animals in year 40 of the simulation (Fig. 2). Mean age of females in the population stabilized at 8.65 years and in the kill at 8.3 years (Fig. 3, Table 1). This difference reflected the model's removal of natural mortality prior to removal of harvest mortality. For males, mean age initially declined because of adjustment to change in vulnerability from initial conditions and then stabilized at 7.27 years for the population and at 7.13 years for the kill (Fig. 4, Table 1). The smaller difference between mean age in harvest and in kill compared with females reflects the relatively heavy harvest of males; there were fewer older males surviving to bring up the mean age because they were killed at younger ages.

In this growing population, percent females in the population stabilized at 58% and at 40% in the kill (Fig. 5, Table 1). Regressions of percent males on age class fit the model proposed by Fraser et al. (1982) very poorly in the first 10 years of scenario 1 but started to fit it better subsequently (Table 1). The poor fit in the early years reflected the abrupt change in vulnerabilities from the stabilized initial population in this scenario.

Scenario 2:

The population of 2,228 bears produced by scenario 1 was subjected to an abrupt change in harvest pressure (Fig. 6). Harvest rates were adjusted to produce a population that declined at a rate of 2.6%/year (Fig. 7, Table 1). Older animals were progressively less vulnerable than younger animals, a situation that might exist where bears were being shot opportunistically. In each age class, males remained twice as vulnerable as females.

The percentage of the population harvested stabilized at 14% for bears >2 years old and at 12% for bears >5 years old, compared with 7% and 6.75%, respectively, for scenario 1. Mean age of harvested bears stabilized at a younger age than in scenario 1; for females it was 7.6 years and for males it was 5.3 years (Figs. 8 and 9, Table 1). This was because of the higher vulnerability of young animals. Even though males were twice as vulnerable as females in both scenarios, percentages of females in the kill and in the population were also higher than those in Scenario 1: 47% and 66%, respectively (Figs. 5 and 10, Table 1).

Scenario 3:

Like scenario 2, this one started with the growing population produced by scenario 1; however, the population was then over-harvested by increasing vulnerabilities. Like scenario 2, males were twice as vulnerable as females in each age class. Unlike scenario 2, however, older animals of both sexes were progressively more vulnerable than younger animals (Fig. 11). This is analogous to a situation where hunters were selecting for large animals, rather than hunting opportunistically. Because of the comparatively light hunting on young bears, the hunting vulnerabilities had to be set higher than in scenario 2 to make this population decline (Fig. 11). The population declined at 1.6%/year (Table 1).

The mean age of females and males in the kill was older than in the population (Figs. 13 and 14, Table 1); the reverse was true in scenario 2 (Figs. 8 and 9, Table 1). Although this result may be obvious, it illustrates the difference in the way managers should view harvest age data under conditions of trophy vs. opportunistic hunting.

In scenario 2 and scenario 3, mean age of males showed a dramatic decline in the first years of heavy exploitation (Figs. 9 and 14), but mean age of females revealed either no change (e.g., scenario 2; Fig. 8) or a less dramatic decline than for males (e.g., scenario 3, Fig. 13). I believe the less-dramatic response for females reflects the lighter exploitation rate for females (i.e., half that of males in both cases). The greater response for females in scenario 3, compared with scenario 2, probably reflects the higher exploitation rate of females >5.0 years old: 10.2% in scenario 3, compared with 9.1% in scenario 2 (Table 1). It is unclear why a regression of percent males on age class should be a perfect fit to the linear model in all years ($r^2 = 1.0$) in this scenario (Table 1).

Scenario 4:

Scenario 4 combined the situation in scenario 2 (i.e., identical female vulnerabilities with old females progressively less vulnerable than younger animals) with a situation where male vulnerability increased with age. At ages 2-4 years, males were twice as vulnerable as females, at 5-10 years they were 2.5 times as vulnerable, at ages 11-16 years they were 3 times as vulnerable, and at ages older than 16 years they were 4 times as vulnerable. In real life this situation might exist where older males were especially vulnerable, compared with older females; e.g., during spring seasons (Miller 1988) or trophy hunting. This also might be the case when older females were less vulnerable than younger females because they were more likely to be accompanied by offspring. In this scenario the population declined at 2.6%/year, the same as in scenario 2 where female vulnerability was identical (Table 1). This was not a coincidence, and it reflected the degree to which this model is female-driven. Even if male exploitation rates had been greatly increased, the population in year 40 would still have declined at 2.6%/year, as long as female exploitation rates had remained unchanged.

Because mortality of females was identical in scenarios 2 and 4, population growth rates (Figs. 7 and 17) and mean age of females in the kill and population (Figs. 8 and 18) were also identical in these scenarios. For males, however, the heavy exploitation of old males in scenario 4 yielded a situation where mean age in the kill of males was slightly older than mean age of males in the population (Fig. 19, Table 1); the same pattern resulted from the comparison of scenarios 2 and 3.

Despite the increasing vulnerability of older males in scenario 4, compared with scenario 2, the percentage of females in the kill was the same in both cases (Figs. 10 and 20, Table 1). In none of these scenarios did the percentage of females in the kill exceed 50%, because the scenarios had been designed with very little natural mortality. Correspondingly, the sex ratio of all harvested animals approached the sex ratio at birth; i.e., 50% males in these scenarios (Harris 1984:14).

Differences in vulnerability between males and females may be used as a trend indicator. When males have higher vulnerability than females, males become progressively more depleted in older age classes in the population. This will lead to more females than males in the harvests of older age classes. This model was used by Fraser et al. (1982) to estimate harvest rate for black bears. When the percentage of males is regressed on age class, the reciprocal of the age where sex ratio in harvest equals 50% females is a rough estimate of harvest rate (Fraser et al. 1982). Harris and Metzgar (1987) pointed out that this method was sensitive to violations of underlying assumptions and provided an adequate estimate of harvest rate only when population age structure was stabilized.

This second conclusion was also evident using the Fraser approach with the LOTUS model. Good fits with the linear regression was evident only after 10-15 years, when age structures began to stabilize (Table 1). However, after this period, the reciprocal of age (where y = 50% males) was a good estimator of harvest rate (Table 1). One interesting result of this analysis was the extremely poor fit to the linear model in years 3 and 5 of scenario 1 (Table 1). This reflected the abrupt change from a population stabilized by hunting to a growing population with light hunting. A similar poor fit to the linear Fraser model was found in the GMU 13 brown bear harvest data lumped for 1970-1979 (Miller 1988: Fig. 15). I suspect the reason for the poor fit was similar to that in the early years of scenario 1 (i.e., a change in exploitation rates and relative vulnerabilities).

Illustrations of the composition of the population and of the harvest in years 3 of the simulation for scenario 4 are provided in Figs. 21 and 22. The oldest age at which males predominate in the harvest was age 18 (Fig. 22). In year 5 of this scenario, the population structure was similar (Fig. 23), but females predominated in the harvest of bears ≧ 8 years old (Fig. 24). The age structure of the harvest remained about the same as this in year 10 of this scenario (Figs. 25 and 26) and in subsequent years, with females predominating in harvested bears ≧ 8 years old. This suggests that the shift to predominance of females in progressively younger age classes may occur quickly under circumstances of a rapid shift from underexploitation (scenario 1) to overexploitation (scenario 4).

The regression model for these data proposed by Fraser et al. (1982) revealed a similar pattern for scenario 4 (Table 1, Figs. 27-32). The age where a regression of percent males in harvest on age class equals 50% males declined from 15.3 years in year 3 (Fig. 27) to 10.0 years in year 5 (Fig. 28), 8.2 years in year 7 (Fig. 29), 7.3 years in year 10 (Fig. 30), and 7.1 years in years 15-40 (Figs. 31 and 32). The reciprocal of these ages approximated the exploitation rate as proposed by Fraser et al. (1982). As the age structure stabilized with time, the regressions fit the linear model better (Table 1). There was no change in the age where percentage of males equals 50% during the last 35 years of this scenario, even though this population was declining at 2.6%/year (Fig. 17). The same pattern was evident for these regressions for the declining population in scenario 2; the age where percentage of males equals 50% declined from 11.8 years in year 3 to a stable 7.2 years in year 15 and subsequently (Figs. 33-36, Table 1).

The point of these analyses is that an increase in vulnerability may result in a shift to a younger age in the age where percentage of males equals 50%. This occurs regardless of whether male vulnerability is a constant function of female vulnerability in all ages (scenario 2) or whether males become progressively more vulnerable, compared with females in the older age classes (scenario 4). However, unless another change in relative vulnerability occurs, the age structure will stabilize and the composition of harvest derived from this population will also stabilize, regardless of population trend.

This result may appear obvious, but it is not uncommon for biologists to interpret stability in harvest data as indicative of stability in population numbers or to expect a trend in some harvest statistic to continue. Stability in harvest composition may indicate nothing more than constant relative vulnerabilities in a population that may be expanding or declining. This was evident in all 4 scenarios discussed above. When vulnerabilities are changed, through initiation of a spring season, for example, composition of harvests may show perturbations. These will be large if the changes in relative vulnerabilities by sex or by age are large and small if they are small. After a period of time under the new regime, the population and harvest compositions will again stabilize; the period of time to reach this new stability is approximately 1 maximum life-span, although essential stability will occur in about a third of this time (Table 1) in situations where more animals are young than old.

Using the LOTUS Model to Estimate Sustainable Harvest Rates

The LOTUS model discussed previously was used to estimate sustainable harvest rates for brown bear and to compare these rates with actual harvest levels by Miller (1988). A similar exercise for Yukon grizzly bears resulted in an estimate of sustainable harvests of no more than 2-3%/year (all sexes and ages) (Sidorowicz and Gilbert 1981). A similar exercise is reported here for black bears (>1.0 year), using data on reproductive rates in GMU 13 (Miller 1987b) and in the Kenai Peninsula (Schwartz and Franzmann in press).

Unlike the brown bear example, an effort was made in this exercise for black bears to end up with a population composition similar to that reported for the MRC area on the Kenai Peninsula: 21% yearlings, 10% 2-year-olds, 31% adult males, and 38% adult females (Schwartz and Franzmann 1988). The percentage data presented by these authors (21% cubs, 16% yearlings, 8% 2-year-olds, 24% adult males, and 30% adult females) were converted to exclude the cub cohort. As these investigators recognized, the composition observed on the Kenai Peninsula underrepresented 2-year-olds (Schwartz and Franzmann 1988). The observed composition would indicate a 50% mortality between yearling and the 2-year-old age classes, and they observed a mortality rate of only 18% for yearlings (Schwartz and Franzmann in press). Also, a stable population with this level of mortality in the yearling age class couldn't be derived. The population we modeled for scenario 5 had a final composition of 17% yearlings, 13% 2-year-olds, 29% adult males, and 41% adult females.

In these exercises, sustainable harvest levels of modelled populations were estimated to be the sum of calculated exploitation rate (using inputted vulnerabilities) and population growth rate. These estimates should be considered first approximations that may be altered in the future, based on additional information or alternative approaches. The exploitation rate percentages expressed are for the population >1.0 year old.

Scenario 5:

This scenario was designed to estimate sustainable harvest levels for a black bear population with (1) the reproductive characteristics observed in GMU 13 (Miller 1987) and (2) low levels of natural mortality (10% for yearlings, 5% for 2-year-olds, 4% for 3- to 5-year-olds, 3% for 4- to 15-year-olds, 10% for 16- to 19-year-olds, 20% for 20- to 23-year-olds, and 50% for ≧24-year-olds. Vulnerability to hunting was set at 16% for males age 1-4 years (12% for females), 13% for males age ≧4 years, 11% for females age 4 years, 10% for females age 5 years, and 8% for females age ≧6 years. These parameters are illustrated in Fig. 37. This hunting vulnerability was set to reflect decreased vulnerability of female bears accompanied by cubs.

This population had a growth rate near zero and an exploitation rate of 11.2% for bears >1 year (9.7% for bears >5 years). The estimated sustainable exploitation rate was 11.3%. The survivorship estimates for natural mortality were adjusted to achieve a near-zero growth rate in order to minimize the contribution of population growth to the sustainable rate of harvest estimate.

If hunting vulnerability had remained the same and all natural mortality had been eliminated in age classes 1-15 but had remained the same for bears >16 years old, this population would have had a growth rate of 3.9%/year and an exploitation rate of 11.8%/year for bears >1.0 year (10.0% for bears >5.0 years). Because natural mortality was set to zero, except in the oldest age classes, the population (>1.0) could have sustained a total mortality of approximately 15.7% (i.e., 3.9% + 11.8%).

Scenario 6:

This scenario was designed to estimate sustainable harvest levels for a black bear population with the reproductive characteristics observed in the Kenai Peninsula (Schwartz and Franzmann in press). For reproductive rates, the data for 2 different study areas (i.e., MRC and Finger Lakes) were combined and recalculated from the raw data. Compared with GMU 13 (Fig. 37), the Kenai population had a younger age at first reproduction (mean = 4.96 instead of 6.13 years), a larger litter size (2.02 instead of 1.9 yearlings), and a shorter interval between litters of yearlings (mean = 2.26 instead of 2.7 years). This scenario started with the same initial population and vulnerability to hunting as scenario 5.

The Kenai population had a growth rate of 3.6% (compared with 0.05% in scenario 5) and an exploitation rate of 11.4% for bears >1 year (compared with 11.2 for scenario 5) and 9.8% for bears >5 years. In this scenario, sustainable mortality was then approximately 15.0% (i.e., 3.6% + 11.4%), which is 4.4% greater than the equivalent figure (i.e., 11.3%) estimated for black bears in GMU 13 with equivalent levels of vulnerability to hunting and natural mortality.

If hunting vulnerability had remained the same and natural mortality had been set to 0 in age classes 1-15 years but had remained the same for bears ≥16, this population would have had a growth rate of 7.7%/year (compared with 3.9% in GMU 13) and an exploitation rate of 12.1% and 10.1% for bears >1.0 and >5 years, respectively (compared with 11.8% and 10.0% in GMU 13). In this scenario the population could have sustained a total mortality of approximately 19.8% (i.e., 7.7% + 12.1%), which is 4.1% higher than calculations based on the same assumptions for black bears with the reproductive characteristics found in GMU 13.

Conversions:

The sustainable harvest rates reported above are for bears >1.0 year. A straightforward conversion can provide estimates of harvest rates for all age classes if the proportion of cubs in the population is known. If 21% of the spring population is <1.0 year (Schwartz and Franzmann in press), then 1.21 multiplied by the exploitation rate for a population >1 year will provide an estimate for the sustainable exploitation rate for the population of all bears (assuming no mortality of cubs). In GMU 13 this conversion would yield estimates of 13.7% (i.e., 1.21 multiplied by 11.3) and 19% for populations with minimal and no natural mortality, respectively (18.2% and 24%, respectively, for the Kenai estimates). Cub mortality could be approximately included in these estimates by using the proportion of the spring population that is represented by yearling bears instead of that represented by cubs. Schwartz and Franzmann (in press) reported 16% of their population were yearlings; therefore, 1.16 multiplied by the exploitation rate for a population >1 year would approximate sustainable mortality, including first-year mortality. For the estimate with low natural mortality, this provides estimates of 13.1% and 18.2% for GMU 13 and Kenai populations, respectively.

Application:

Managers of exploited bear populations seldom have a very precise estimate of the size of their population. Additionally, the reported harvest in some parts of Alaska is thought to be significantly less than the number actually killed. This means that for a real bear population, both the numerator and denominator of the actual exploitation-rate equation are uncertain. Under these circumstances, the value of estimating sustainable exploitation rates is limited.

Managers may find these estimates useful in determining the size their populations would have to be to sustain existing reported levels of harvest (i.e., under the assumption that the sustainable-rate calculations are correct and that there is little unreported harvest). They can further roughly estimate what their existing populations are by extrapolation from areas where density estimates are available. When the second population estimate exceeds the first, managers have some basis to be concerned about exploitation in excess of sustainable levels. This exercise was done for brown bears in GMU 13 (Miller 1988) and for black bears in GMU 14 (Grauvogel and Sherburne in press).

CONCLUSIONS

The results of these simulations and the analyses of harvest data from a brown bear population in GMU 13 that was independently determined to be declining (Miller 1988) suggest that data on sex and age composition of harvested bears can be a useful tool in helping managers evaluate trends in exploited bear populations. Such evaluations are not very sensitive and may be slow to respond to altered status of the underlying population, and similar patterns may be generated by opposite circumstances (Harris 1984, Caughley 1974). Managers should be especially cautious about inferring stability in bear populations based on stability in mean age statistics; the distribution of ages is more informative.

Even though age composition of harvest data is expensive to collect for bear populations, the insights into population trend that can potentially be gained from a thorough and open-minded examination of these data may be worth the expense. Additional study is necessary to more completely evaluate the usefulness of age data; at present it would be premature to stop collecting it. This is especially true for bear populations for which there are few techniques available to directly measure numbers or trends (Harris 1986) and where the techniques that are available are usually very expensive, typically imprecise, and applicable only to areas that are small, compared with the size of the areas for which managers are responsible.

LITERATURE CITED

Caughley, G. 1974. Interpretation of age ratios. J. Wildl. Manage. 38(3):557-562.

Fraser, D., J. Gardner, G. Kolenosky, and S. Strathern. 1982. Estimation of harvest rate of black bears from age and sex data. Wildl. Soc. Bull. 10(1):53-57.

Grauvogel, C.A., and J. Sherburne. In press. Black Bear Survey-Inventory Progress Report, Game Management Unit 14A and 14B. Annual report of survey-inventory activities. S.O. Morgan (ed.). Juneau.

Harris, R. B. 1984. Harvest age-structure as an indicator of grizzly bear population status. MS thesis, Univ. of Montana, Missoula. 204 pp.

__________. 1986. Grizzly bear population monitoring: Current options and considerations. Mont. Forest and Conservation Expt. Station, School of Forestry, Univ. of Montana., Missoula Misc. Publ. #45. 80pp.

__________, and L.H. Metzgar. 1987. Estimating harvest rates of bears from sex ratio changes. J. Wildl. Manage. 51(4):802-811.

__________, __________, and C.D. Bevins. 1986. GAPPS User's Manual, Version 3.0. 123 pp.

Knight, R.R., and L.L. Eberhardt. 1984. Projected future abundance of the Yellowstone grizzly bear. J. Wildl. Manage. 48(4):1434-1438.

__________, and __________. 1985. Population dynamics of Yellowstone grizzly bears. Ecology 62(2):323-334.

Miller, S.D. 1987. Susitna hydroelectric project final report, big game studies, Vol. VI black bear and brown bear. mimeo. 276 pages.

__________. 1988. Impacts of increased hunting pressure on the density, structure, and dynamics of brown bear populations in Alaska's Game Management Unit 13. Progress report, Fed. Aid in Wildl. Restor. Proj. W-22-6, Job 4.21. In prep.

__________, and S.M. Miller. 1986. Interpretation of bear harvest data. Prog. Rep. Fed. Aid in Wildl. Restor. Job. W-22-5, Job 4.18R. 11 pp.

__________, and __________. 1987. Interpretation of bear harvest data. Prog. Rep. Fed. Aid in Wildl. Restor. Proj. W-22-5, Job 4.18R. 4 pp.

Pojar, T.M. 1981. A management perspective of population modeling. Pages 241-262 in C.W. Fowler and T. W. Smith, eds. Dynamics of large mammal populations. Wiley. 477pp.

Schwartz, C.C., and A.W. Franzmann. In press. Black bear ecology of the Kenai Peninsula, Alaska.

Sidorowicz, G.A., and F.F. Gilbert. 1981. The management of grizzly bears in the Yukon, Canada. Wildl. Soc. Bull. 9(2):125-135.

Tait, D.E.N. 1983. An analysis of hunter kill data. Ph.D. thesis, Univ. of British Columbia. Vancouver. 129 pp.

Taylor, M.K., D.P. Demaster, F.L. Bunnell, and R.S. Schweinsburg. 1987a. Modeling the sustainable harvest of female polar bears. J. Wildl. Manage. 51(4):811-820.

__________, F. Bunnell, D. DeMaster, R. Schweinsburg, and J. Smith. 1987b. ANURSUS: A population analysis system for polar bears. Intl. Conf. Bear Res. and Manage. 7:117-125. Table 1. Figure 1.

Table 1. Summary of output from 4 exploitation scenarios discussed in text.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GROWTH RATE IN YEAR 40				
Bears > 2.0	+2.9	-2.6	-1.6	-2.6
Bears > 5.0	+2.9	-2.6	-1.6	-2.6
EXPLOITATION RATE IN YEAR 40				
Bears > 2.0	7.0%	14.0%	12.7%	14.6%
Males	9.1%	22.0%	18.0%	25.1%
Females	4.9%	9.9%	9.5%	9.9%
Bears > 5.0	6.0%	12.0%	13.1%	12.8%
Males	9.8%	19.9%	19.6%	26.6%
Females	4.8%	9.1%	10.2%	9.1%
MEAN AGE OF FEMALES >2.0 IN YEAR 40				
In population	8.7	8.7	8.3	8.7
In kill	8.4	7.6	8.9	7.6
MEAN AGE OF MALES >2.0 IN YEAR 40				
In population	7.3	5.8	6.0	4.9
In kill	7.1	5.3	6.4	5.0
PERCENT FEMALES IN YEAR 40				
In population	58%	67%	63%	69%
In kill	40%	47%	48%	47%
AGE WHERE REGRESSION OF PERCENT MALES ON AGE CLASS = 50%				
In year 3	-71.9	11.8	11.3	15.3
In year 5	65.6	9.8	10.0	10.0
In year 7	16.2	8.5	9.3	8.2
In year 10	20.2	7.5	8.8	7.3
In year 15	13.7	7.2	8.6	7.1
In year 20	14.8	7.2	8.6	7.1
In year 40	14.8	7.2	8.6	7.1
SLOPE AND (R SQUARED) VALUES FOR PRECEDING REGRESSIONS				
In year 3	+0.16(0.01)	-1.27(0.94)	-1.73(1.0)	-0.94(0.75)
In year 5	-0.20(0.01)	-1.41(0.87)	-2.00(1.0)	-1.51(0.82)
In year 7	-1.21(0.51)	-1.66(0.85)	-2.26(1.0)	-2.10(0.87)
In year 10	-0.80(0.41)	-2.12(0.91)	-2.57(1.0)	-2.84(0.93)
In year 15	-1.54(0.94)	-2.68(0.98)	-2.82(1.0)	-3.77(0.97)
In year 20	-1.32(1.00)	-2.72(0.99)	-2.84(1.0)	-3.77(0.97)
In year 40	-1.32(1.00)	-2.72(0.99)	-2.84(1.0)	-3.77(0.97)

Figure 1. Input parameters for Scenario 1, a rapidly growing population with low harvest and natural mortality.

SCENARIO 1. This input is for a lightly hunted brown bear population with no natural mortality until age 15 and the reproductive characteristics of the GMU 13 population. This population grows at 2.86%/year and after 40 years has 2228 bears ¶2.0. Males are twice as vulnerable to hunters as females in all age classes.

INITIAL POPULATION (No.)--Suggest using GAPPS or this model to configure initial population as you want it

Age=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Males*	43	32	36	36	27	32	18	20	21	10	22	22	10	24	4	7	11	10
Females*	49	48	28	25	29	24	22	38	31	20	15	7	8	21	14	10	10	7

INITIAL POPULATION (continued)

Age=	20	21	22	23	24	25	26	27	28	29	30		CALCULATED TOTALS
Males*	6	4	1	1	0								397
Females*	8	1	3	1	1								420
												SUM =	817

EXPLOITATION SURVIVORSHIP RATE (PROPORTION NOT SHOT IN EACH AGE CLASS)

Males*	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Females*	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

EXPLOITATION SURVIVORSHIP RATE (continued)

Males*	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Females*	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

NATURAL SURVIVORSHIP RATE (PROPORTION NOT DYING FROM NATURAL MORTALITY)

Males*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8
Females*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8

NATURAL SURVIVORSHIP RATE (continued)

Males*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0
Females*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0

REPRODUCTIVE RATE

Mean Interval in years between successive successful litters* = 4.5 (= period between successful weaning of one litter and production of the next litter that becomes 2 years old; value in GMU 13 is about 4.5 years)

Litter size at age 2* = 1.7 Value in GMU 13 is about 1.7.

Calculated natality rate (cubs weaned/year/adult female)
Recruitment = 0.378

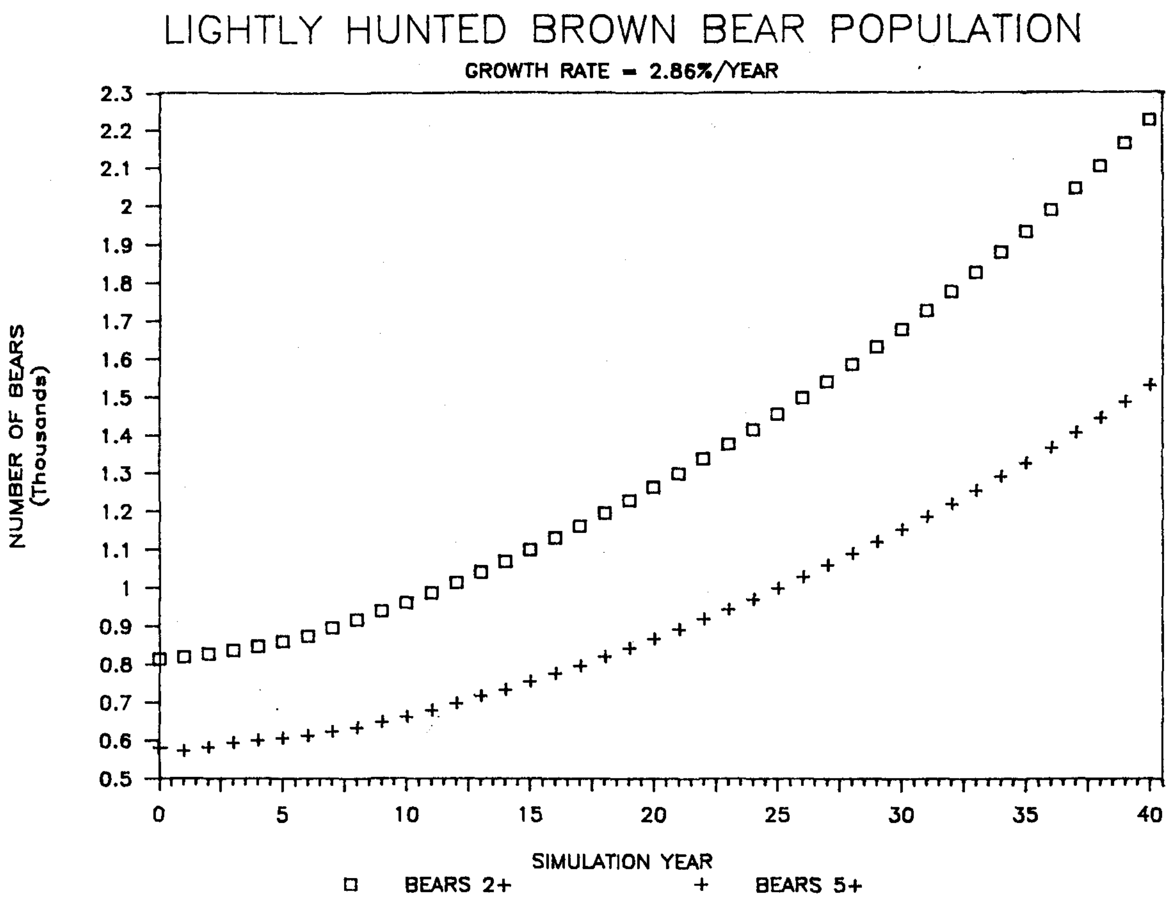
Age at first reproduction (proportion of adult females capable of giving birth by age-class):

Age =	3	4	5	6	7	8	9	10
Proportion* =	0	0.22	0.44	0.89	0.94	1	1	1
GMU 13 example =	(0	0.22	0.44	0.89	0.94	1	1	1)

Sex ratio at weaning
Proportion males* = 0.5

Figure 2. Brown bear population growth rate under scenario 1.

Figure 3. Mean age in kill and in population of brown bear females under scenario 1.


LIGHTLY HUNTED BROWN BEAR POPULATION
GROWTH RATE = 2.86%/YEAR
NUMBER OF BEARS (Thousands)
SIMULATION YEAR
BEARS 2+
BEARS 5+

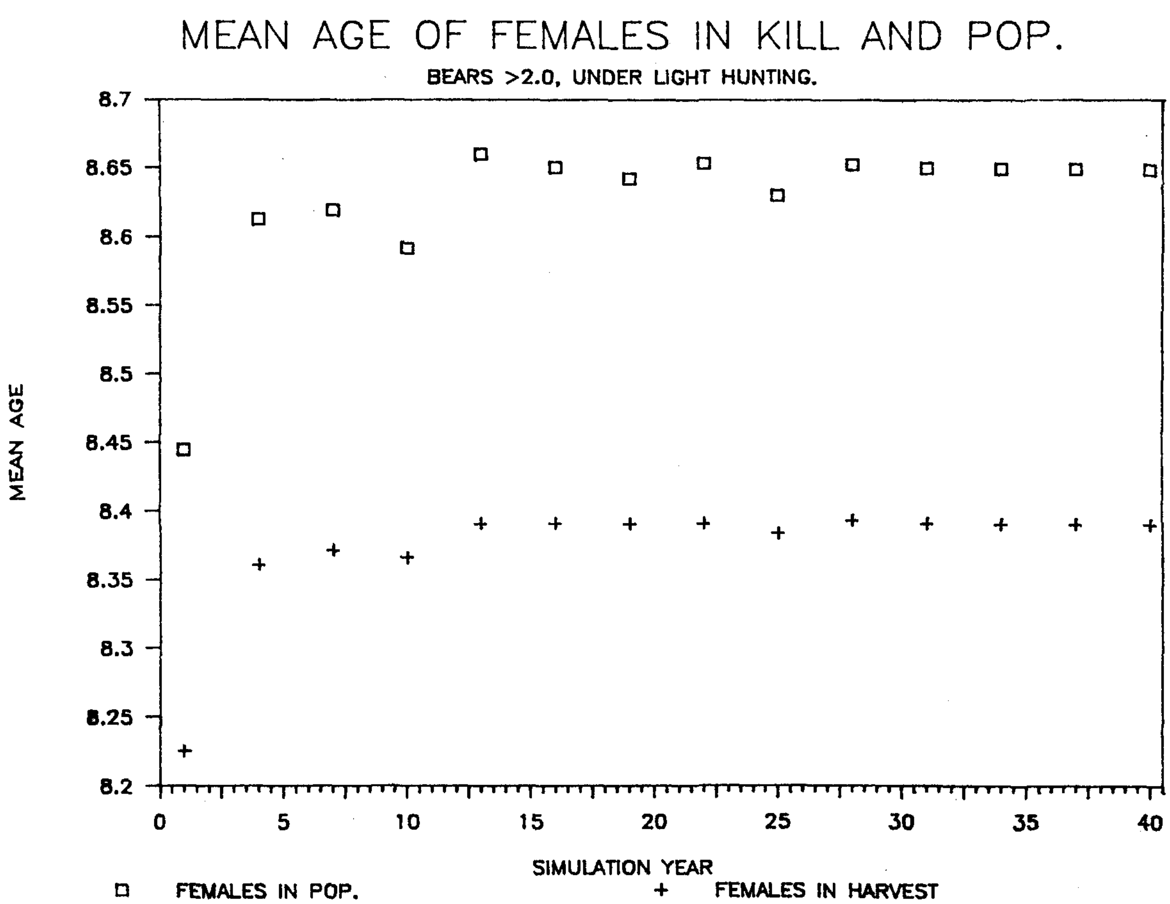
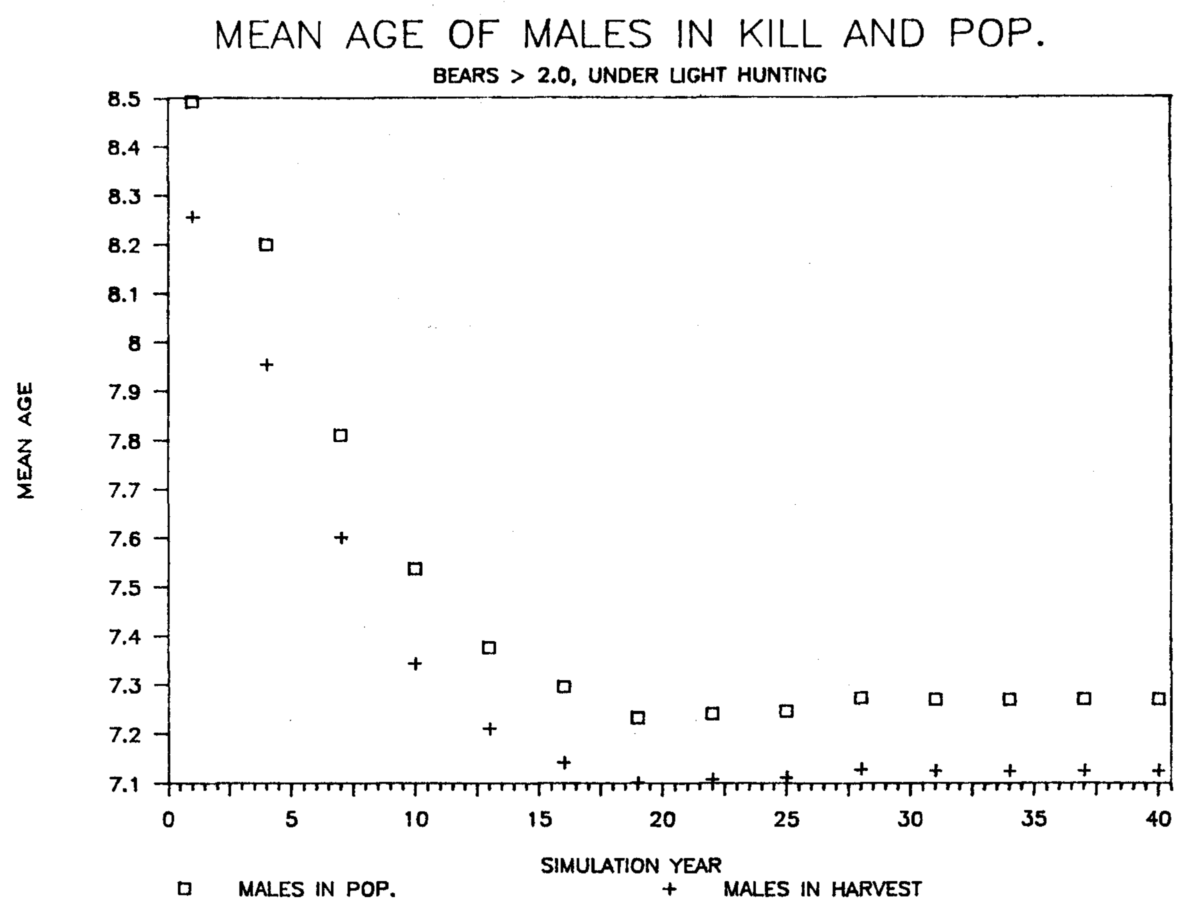

MEAN AGE OF FEMALES IN KILL AND POP.
BEARS >2.0, UNDER LIGHT HUNTING.
MEAN AGE
SIMULATION YEAR
FEMALES IN POP.
FEMALES IN HARVEST

Figure 4. Mean age in kill and in population of brown bear males under scenario 1.

Figure 5. Percent females in kill and in population of brown bear females under scenario 1.


MEAN AGE OF MALES IN KILL AND POP.
BEARS > 2.0, UNDER LIGHT HUNTING
MEAN AGE
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
MALES IN POP.
+ MALES IN HARVEST

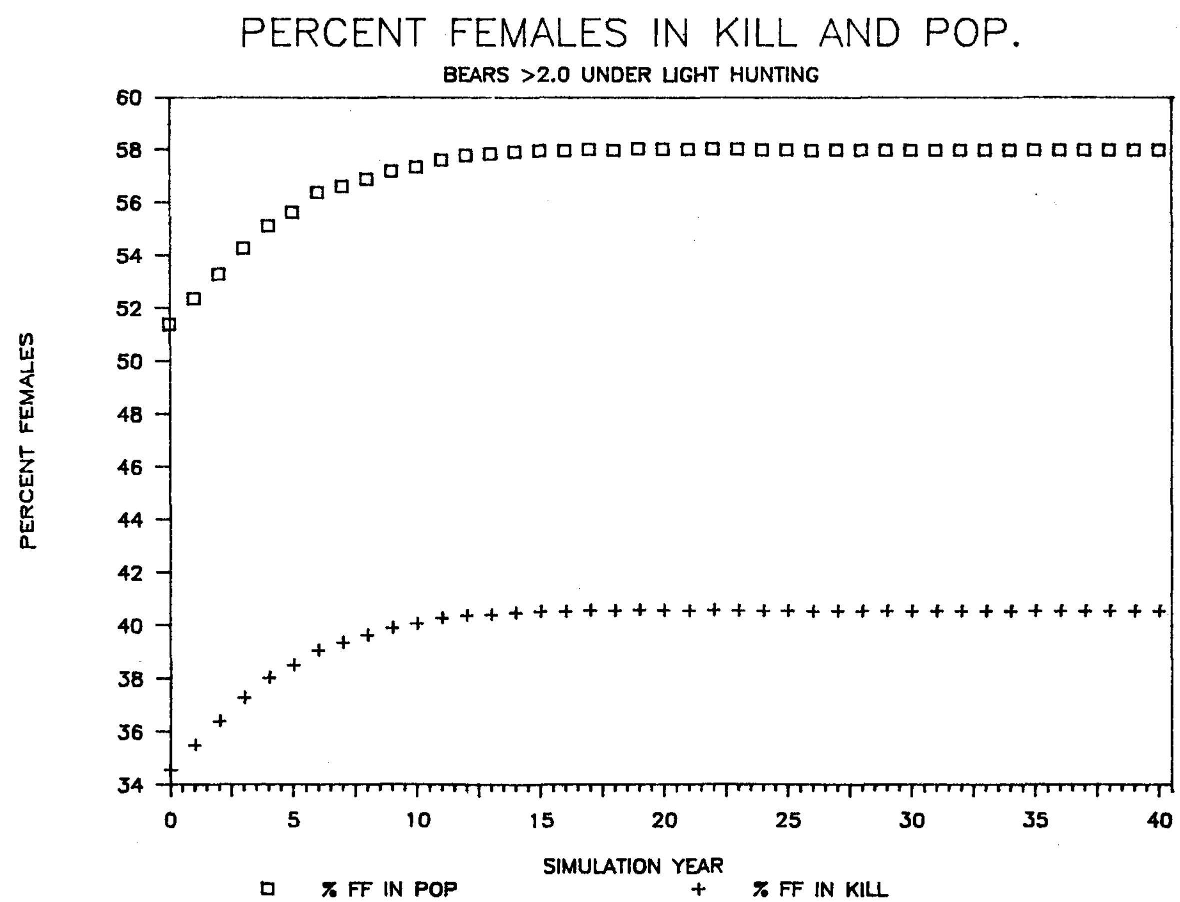

PERCENT FEMALES IN KILL AND POP.
BEARS >2.0 UNDER LIGHT HUNTING
PERCENT FEMALES
60
58
56
54
52
50
48
46
44
42
40
38
36
34
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
% FF IN POP
+ % FF IN KILL

Figure 6. Input parameters for Scenario 2 in which the growing population from Scenario 1 is subjected to heavy hunting pressure.

SCENARIO 2. This input illustrates increased hunting pressure on a formerly lightly hunted populations that was growing at 2.86%/year. Older animals are progressively LESS vulnerable than younger ones, but males remain twice as vulnerable as females and natural mortality remains low like previously. Pop. declines from 2228 to 700 in 40 years ending at -2.6% growth/year. Reproductive parameters identical to Scenario 1.

INITIAL POPULATION (No.)--Suggest using GAPPS or this model to configure initial population as you want it

Age=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Males*	128.5	112.5	98.4	86.1	75.3	65.9	57.7	50.4	44.1	38.6	33.8	29.6	25.9	22.6	17.8	14.0	11.1	8.7
Females*	128.5	118.7	109.6	101.2	93.5	86.3	79.7	73.7	68.0	62.8	58.1	53.6	49.5	45.6	37.9	31.5	26.3	21.8

INITIAL POPULATION (continued)

Age=	20	21	22	23	24	25	26	27	28	29	30		CALCULATED TOTALS
Males*	6.1	4.3	3.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0		935.879967
Females*	16.1	11.9	8.8	4.9	2.7	1.5	0.0	0.0	0.0	0.0	0.0		1292.49997
												SUM =	2228.37994

EXPLOITATION SURVIVORSHIP RATE (PROPORTION NOT SHOT IN EACH AGE CLASS)

Males*	0.76	0.76	0.76	0.78	0.78	0.78	0.8	0.8	0.8	0.82	0.82	0.82	0.84	0.84	0.84	0.86	0.86	0.86
Females*	0.88	0.88	0.88	0.89	0.89	0.89	0.9	0.9	0.9	0.91	0.91	0.91	0.92	0.92	0.92	0.93	0.93	0.93

EXPLOITATION SURVIVORSHIP RATE (continued)

Males*	0.88	0.88	0.88	0.9	0.9	0.9	0.92	0.92	0.92	0.92	0.92
Females*	0.94	0.94	0.94	0.95	0.95	0.95	0.96	0.96	0.96	0.96	0.96

NATURAL SURVIVORSHIP RATE (PROPORTION NOT DYING FROM NATURAL MORTALITY)

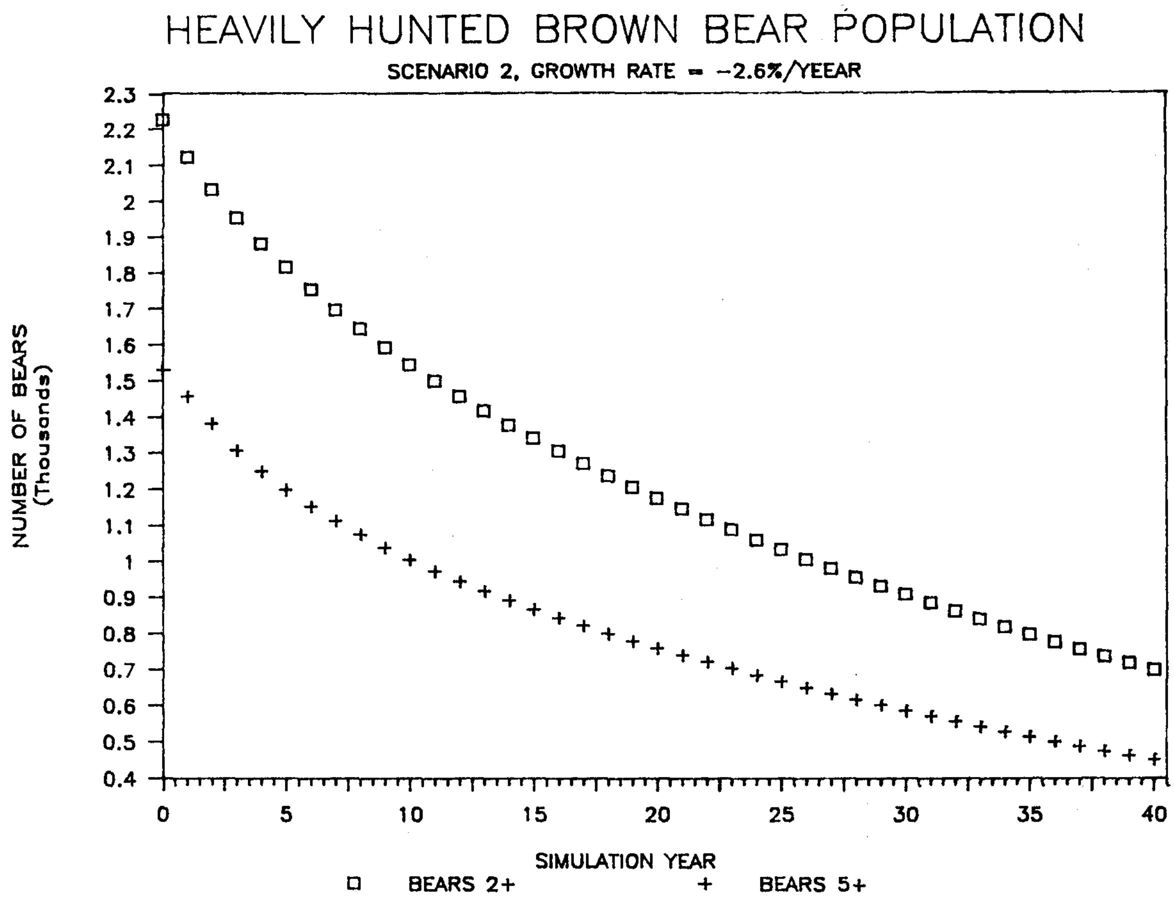
Males*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8
Females*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8

NATURAL SURVIVORSHIP RATE (continued)

Males*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0
Females*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0

Figure 7. Brown bear population growth rate under scenario 2.

Figure 8. Mean age in kill and in population of brown bear females under scenario 2.


HEAVILY HUNTED BROWN BEAR POPULATION
SCENARIO 2, GROWTH RATE = -2.6%/YEEAR
NUMBER OF BEARS (Thousands)
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
BEARS 2+
BEARS 5+

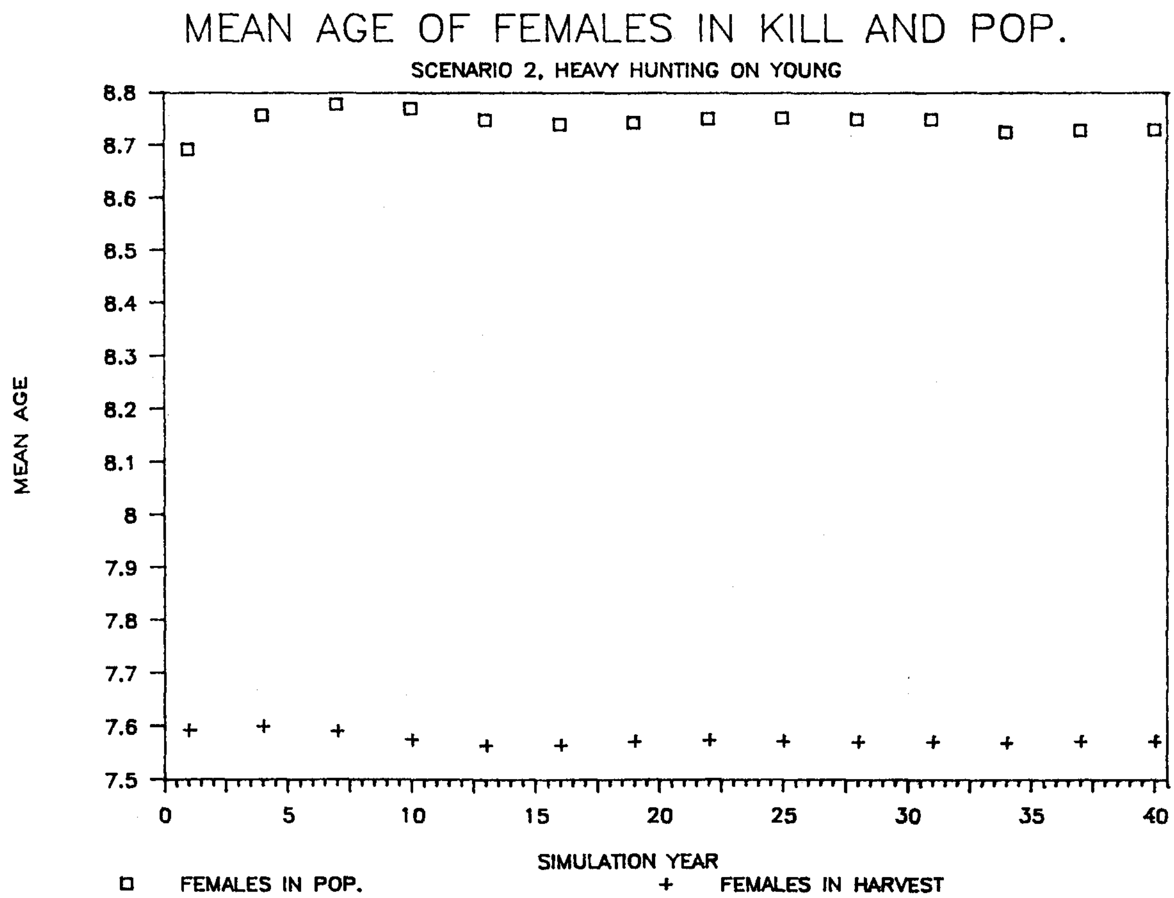
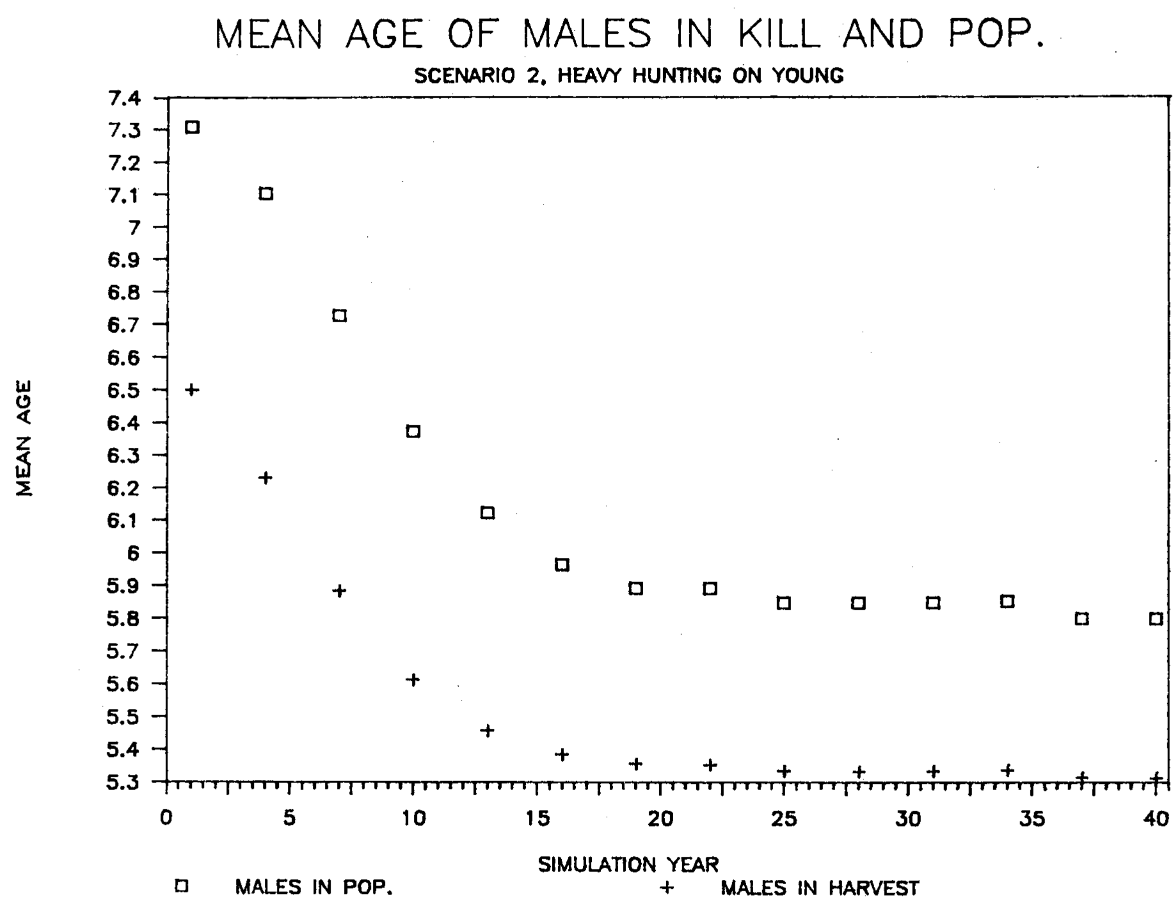

MEAN AGE OF FEMALES IN KILL AND POP.
SCENARIO 2, HEAVY HUNTING ON YOUNG
MEAN AGE
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
FEMALES IN POP.
FEMALES IN HARVEST

Figure 9. Mean age in kill and in population of brown bear males under scenario 2.

Figure 10. Percent females in kill and in population of brown bear females under scenario 1.


MEAN AGE OF MALES IN KILL AND POP.
SCENARIO 2, HEAVY HUNTING ON YOUNG
MEAN AGE
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
MALES IN POP.
MALES IN HARVEST

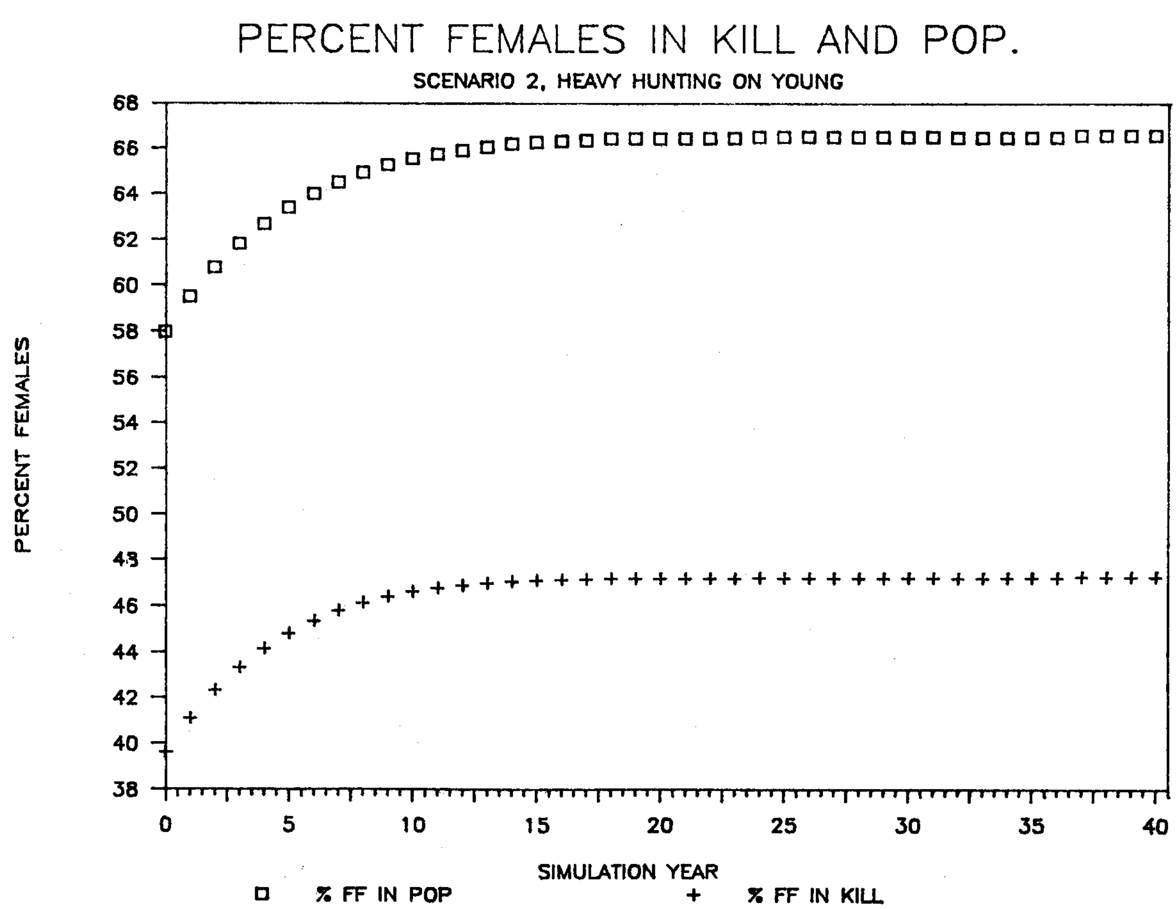

PERCENT FEMALES IN KILL AND POP.
SCENARIO 2, HEAVY HUNTING ON YOUNG
PERCENT FEMALES
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
% FF IN POP
% FF IN KILL

Figure 11. Input parameters for Scenario 3 which is like Scenario 2 except that older animals are progressively more vulnerable than younger animals.

SCENARIO 3. This input illustrates overhunting on a formerly lightly hunted populations that was growing at 2.86%/year. Older animals are progressively LESS vulnerable than younger ones, but males remain twice as vulnerable as females and natural mortality remains low like previously. Pop. declines from 2228 to 700 in 40 years ending at -2.6% growth/year. Reproductive parameters identical to Scenario 1.

INITIAL POPULATION (No.)--Suggest using GAPPS or this model to configure initial population as you want it

Age=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Males*	128.5	112.5	98.4	86.1	75.3	65.9	57.7	50.4	44.1	38.6	33.8	29.6	25.9	22.6	17.8	14.0	11.1	8.7
Females*	128.5	118.7	109.6	101.2	93.5	86.3	79.7	73.7	68.0	62.8	58.1	53.6	49.5	45.6	37.9	31.5	26.3	21.8

INITIAL POPULATION (continued)

Age=	20	21	22	23	24	25	26	27	28	29	30		CALCULATED TOTALS
Males*	6.1	4.3	3.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0		935.879967
Females*	16.1	11.9	8.8	4.9	2.7	1.5	0.0	0.0	0.0	0.0	0.0		1292.49997
												SUM =	2228.37994

EXPLOITATION SURVIVORSHIP RATE (PROPORTION NOT SHOT IN EACH AGE CLASS)

Males*	0.84	0.84	0.84	0.82	0.82	0.82	0.8	0.8	0.8	0.78	0.78	0.78	0.76	0.76	0.76	0.74	0.74	0.74
Females*	0.92	0.92	0.92	0.91	0.91	0.91	0.9	0.9	0.9	0.89	0.89	0.89	0.88	0.88	0.88	0.87	0.87	0.87

EXPLOITATION SURVIVORSHIP RATE (continued)

Males*	0.72	0.72	0.72	0.7	0.7	0.7	0.68	0.68	0.68	0.68	0.68
Females*	0.86	0.86	0.86	0.85	0.85	0.85	0.84	0.84	0.84	0.84	0.84

NATURAL SURVIVORSHIP RATE (PROPORTION NOT DYING FROM NATURAL MORTALITY)

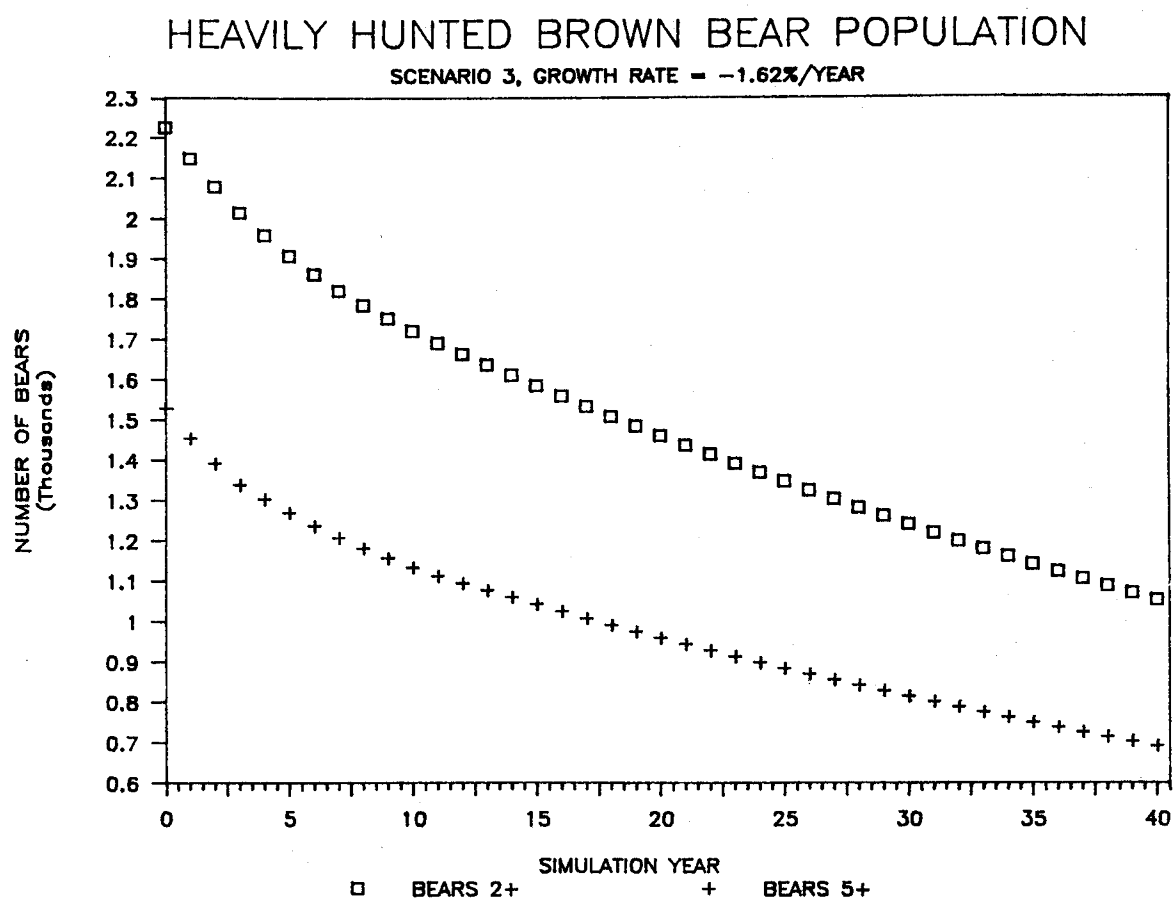
Males*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8
Females*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8

NATURAL SURVIVORSHIP RATE (continued)

Males*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0
Females*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0

Figure 12. Brown bear population growth rate under scenario 3.

Figure 13. Mean age in kill and in population of brown bear females under scenario 3.


HEAVILY HUNTED BROWN BEAR POPULATION
SCENARIO 3, GROWTH RATE = −1.62%/YEAR
NUMBER OF BEARS
(Thousands)
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
BEARS 2+
BEARS 5+

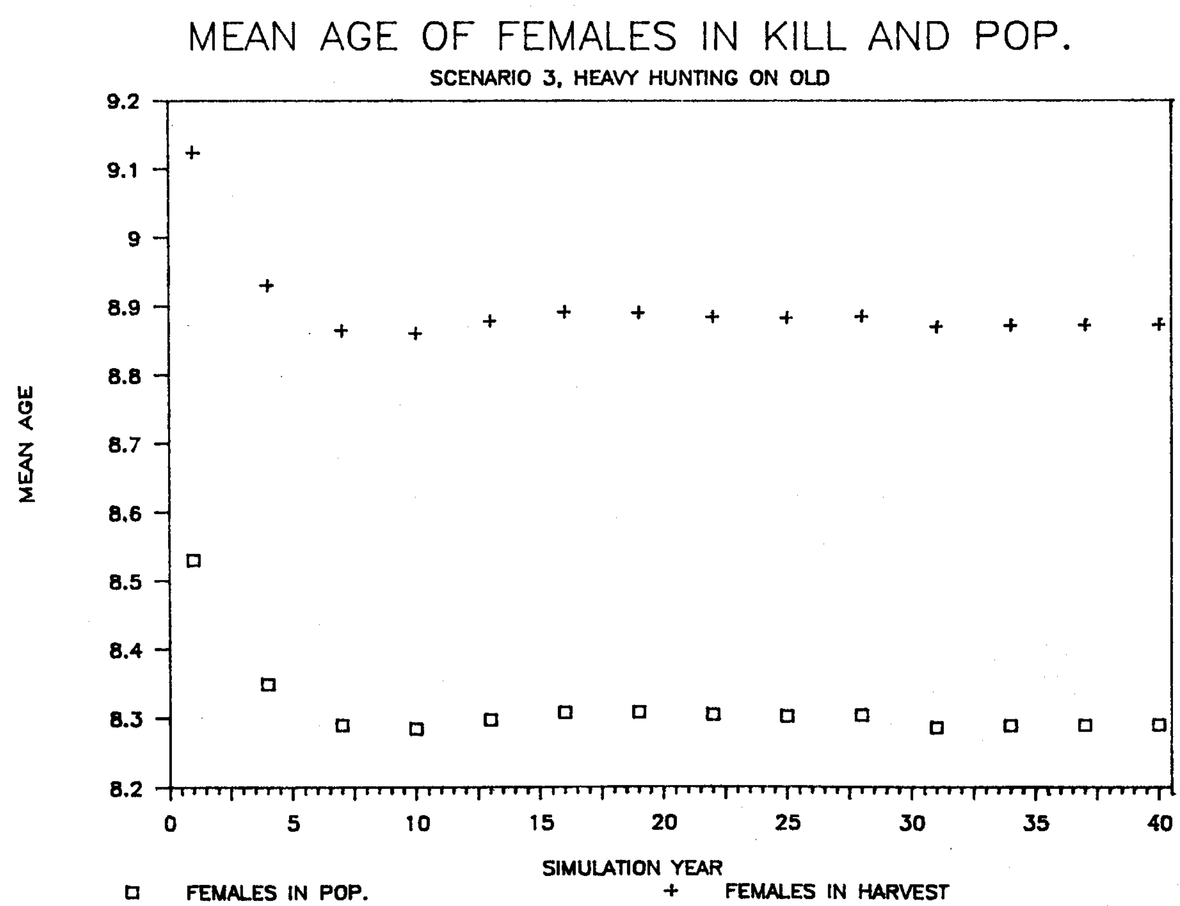
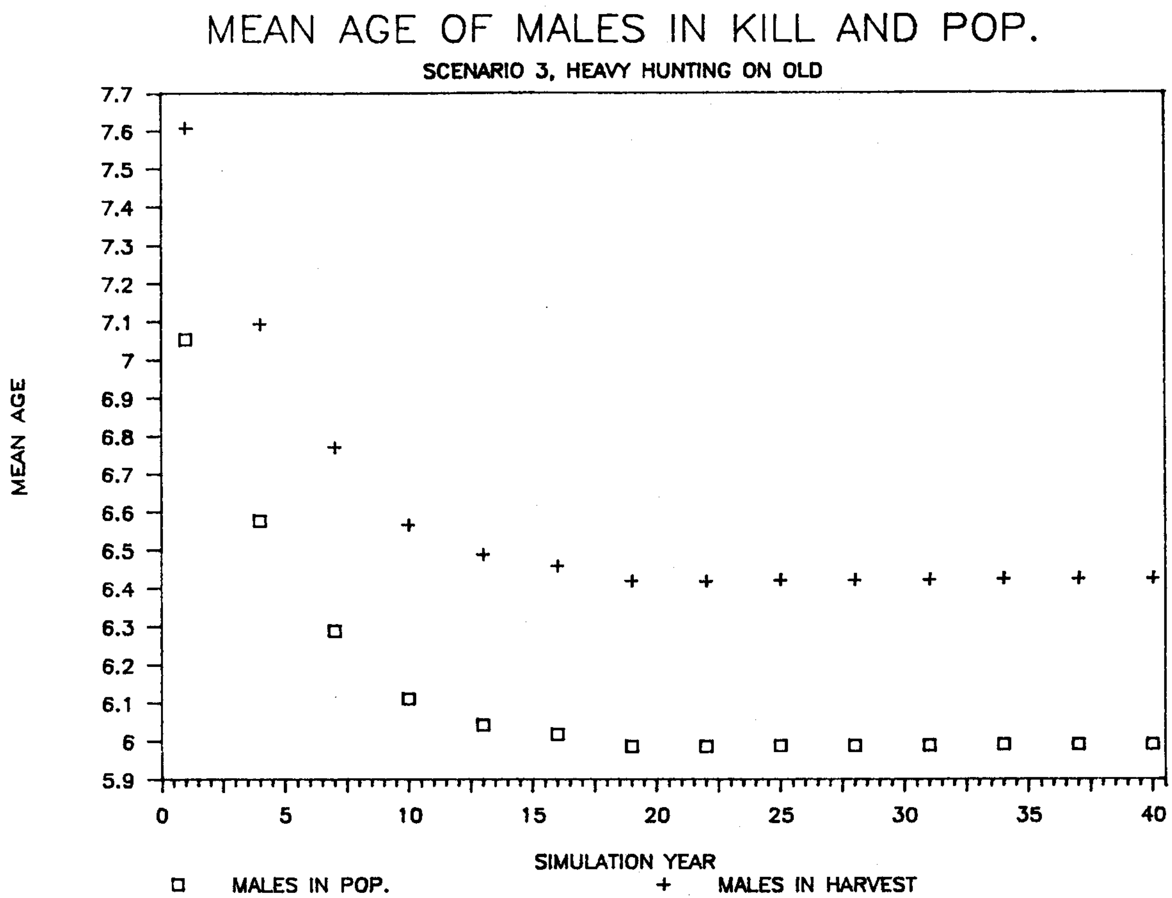

MEAN AGE OF FEMALES IN KILL AND POP.
SCENARIO 3, HEAVY HUNTING ON OLD
MEAN AGE
9.2
9.1
9
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
FEMALES IN POP.
FEMALES IN HARVEST

Figure 14. Mean age in kill and in population of brown bear males under scenario 3.

Figure 15. Percent females in kill and in population of brown bear females under scenario 3.


MEAN AGE OF MALES IN KILL AND POP.
SCENARIO 3, HEAVY HUNTING ON OLD
MEAN AGE
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
5.9
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
MALES IN POP.
MALES IN HARVEST

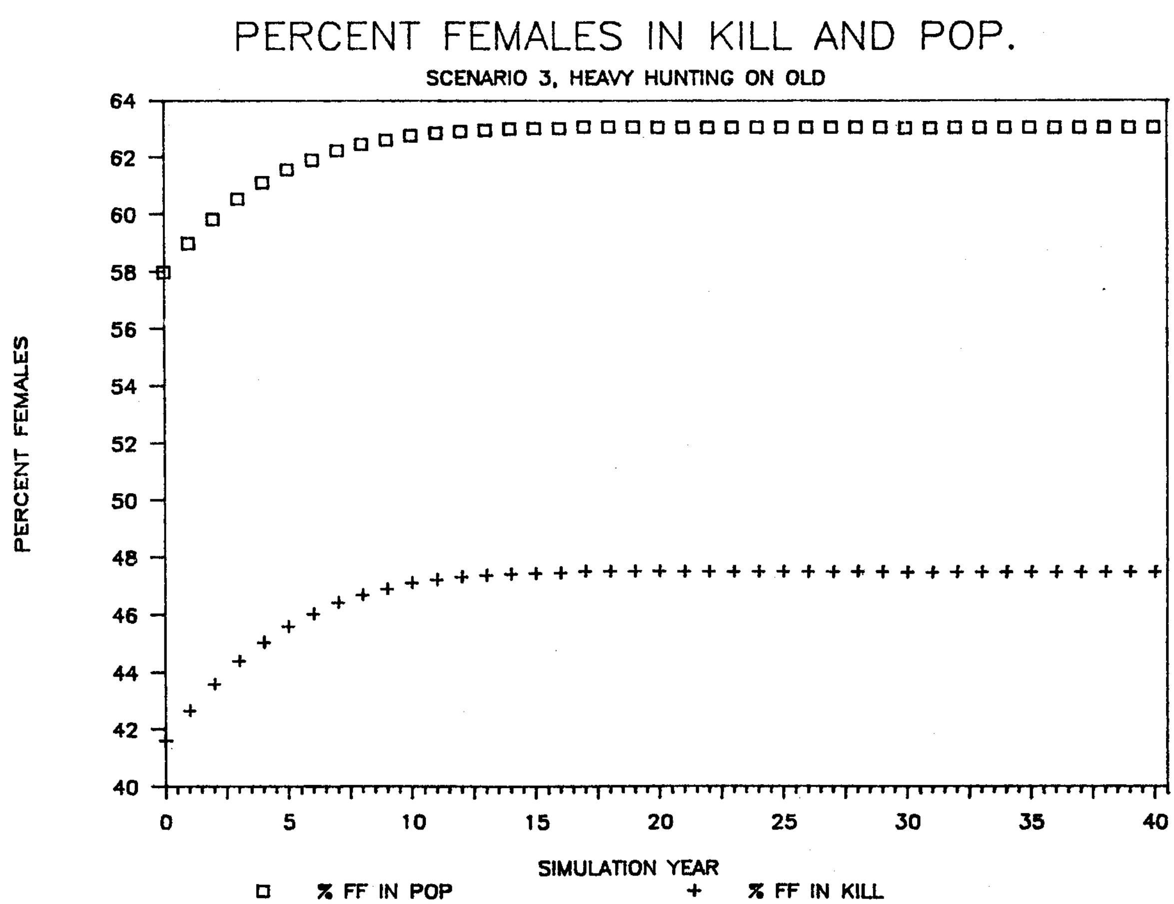

PERCENT FEMALES IN KILL AND POP.
SCENARIO 3, HEAVY HUNTING ON OLD
PERCENT FEMALES
64
62
60
58
56
54
52
50
48
46
44
42
40
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
% FF IN POP
% FF IN KILL

Figure 16. Input parameters for Scenario 4 which is like Scenario 2 (young animals more vulnerable than older ones) with the addition that older males become progressively more vulnerable.

SCENARIO 4. This input illustrates increased hunting pressure on a formerly lightly hunted populations that was growing at 2.86%/year. Older animals are progressively vulnerable than younger ones, but males become progressively more vulnerable relative to females in the older age classes. Natural mortality remains low. Population is declining at -2.56% per year at end of 40 years. Reproductive parameters identical to Scenario 1.

INITIAL POPULATION (No.)--Suggest using GAPPS or this model to configure initial population as you want it

Age=	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Males*	128.5	112.5	98.4	86.1	75.3	65.9	57.7	50.4	44.1	38.6	33.8	29.6	25.9	22.6	17.8	14.0	11.1	8.7
Females*	128.5	118.7	109.6	101.2	93.5	86.3	79.7	73.7	68.0	62.8	58.1	53.6	49.5	45.6	37.9	31.5	26.3	21.8

INITIAL POPULATION (continued)

Age=	20	21	22	23	24	25	26	27	28	29	30		CALCULATED TOTALS
Males*	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		935.87
Females*	16.1	11.9	8.8	4.9	2.7	1.5	0.0	0.0	0.0	0.0	0.0		1292.49997
												SUM =	2228.37994

EXPLOITATION SURVIVORSHIP RATE (PROPORTION NOT SHOT IN EACH AGE CLASS)

Males*	0.76	0.76	0.76	0.725	0.725	0.725	0.75	0.75	0.75	0.73	0.73	0.73	0.76	0.76	0.76	0.72	0.72	0.72
Females*	0.88	0.88	0.88	0.89	0.89	0.89	0.9	0.9	0.9	0.91	0.91	0.91	0.92	0.92	0.92	0.93	0.93	0.93

EXPLOITATION SURVIVORSHIP RATE (continued)

Males*	0.76	0.76	0.76	0.8	0.8	0.8	0.84	0.84	0.84	0.84	0.84
Females*	0.94	0.94	0.94	0.95	0.95	0.95	0.96	0.96	0.96	0.96	0.96

NATURAL SURVIVORSHIP RATE (PROPORTION NOT DYING FROM NATURAL MORTALITY)

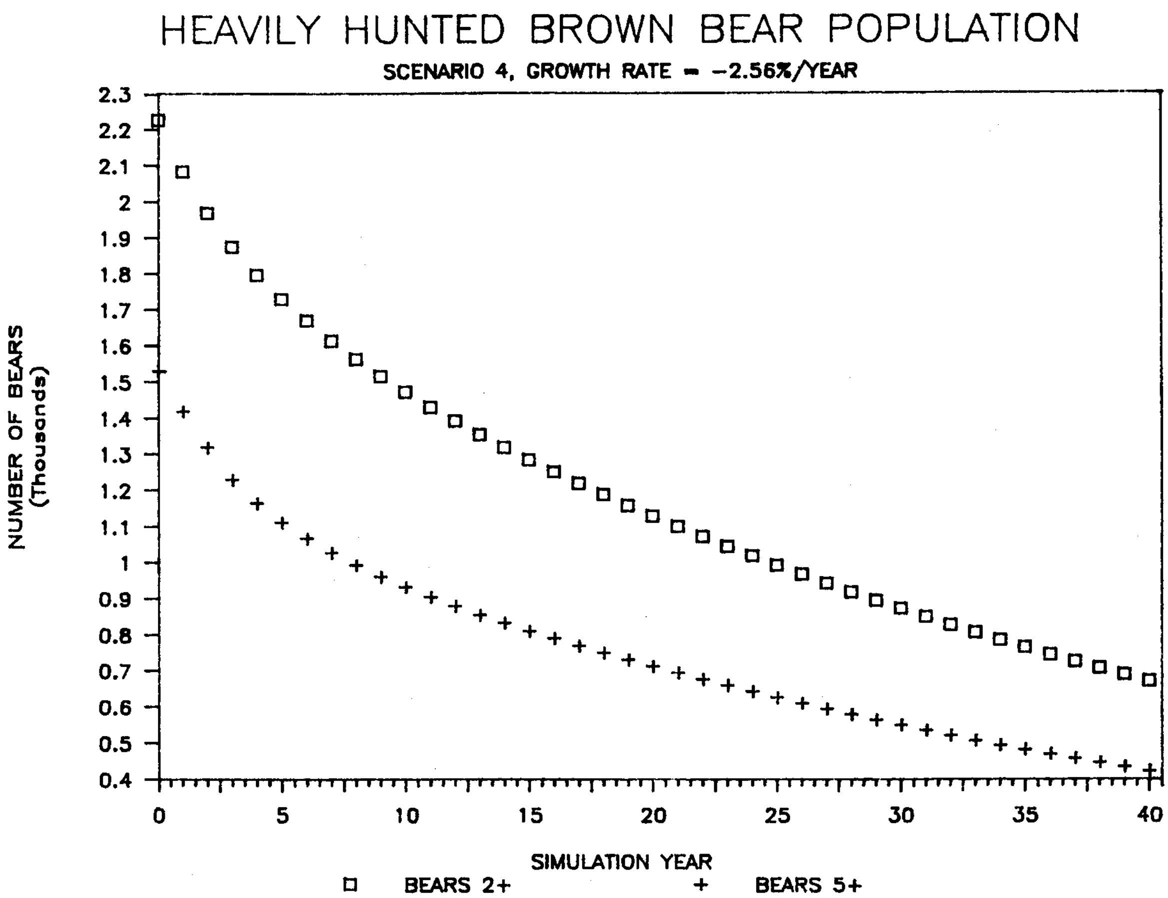
Males*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8
Females*	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	0.9	0.9	0.9	0.8

NATURAL SURVIVORSHIP RATE (continued)

Males*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0
Females*	0.8	0.8	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.1	0

Figure 17. Brown bear population growth rate under scenario 4.

Figure 18. Mean age in kill and in population of brown bear females under scenario 4.


HEAVILY HUNTED BROWN BEAR POPULATION
SCENARIO 4, GROWTH RATE = -2.56%/YEAR
NUMBER OF BEARS
(Thousands)
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
BEARS 2+
BEARS 5+

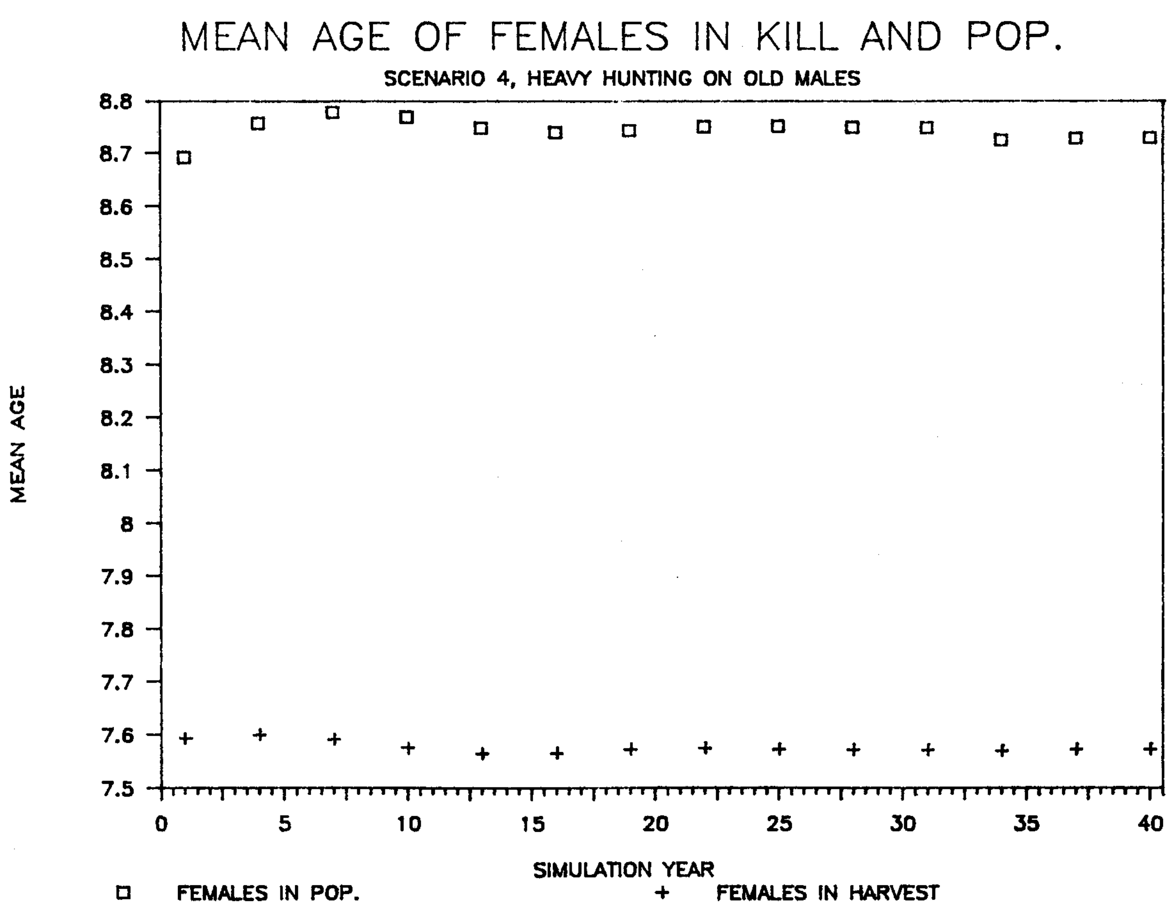
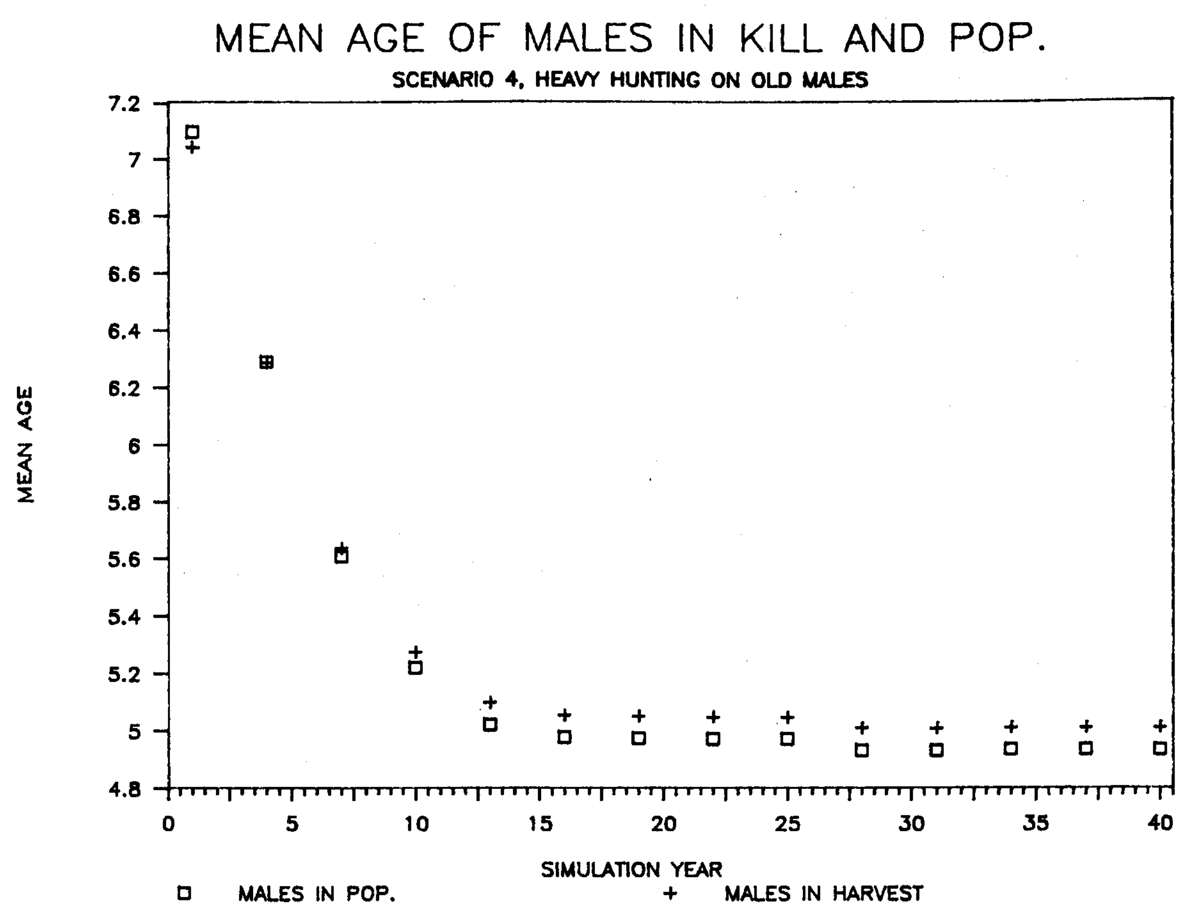

MEAN AGE OF FEMALES IN KILL AND POP.
SCENARIO 4, HEAVY HUNTING ON OLD MALES
MEAN AGE
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
FEMALES IN POP.
FEMALES IN HARVEST

Figure 19. Mean age in kill and in population of brown bear males under scenario 4.

Figure 20. Percent females in kill and in population or brown bear females under scenario 4.


MEAN AGE OF MALES IN KILL AND POP.
SCENARIO 4, HEAVY HUNTING ON OLD MALES
MEAN AGE
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
MALES IN POP.
MALES IN HARVEST

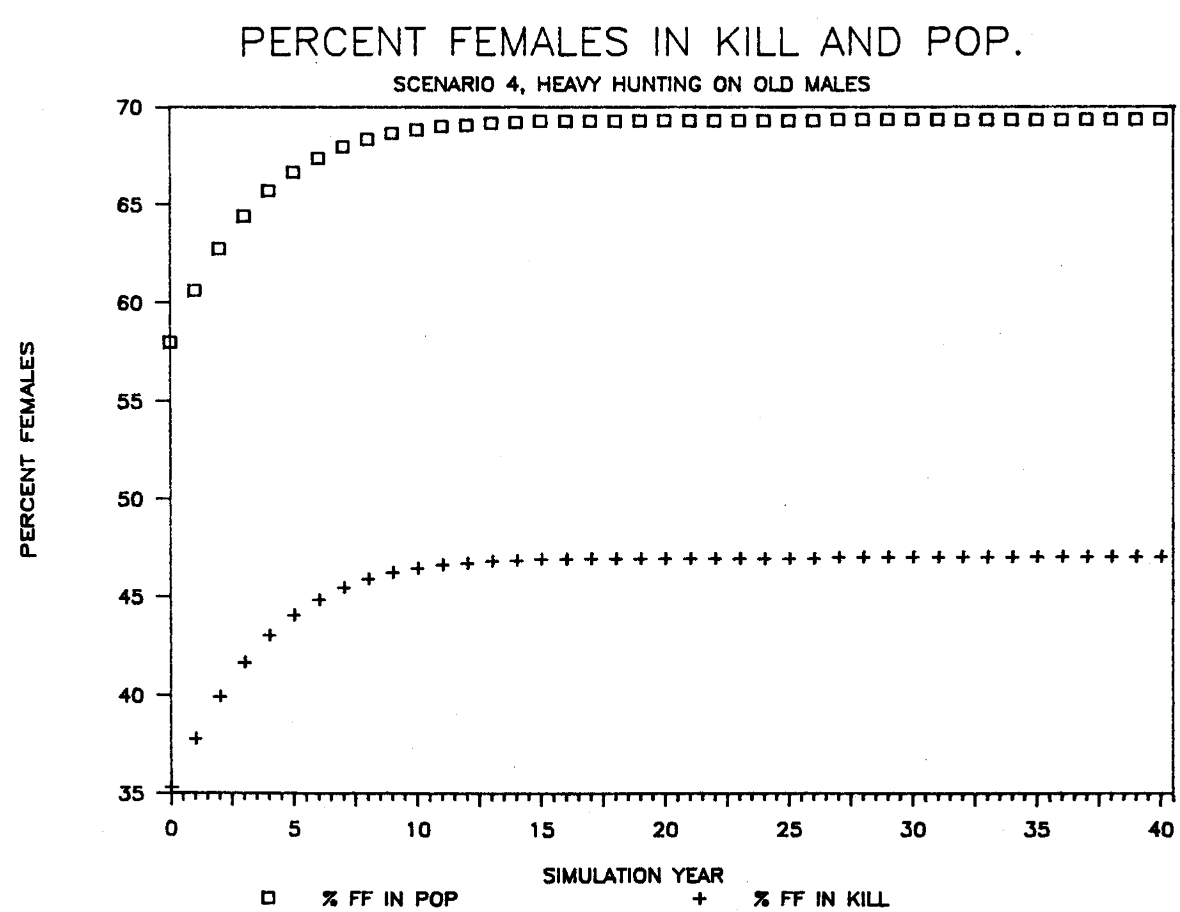
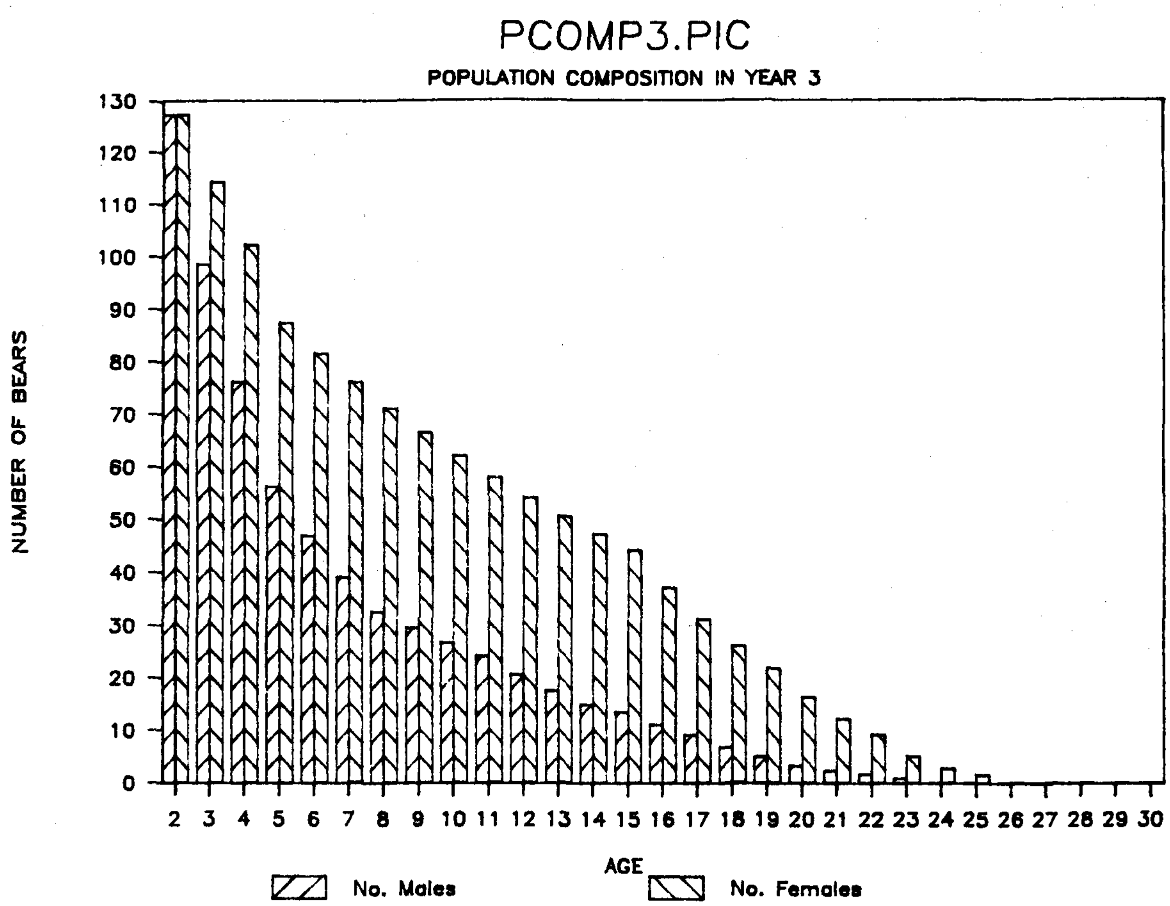

PERCENT FEMALES IN KILL AND POP.
SCENARIO 4, HEAVY HUNTING ON OLD MALES
PERCENT FEMALES
70
65
60
55
50
45
40
35
0
5
10
15
20
25
30
35
40
SIMULATION YEAR
% FF IN POP
% FF IN KILL

Figure 21. Population composition in year 3 of scenario 4.

Figure 22. Harvest composition in year 3 of scenario 4. Arrow indicates last age class where number of males harvested exceed number of females harvested.


PCOMP3.PIC
POPULATION COMPOSITION IN YEAR 3
NUMBER OF BEARS
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
AGE
No. Males
No. Females

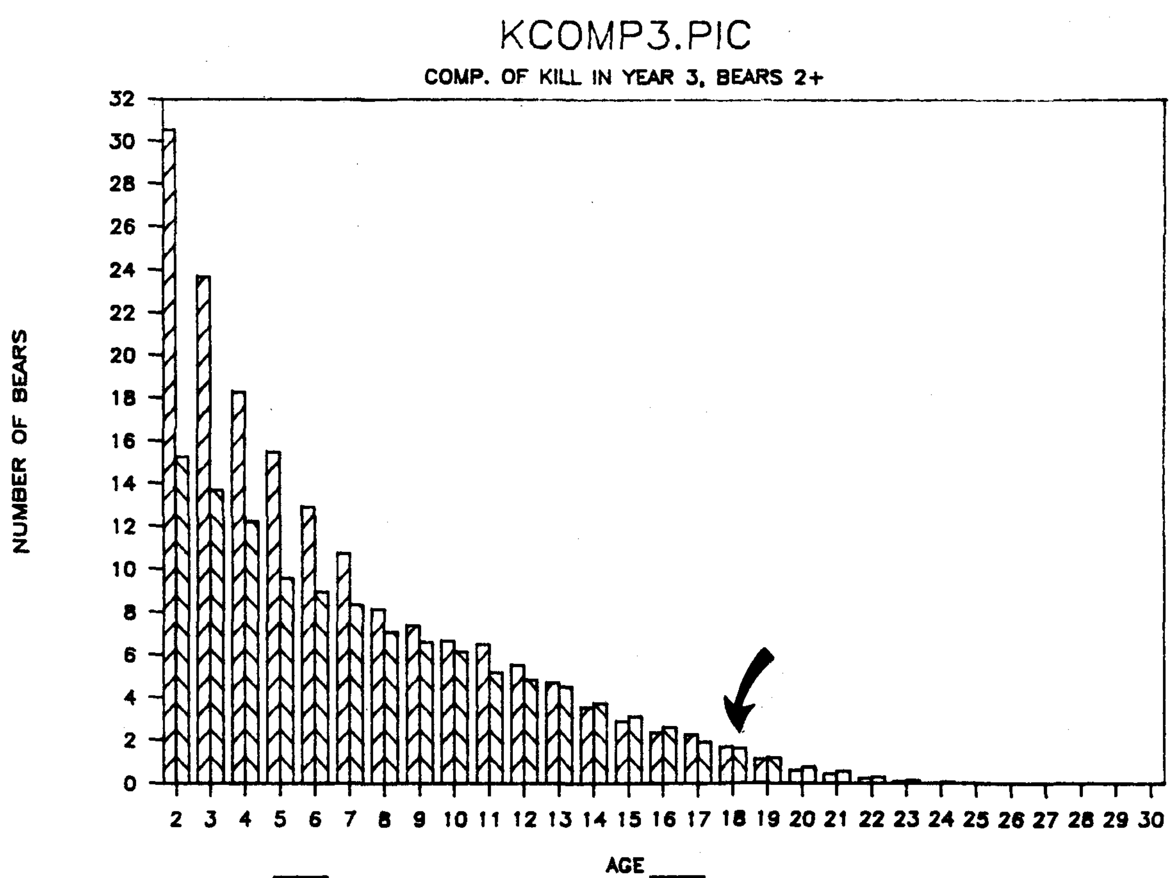
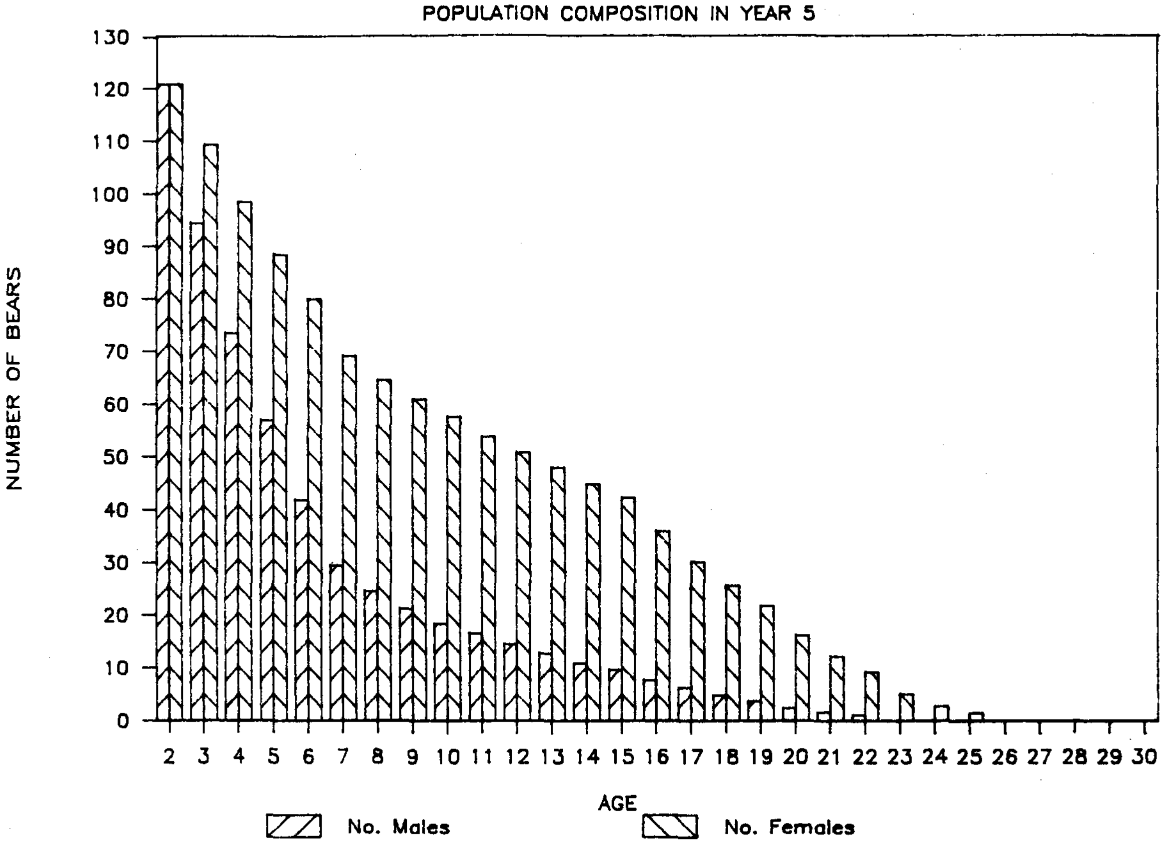

KCOMP3.PIC
COMP. OF KILL IN YEAR 3, BEARS 2+
NUMBER OF BEARS
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
AGE
No. Males
No. Females

Figure 23. Population composition in year 5 of scenario 4.

Figure 24. Harvest composition in year 5 of scenario 4. Arrow indicates last age class where number of males harvested exceed number of females harvested.

PCOMP5.PIC



KCOMP5.PIC

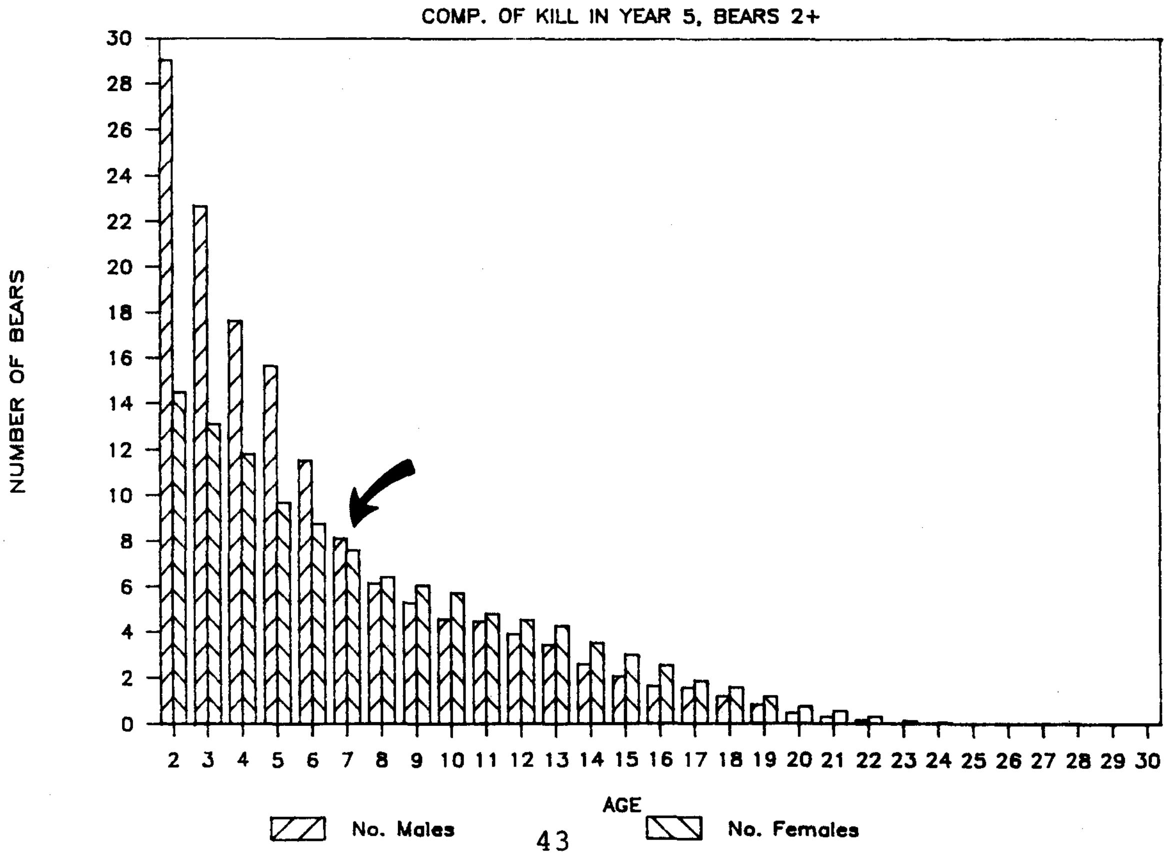
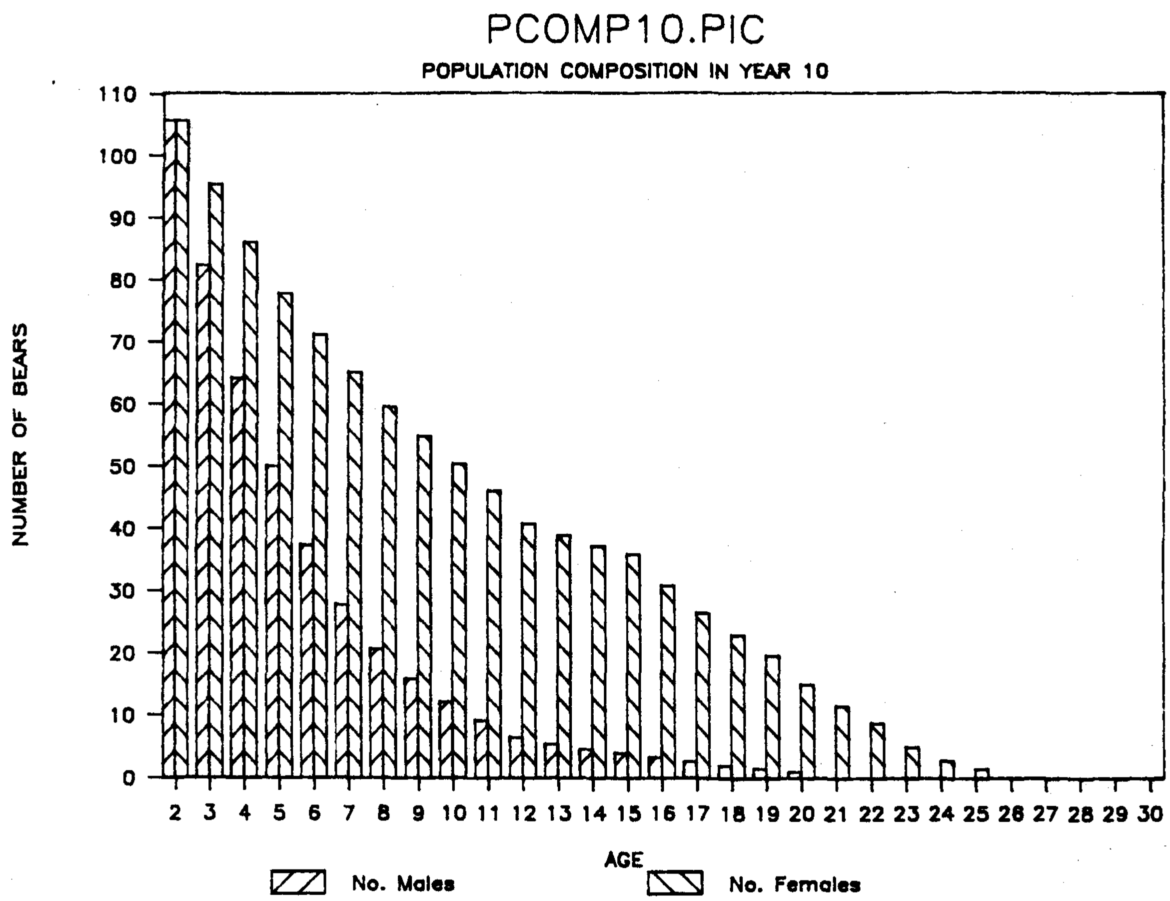
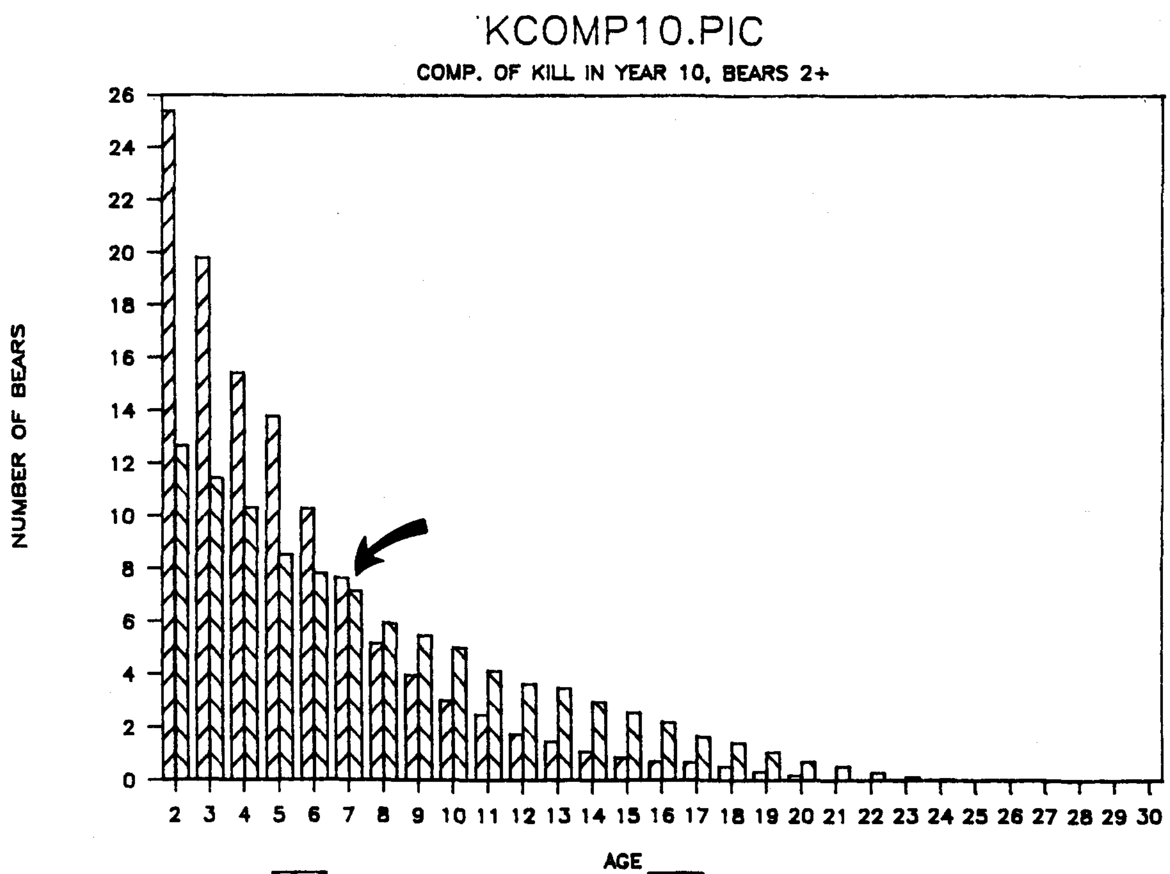


Figure 25. Population composition in year 10 of scenario 4.

Figure 26. Harvest composition in year 10 of scenario 4. Arrow indicates last age class where number of males harvested exceed number of females harvested.



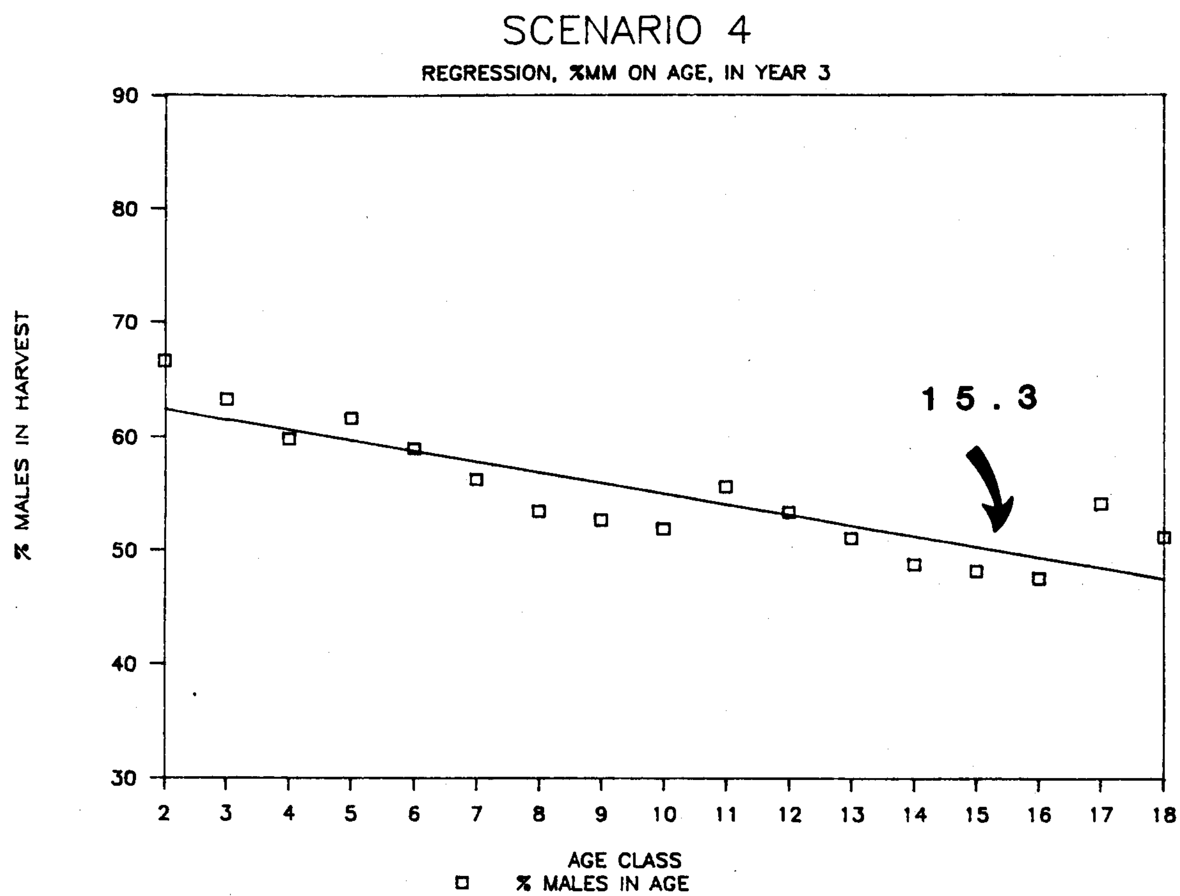
PCOMP10.PIC
POPULATION COMPOSITION IN YEAR 10
NUMBER OF BEARS
0
10
20
30
40
50
60
70
80
90
100
110
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
AGE
No. Males
No. Females



KCOMP10.PIC
COMP. OF KILL IN YEAR 10, BEARS 2+
NUMBER OF BEARS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
AGE
No. Males
No. Females

Figure 27. Regression of percent males harvested on age class in year 3 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.

Figure 28. Regression of percent males harvested on age class in year 5 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.


SCENARIO 4
REGRESSION, %MM ON AGE, IN YEAR 3
% MALES IN HARVEST
AGE CLASS
% MALES IN AGE
15.3
90
80
70
60
50
40
30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

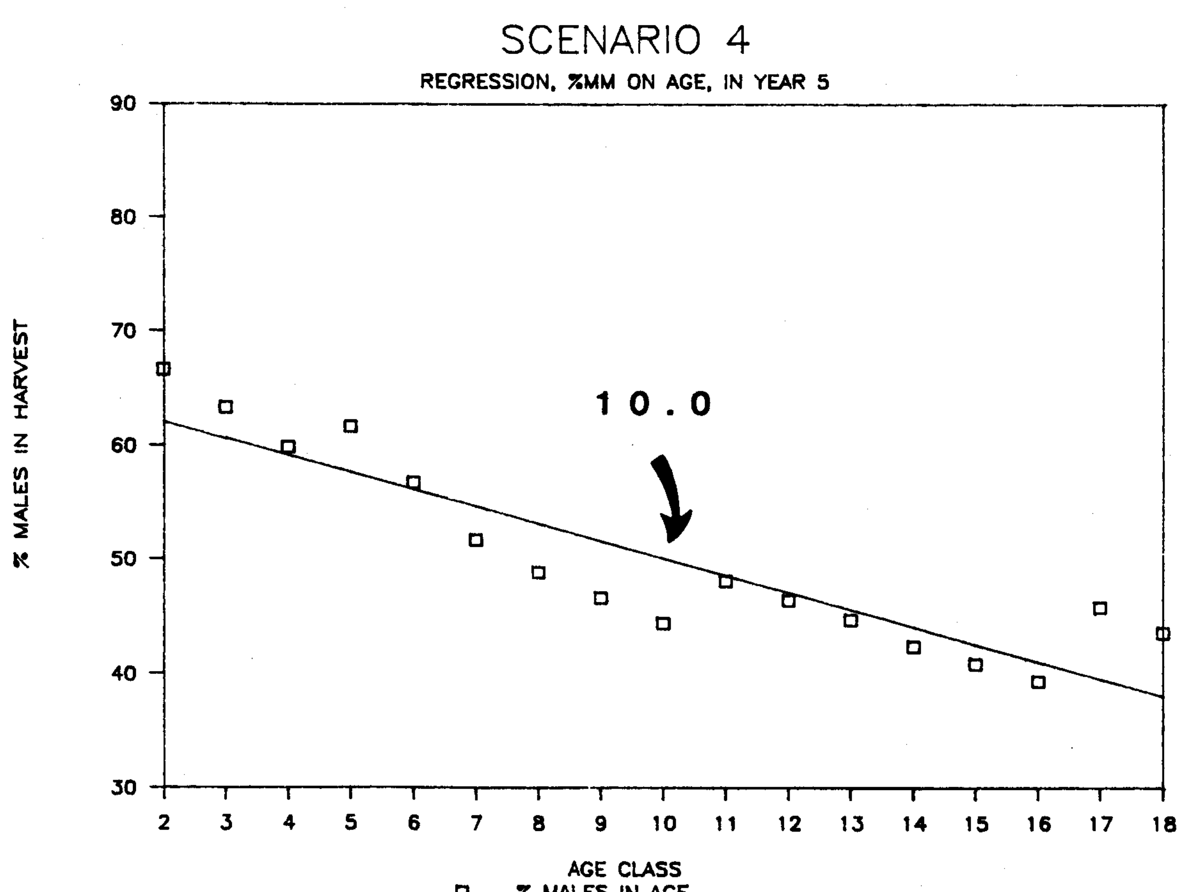
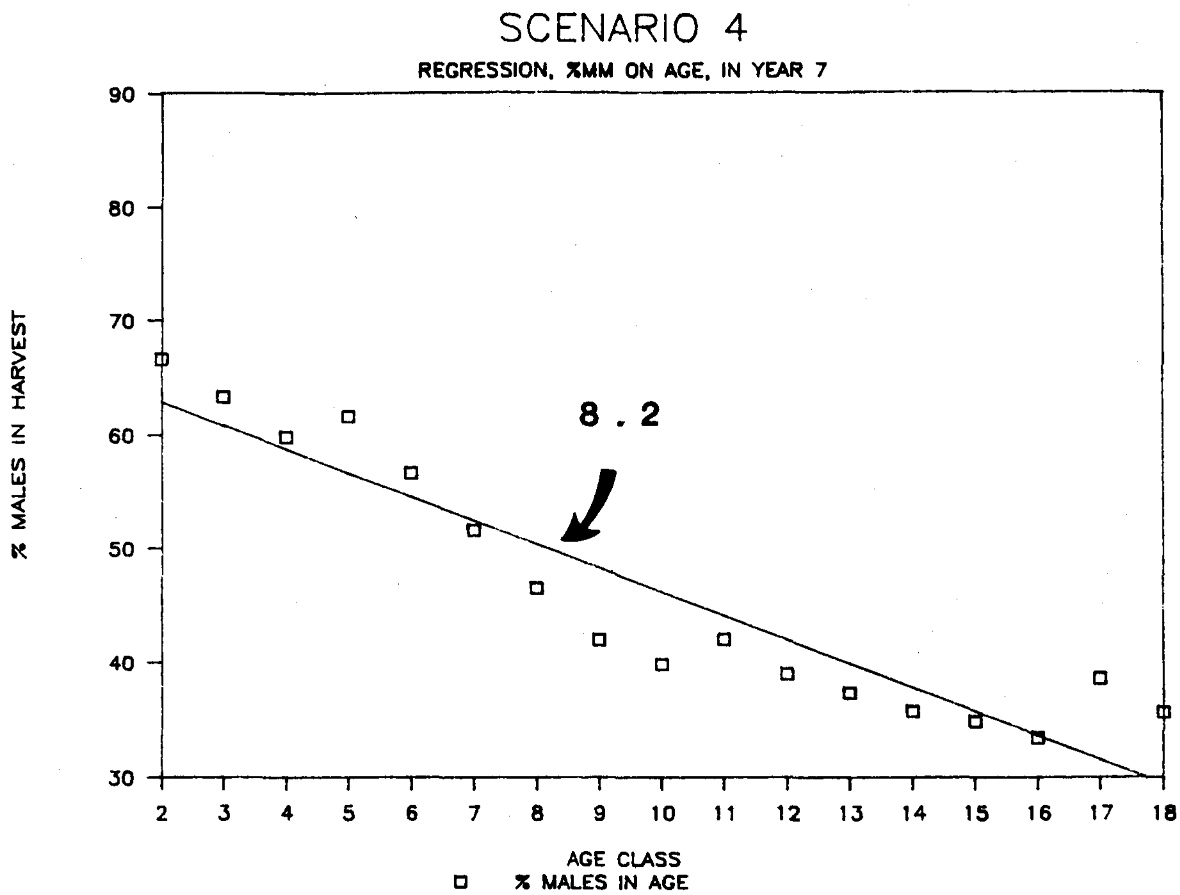

SCENARIO 4
REGRESSION, %MM ON AGE, IN YEAR 5
% MALES IN HARVEST
AGE CLASS
% MALES IN AGE
10.0
90
80
70
60
50
40
30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Figure 29. Regression of percent males harvested on age class in year 7 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.

Figure 30. Regression of percent males harvested on age class in year 10 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.


SCENARIO 4
REGRESSION, %MM ON AGE, IN YEAR 7
% MALES IN HARVEST
90
80
70
60
50
40
30
8 . 2
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
AGE CLASS
% MALES IN AGE

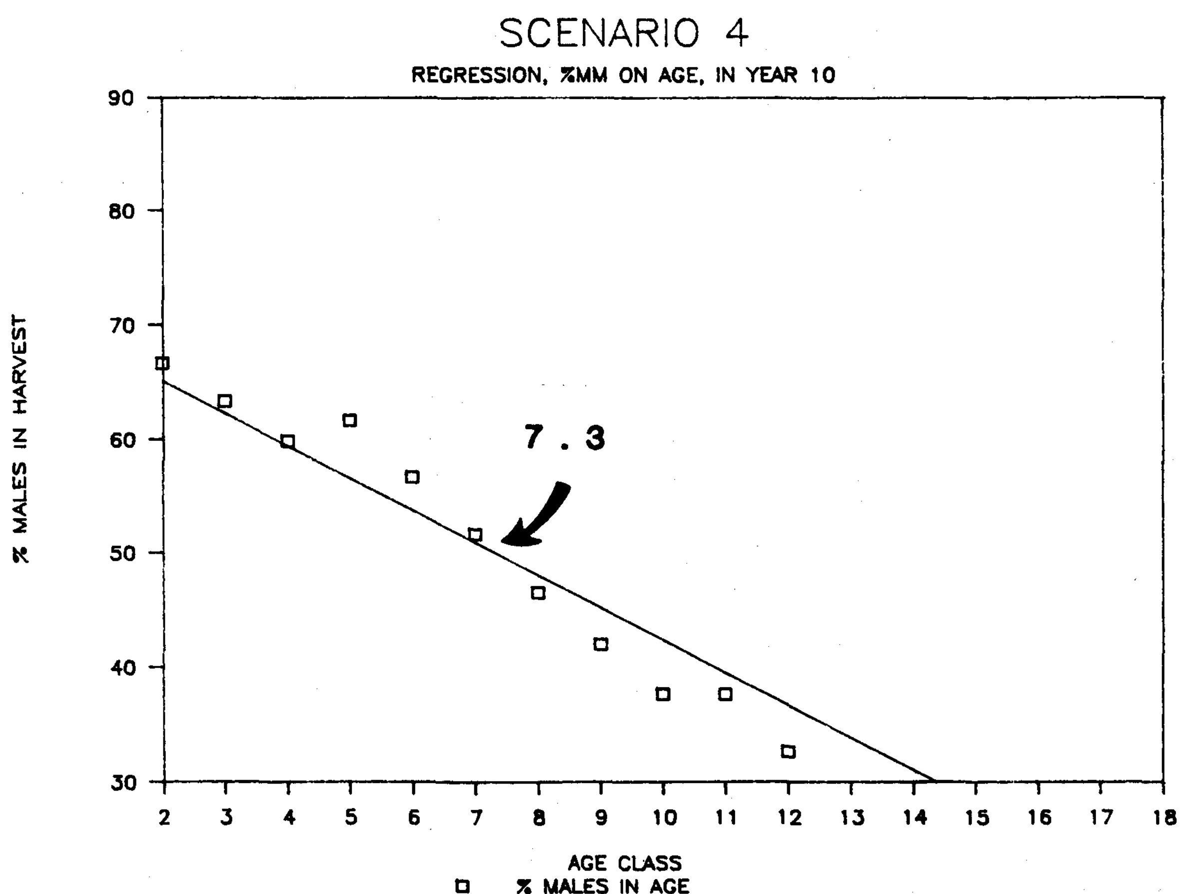
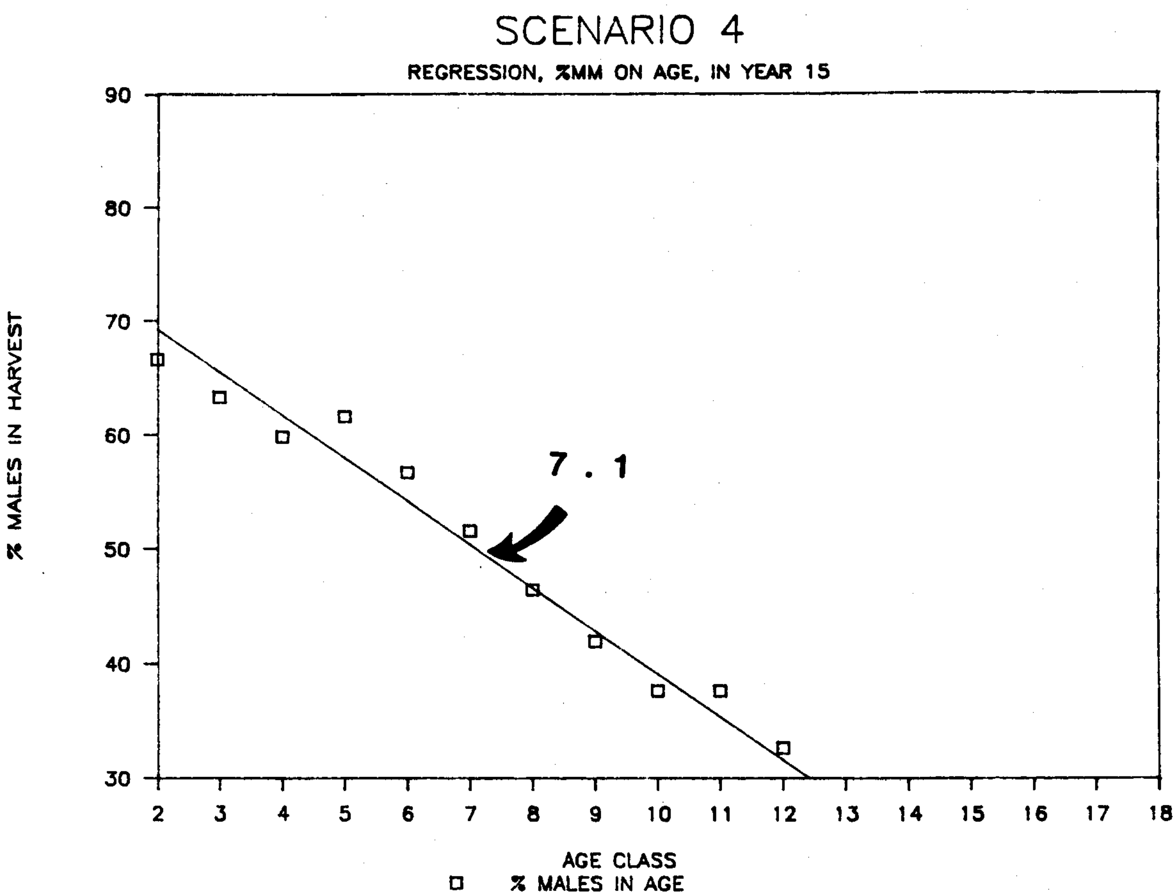

SCENARIO 4
REGRESSION, %MM ON AGE, IN YEAR 10
% MALES IN HARVEST
90
80
70
60
50
40
30
7 . 3
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
AGE CLASS
% MALES IN AGE

Figure 31. Regression of percent males harvested on age class in year 15 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.

Figure 32. Regression of percent males harvested on age class in year 40 of scenario 4. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.


SCENARIO 4
REGRESSION, %MM ON AGE, IN YEAR 15
90
80
70
60
50
40
30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
% MALES IN HARVEST
AGE CLASS
% MALES IN AGE
7 . 1

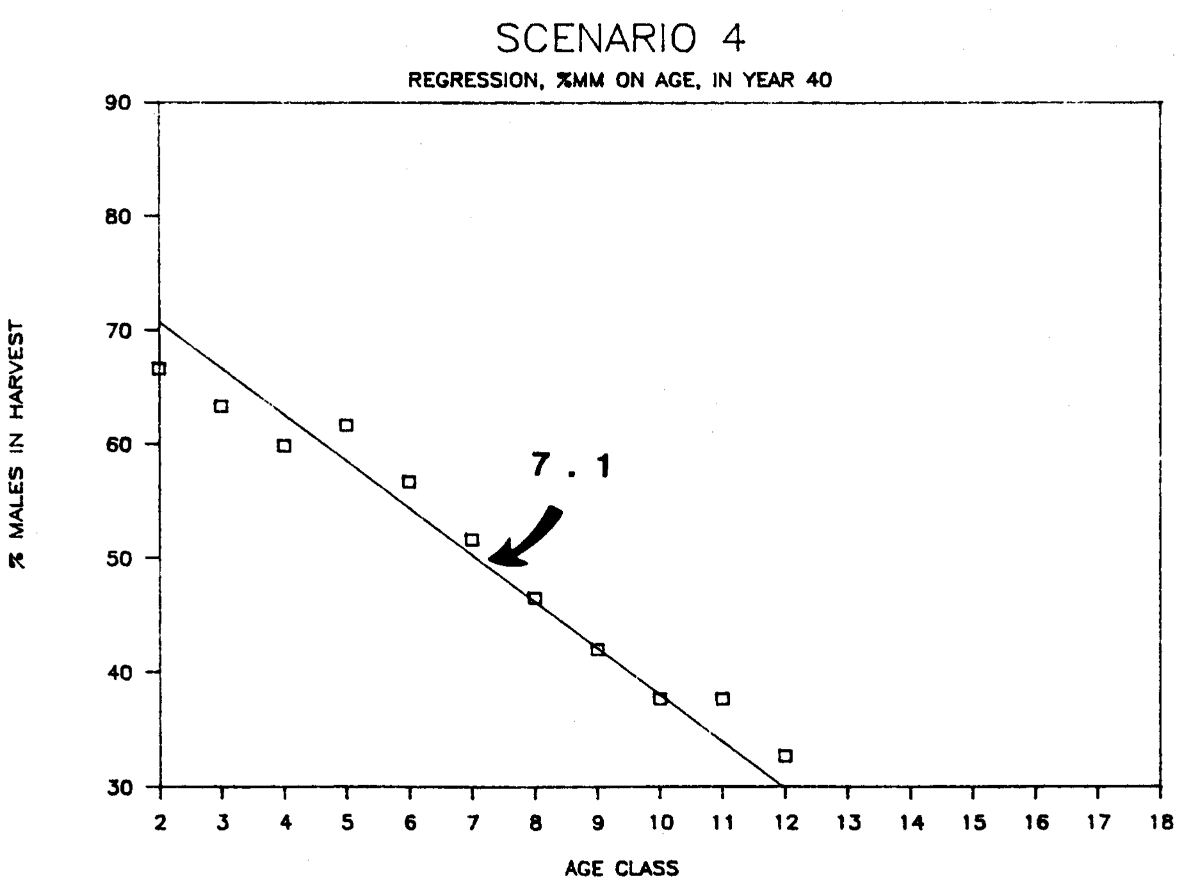
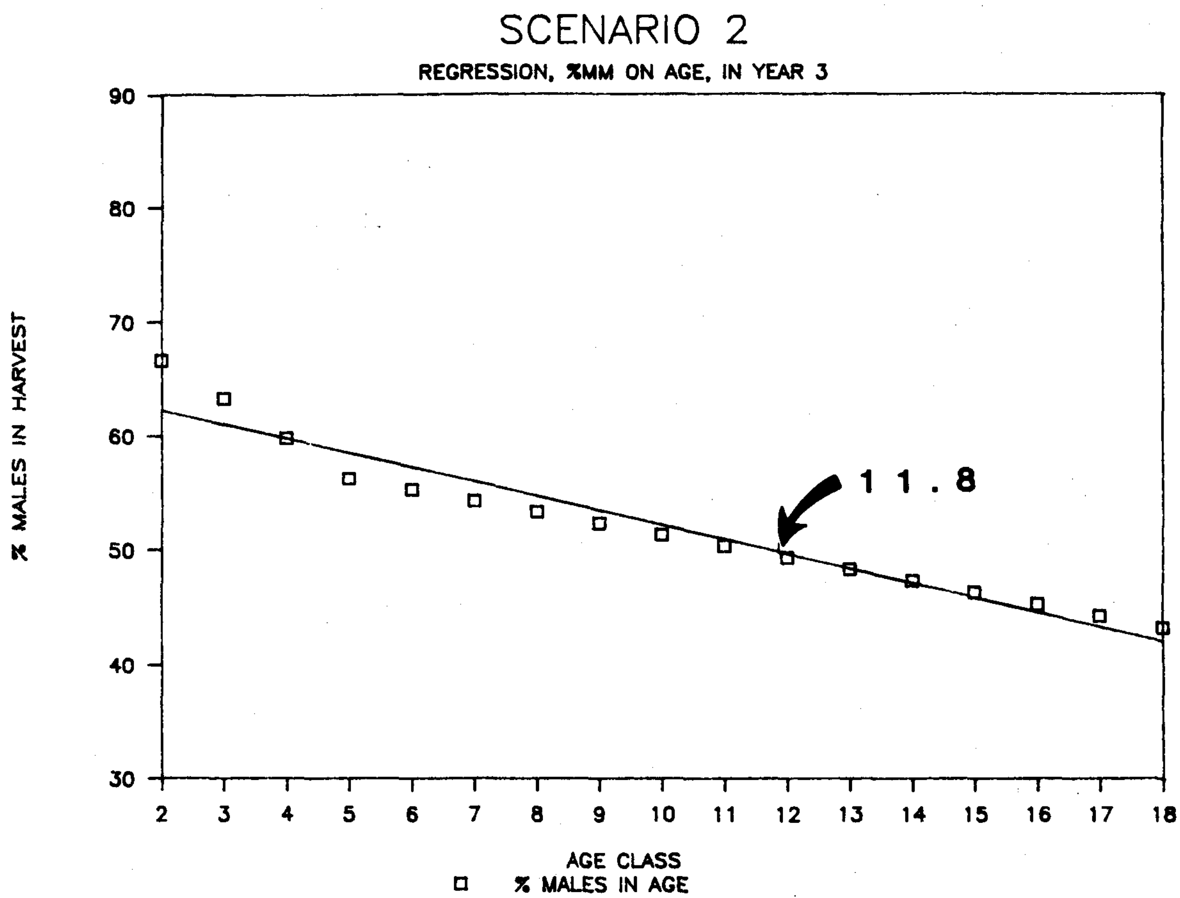
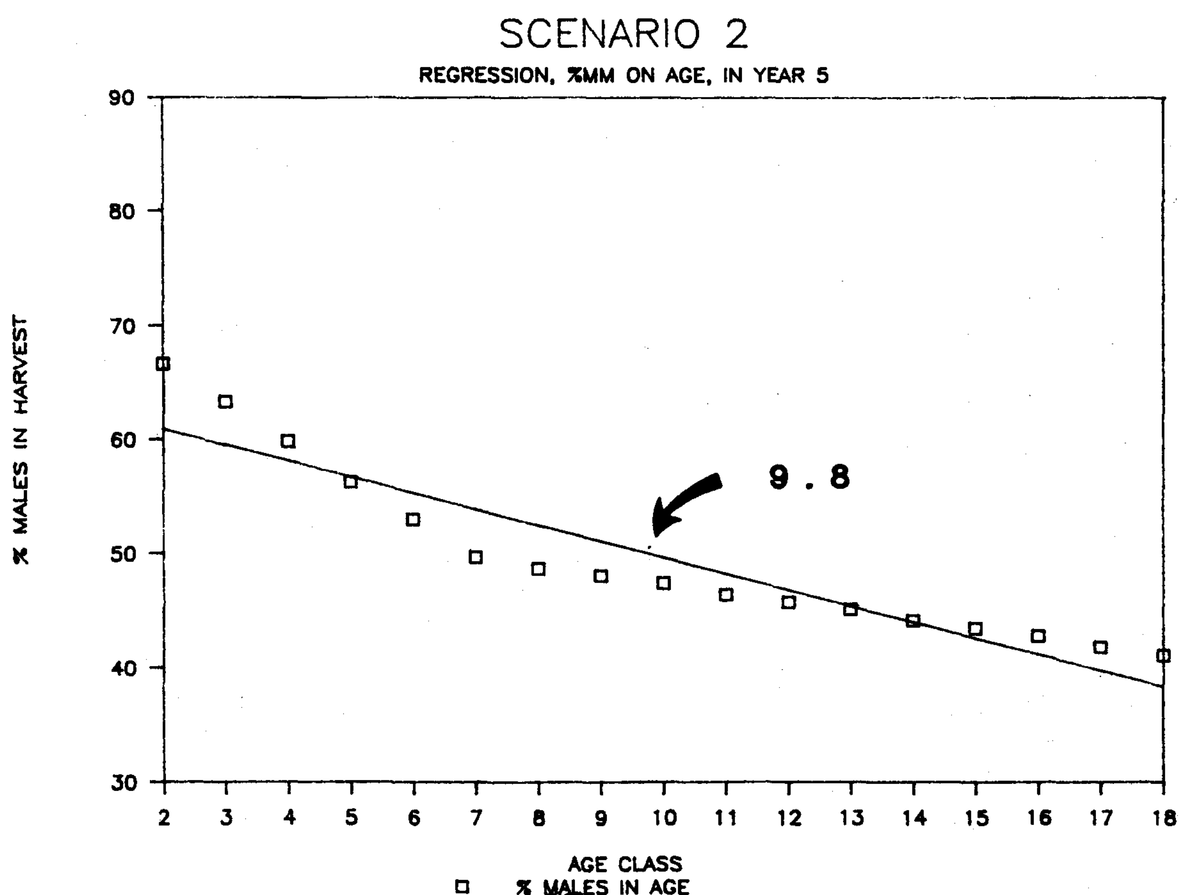

SCENARIO 4
REGRESSION, %MM ON AGE, IN YEAR 40
90
80
70
60
50
40
30
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
% MALES IN HARVEST
AGE CLASS
% MALES IN AGE
7 . 1

Figure 33. Regression of percent males harvested on age class in year 3 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.

Figure 34. Regression of percent males harvested on age class in year 5 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.



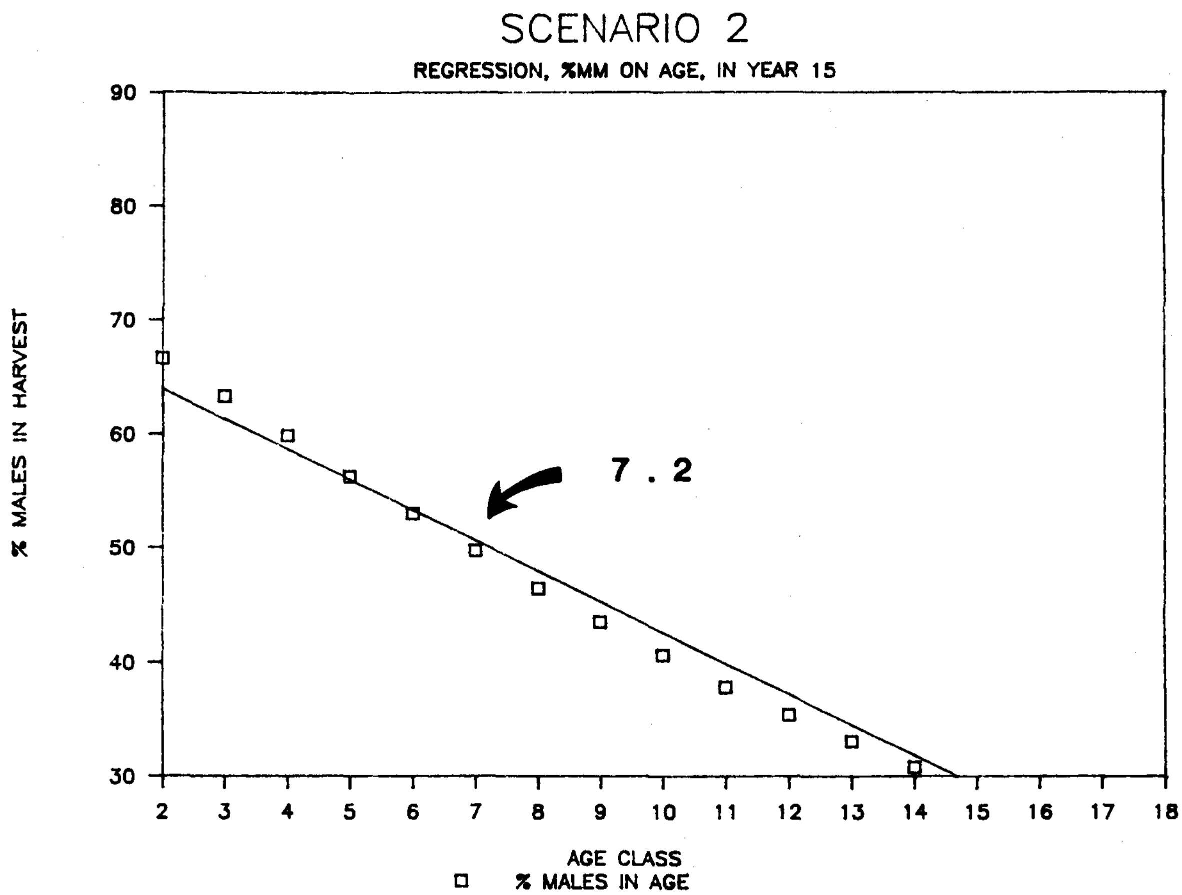
SCENARIO 2
REGRESSION, %MM ON AGE, IN YEAR 3
% MALES IN HARVEST
90
80
70
60
50
40
30
11.8
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
AGE CLASS
% MALES IN AGE



SCENARIO 2
REGRESSION, %MM ON AGE, IN YEAR 5
% MALES IN HARVEST
90
80
70
60
50
40
30
9.8
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
AGE CLASS
% MALES IN AGE

Figure 35. Regression of percent males harvested on age class in year 15 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.

Figure 36. Regression of percent males harvested on age class in year 20 of scenario 2. Arrow indicates age where y = 50% males (reciprocal of this value is an estimate of harvest rate according to Fraser et al. (1982). Regression values provided in Table 1.


SCENARIO 2
REGRESSION, %MM ON AGE, IN YEAR 15
% MALES IN HARVEST
90
80
70
60
50
40
30
7 . 2
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
AGE CLASS
% MALES IN AGE

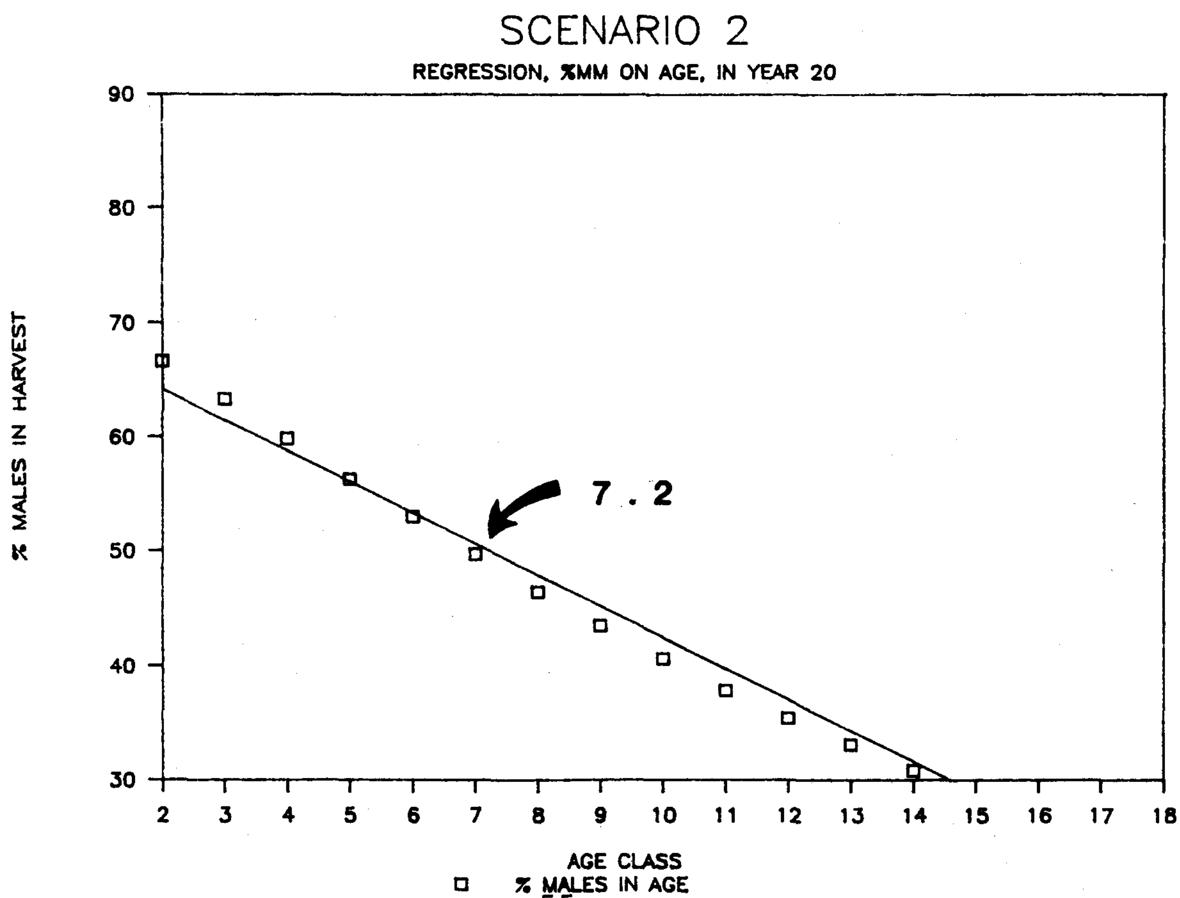

SCENARIO 2
REGRESSION, %MM ON AGE, IN YEAR 20
% MALES IN HARVEST
90
80
70
60
50
40
30
7 . 2
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
AGE CLASS
% MALES IN AGE

Figure 37. Input parameters for Scenario 5, estimation of sustainable harvest level of GMU 13 black bears.

INITIAL POPULATION (No.)--Suggest using GAPPS or this model to configure initial population as you want it

Age=	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Males*	141	114	93	77	64	53	45	37	31	26	21	18	15	12	10	9	7	6	5
Females*	141	119	102	88	77	67	59	51	45	39	34	30	26	23	20	17	14	12	10

INITIAL POPULATION (continued)

Age=	20	21	22	23	24	25	26	27	28	29		CALCULATED TOTALS
Males*	4	3	2	2	1	0	0	0	0	0		795.796834
Females*	9	7	6	4	3	1	0	0	0	0		1003.22654
											SUM =	1799.02337

EXPLOITATION SURVIVORSHIP RATE (PROPORTION NOT SHOT IN EACH AGE CLASS)

Males*	0.84	0.84	0.84	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Females*	0.88	0.88	0.88	0.89	0.9	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92

EXPLOITATION SURVIVORSHIP RATE (continued)

Males*	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Females*	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92

NATURAL SURVIVORSHIP RATE (PROPORTION NOT DYING FROM NATURAL MORTALITY)

Males*	0.9	0.95	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.9	0.9	0.9	0.9
Females*	0.9	0.95	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.9	0.9	0.9	0.9

NATURAL SURVIVORSHIP RATE (continued)

Males*	0.9	0.9	0.9	0.8	0.8	0.5	0.5	0.5	0.5	0.5
Females*	0.9	0.9	0.9	0.8	0.8	0.5	0.5	0.5	0.5	0.5

REPRODUCTIVE RATE

Mean Interval in years between successive successful litters* = 2.7 (= period between successful weaning of one litter and production of the next litter that becomes 2 years old; value in GMU 13 is about 2.7 years, 2.13 YRS on Kenai)

Litter size at age 1* = 1.9 Value in GMU 13 is about 1.9, 2.19 on Kenai

Calculated natality rate (cubs weaned/year/adult female)
Recruitment = 0.704

Age at first reproduction (proportion of adult females capable of giving birth by age-class):

Age =	3	4	5	6	7	8	9	10
Proportion* =	0	0	0.21	0.71	0.93	1	1	1
GMU 13 example =	(0	0	0.21	0.71	0.93	1	1	1)
KENAI EX.	(0	0.281	0.688	0.875	1	1	1	1)

Sex ratio at weaning
Proportion males* = 0.5

APPENDIX

M E M O R A N D U M

S T A T E O F A L A S K A
D E P A R T M E N T O F F I S H A N D G A M E

TO: Distribution

DATE: July, 1988

TELEPHONE NO: 267-2203

FROM: Sterling Miller
Game Biologist
Division of Game
Anchorage

SUBJECT: Documentation for LOTUS bear population model (6-88 version for black and brown bears).

This is to describe how to use the LOTUS models (model.wk1 for brown bears and bkmodel.wk1 for black bears) on the attached diskettes. If more detail is given than is necessary for you, it is to benefit those users less familiar with LOTUS.

PURPOSE: The original purpose of the model is to determine what mortality rates are sustainable to populations of bears given information on recruitment rate. For grizzly bears I define recruitment as into the 2-year old age-class as this is the first age that is legally huntable. In the black bear version this is changed to yearlings. If you have information on productivity, an estimate of population size for huntable bears, and know the number hunted you can use this model to estimate how the number being killed compares with sustainable mortality rates. The model can also be used to compare sex-ratios or mean ages in harvests and in populations, to look at growth rates, impacts on population structure of different relative vulnerabilities of sex-age classes, etc. An example on how to use the model to deduce the significance of different magnitudes of relative sex-specific vulnerabilities on sex ratio in kill is presented at the end of this memo.

HARDWARE AND SOFTWARE: LOTUS needs lots of space and this model is relatively inefficient in use of space. As a result you need 640K RAM in your computer to run the model, even with this it takes 2-3 minutes (of flashing WAIT) to load the model. If you add any more graphs or output (additional years, for example), you'll soon exceed the 640K RAM (and get a flashing MEM message). If this model proves useful, I'll try to develop a more compact version using macros instead of matrices. I suggest you create a subdirectory on your harddrive (call it MODEL, for example) and copy the file MODEL.wk1 on one diskette and all the associated graphics (*.pic) on the other diskette to this subdirectory. Get into this subdirectory before you enter

LOTUS and LOTUS should default to it for loading files. (If your version of LOTUS defaults elsewhere change it using /Worksheet/Global/Default/Directory and setting your default directory to the subdirectory where you have your files, i.e. C:\MODEL). Get into LOTUS and load the model (/File/Retrieve and then type in MODEL, hit the RETURN key, wait until the model loads (2-3 minutes). The model is Release 2 of LOTUS.

In LOTUS you want to select manual recalculation or else the worksheet will recalculate after each change. Do this as follows: /Worksheet/Global/Recalculation/Manual. Note that after you make changes to the input parameters LOTUS will now tell you "CALC" to indicate that the worksheet needs to be recalculated using these values. After you have made all the changes you want hit the F9 key and it will recalculate. [To avoid having to this each time, permanently alter the default configuration of LOTUS to current settings as follows: /Global/Default/Setup and then, from ready mode save the worksheet, /File/Save and then hit return].

The recalculation will also change all the graphs illustrating the results from the previous run to the current run. If you wish to save the worksheet with these values, instead of the supplied ones do: \File\Save and then hit Return to replace the old worksheet with the new (Note: The graphs will reflect the new worksheet values when you look at them onscreen but if you want to plot them, they will plot the old graphs unless you individually save each graph, with its new values, before you save the worksheet). I expect you'll be primarily interested in looking at the graphs onscreen, to see what effect your changes had, rather than in printing them out so you shouldn't have to do this.

INPUT VARIABLES and MODEL DOCUMENTATION: The values you can vary are indicated with an * in the worksheet and are discussed below.

1. Initial population structure (number in each age class) in lines c11..ae11 for males and lines c12..ae12 for females. You can use the values I've provided, enter your own, or copy values from a simulation year of the run to here (use \Range\Value to copy only the numeric values [not the formulas] of the year you want to use to the initial population cells). There is no place for cubs or yearling animals in the brown bear model as they are not relevant to this model which is based on recruitment of 2-years olds.

Similarly, there is no place for cub animals in the black bear model.

2. Survivorship rates from hunting for each age-sex class are entered in c14..ae15 and survivorship rates for natural mortality in c17..ae18. Unless you know something about natural mortality rates I suggest you leave Natural Mortality Survivorship at 1. This means that your 'harvest' is actually total mortality. These survivorships (hunting and natural) are completely equivalent in the way they affect the results (i.e. the number in age-sex class (x+1) in year (y+1) equals (number in class x natural survivorship). In calculating the number of animals shot, however, the model removes natural mortality according to these rates before determining the number shot using the exploitation survivorship rates. You may wish to start killing off bears to natural mortality at some old age in order to maintain an age structure somewhat like what a bear population might have, otherwise you'll probably get too many old individuals. Note that bears that age from the oldest available age-class (30 for brown bears, 29 for blacks) in year x, disappear into the ozone in year (x+1); this is equivalent to 0% survivorship of this age-class regardless of what value you put there.

3. Reproductive interval is entered in cell d27 and this value should reflect, as near as possible, the intereval between successive successful production of litters that survive to age of recruitment (age 2 in the grizzly model, 1 in the black bear model). The Unit 13 value for this parameter (4.5 years) is provided as a comment.

4. Litter size at age of recruitment into 2-year old age-class (for grizzlies) is entered in cell d28. The Unit 13 value for this parameter (1.7) is provided as a comment.

Given inputed values 3 and 4, the model will calculate natality rate and put this value in cell d32. This is the average number of offspring recruited (into age 2 for grizzlies, age 1 for blacks)/adult female/year*. For the Unit 13 grizzly data given in 3 & 4, for example, the model tells us that adult females will recruit 0.387 2-year olds/year (1.7/4.5). When the model runs it will determine the number of 2 year old male grizzlies produced in year (y+1) as follows: (number of adult females in year y) (natality rate) (proportion of 2-year-olds that are male).

*Note that this method of calculating recruitment will result in overestimating recruitment and sustainable harvest levels in species that have extended (>1 year) periods of parental care (Taylor et al. 1987. Correct and incorrect use of recruitment rates for marine mammals. Marine Mammal Sci. 3(2):171-178.

5. You must supply the information necessary to calculate the number of females that are adult in d37..k37. In this model it is the probability that a female produced its first litter at this age or at an earlier age. Cells are provided for ages 3-10. An example for this kind of data using Unit 13 studies is provided in cells d39..k39.

The female grizzlies that produce first litters at age n, don't actually produce offspring at the above natality rate until they are age (n+2) (age when these offspring become recruits into the 2-year-old age class). The same is true for black bears except that females recruit their offspring a year after they are born. The matrix for this portion of the model is over to the right of the main model (to see it hit the F5 key (GOTO) and then enter the rangename RECRUITS and hit RETURN, or you can space over from cell A1 to cell AT1.

6. The final thing you must enter is the probability of a recruited 2-year old being male (in cell E42).

MODEL OUTPUTS: Given the above inputs, the model will calculate the resulting population structure for simulation-years 1 through 40 for each sex-age class (in cell a49..ae122) (Rangename = model). It produces another matrix showing the number killed by hunting in each year in each sex-age class (in cells a138..ae220) (Rangename = kill). Summary and mean statistics for population (Rangename = popstat) and harvest matrices (rangename = killstat) are to the right of these.

The best way to look at the results is graphically, however. You can look at the trends in populations and in harvests in the graphs included, check them out to see which one shows the parameters or comparisons you're interested in. You do this by entering /Graph/Name/Use and then spacing over (use the arrow keys) to the graphname you want. A hardcopy sample of the graphic outputs available is attached. You can graph other parameters you're interested in. Be careful, however, in adding new columns to the stats output as you'll soon exceed the capacity of a single diskette to hold the worksheet. Also be careful in adding new columns to assure that you don't write over portions of the worksheet below or to the right of where you're working. Note that for the black bear model the graph legends really illustrate animals 1+ or older when they say "2+" (this could be fixed but it would require a whole new set of graphs, not worth the diskette space in my view). The black bear graphs legends are correct for bears aged "5+".

LIMITATIONS: There are many limitations to this model and you should be very careful in believing the output. The model is very much female-driven (males are not even needed for females to reproduce. To assure that females are not reproducing immaculately, check the graph PCOMP40.pic to see the population sex/age structure in year 40 of the simulation. You can compare years 20 and 40 of the simulation for males with 20&40MM.pic (20&40FF.pic for females).

Another potential problem is that females don't really reproduce as modeled. Producing 1.5 2-year-old grizzlies every 3 years is not necessarily the same as producing 0.5 2-year-olds every year.

The model has no compensatory feedback mechanisms of any kind.

The following statement is untrue for the January 1988 version which has no rounding conventions for population, harvest, or recruitment. These values are formatted to show value in the tenths space. I didn't exclude this statement from this documentation as it illustrates why I decided to eliminate the rounding convention and is an explanation of why, for these purposes, you will have fractional parts of bears running about acting and breeding like whole bears.

> The model doesn't go to zero as a real population should. This is because of the rounding convention used. The model doesn't deal with fractions of animals, each mathematical operation is rounded to the nearest whole animal (except if the value in a sex-age class is 1, this is rounded to 0 with an IF statement--this is true for the January 1988 version also). As a result of these rounding conventions, populations don't decline to zero the way a real population would. The reason for this can be seen in the following example. If in sex age class i, you have 2 animals which experience 0.8 survivorship than in class (i+1) you will have (2) (0.8)=1.6 animals but these will live forever at this survivorship rate as the 1.6 will be rounded back to 2. The result of this is that declining populations will usually stabilize, artificially, at some low level. In these circumstances you should restrict your consideration of the model's results to the years of decline.

COMMENTS: The current model runs for 40 years, if you want it to run longer you could copy the population composition from simulation year40 to the initial population (c13..ag14) and recalculate (use /Range/Value and not "/Copy" to copy it). Your graphs will then reflect years 40-80 although the headings won't change. Using the inputs I've used so far, it appears that the composition of population and harvest stabilizes in years 20-30, so 40 years should usually be enough.

The worksheet takes up all available space on one diskette. To save space, this version doesn't calculate some statistics for each year of the simulation (mean age of population and harvest, for example, is calculated only for every 4 years). Once you get the worksheet on your hard drive you can use the /Copy command to fill in the statistics for the missing years if you wish. Note that if you get a flashing MEM signal this means you have overloaded your RAM. If this happens you should save your worksheet and then erase some of the statistics you don't need until it will fit.

If all bears in each sex are assigned the same survivorship rates, mean age and sex ratios should not change much once the population has reached a stable age distribution (once the variability inherent in the initial population structure works its way out of model).

If you want to save and remember your input values for some run you can work with the worksheet INPUT.wk1 and import it to cell A1 of the model (/File/Combine/Entire File). Similarly, you can export the input section of your worksheet to some file to save it complete with your notes on what this input set is designed to do (File/Export/Values and provide a filename for export range INPUT (or A1..AF42).

You can adjust reproductive rates, initial population composition, or relative vulnerabilities to see how much these changes influence the results and rates of population growth. In illustration of how to use this I wanted to find out how sensitive % females in kill was to difference in survival rates of males and females and growth/decline of the grizzly population model. For this all age classes within a sex had same "exploitation" survivorship and there was no natural mortality for any age class. I varied the sex-specific mortality for any age class. I varied the sex-specific mortality for males as twice to three times that of females. Results were:

Inputted survivorship Males	Females	% kill of females in years 35-40	Population Growth rate in in years 35-40
3x difference			
.73	.91	52%	-2%
.70	.9	53.7%	-3.1%
.85	.95	42%	+2%
.82	.94	44.7%	+1%

2x difference			
.82	.91	50%	-2%
.8	.9	52.5%	-3.1%
.9	.95	43.7%	+1.7%
.88	.94	45.6%	+0.7%

This suggests that % females in kill increases as degree of population decline increases , but this doesn't seem to be a very sensitive parameter. The other conclusion is that a two-fold differential in vulnerabilities between males and females doesn't produce much difference in % kill of females from a 3-fold differential. In both cases the amount of fluctuation in these parameters would be masked by noise in a real data set (there are no natural mortality in the input which generated this example).

The following was added to the July 1988 version of the model. In order to do the following you'll have to add the worksheet FRASER.wk1 to the model on your harddrive (I couldn't do this for you because it would make the model to large to fit on one 360k diskette). You do this by moving to cell AX130 in the worksheet (hit the F5 [GOTO] key and enter FRASER which is the address for this cell) and then import FRASER.wk1 to this cell (/File/Combine/Entire file/FRASER). Be sure the worksheet FRASER.wk1 is on your default directory (it is shipped on the diskette with the graphs.

The potential exists to use this model to look at regressions of mean age of males on age class (See Fraser et al. 1982 [W. Soc. Bull. 10(1):53-57]). This is previously set up for years 3, 5, 7, 10, 15, 20, and 40 of the simulation. In order to obtain these data, additional steps are necessary to run regressions for each of these years. These regressions are calculated only for age classes 2-18 as LOTUS will accept only 16 independent variables. Percent males in each age class for each of these 7 years in the simulation is calculated in part ay143..bf171 of the worksheet. LOTUS regression is entered through /Data/Regression. You are prompted for X-range and need to just hit Enter to default to ages 2-18. You then select Y-Range and entered the rangename YIN3 (for y values for simulation year 3). You then select Output-Range and enter OUT3 (to output the regression values in the correct spot for simulation year 3 (BP131 in this case). Finally you select Go and the regression will be calculated, very quickly, and Y values based on this regression will automatically be entered in BH143..BH159. Don't forget to hit your F9 key to recalculate before using these values (necessary whenever the box at the bottom of the screen read "CALC"). You must follow this procedure for each simulation year you wish a regression for; for year 5 you enter YIN5 for Y-Range and OUT5 for Output-range and hit Go, and for year 40 YIN40 and OUT40 and Go, and so on. The age at which this regression indicates that y=50% males is calculated in cells BH162..BN162 (GOTO rangename Y50). This may sound somewhat complicated but it is pretty easy and all 7 years can be done in less than a minute. Graphs illustrating these regressions for each of the 7 years are: FRASER3.PIC, FRASER5.PIC, ...FRASER40.PIC).

Graphs you can select include the following (recall that for the black bear model, when the legends for these graphs say "2+" they really are calculating for 1+ aged bears, "5+" remains correct):

%CHANGE.PIC gives change from initial number for all bears and all females
%FEMALES.PIC gives % females in population of bears 2+ and 5+
%GROWTH.PIC gives % annual change in population size for bears 2+ and 5+.
%HARVEST.PIC gives % of population harvested for bears 2+ and 5+
%KILL5.PIC gives % of population >5 harvested for males and females
%KILLALL.PIC gives % of population >2 harvested for males and females
1GROW40.PIC gives population size in each simulation year for bears 2+ and 5+
20&40FF.PIC gives comparison of number of females living in simulation years 20 and 40
20&40MM.PIC gives comparison of number of males living in simulation years 20 and 40
2GROW2.PIC gives population growth (number of bears) by sex for bears >2
3GROW5.PIC gives population growth (number of bears) by sex for bears >5
DIFFER.PIC gives the number of deaths and of recruits in each simulation year
FEMALES.PIC gives number of females (age 5+) in population and females (age 2+) in kill
FRASER1.PIC, FRASER3.PIC, FRASER5.PIC, FRASER7.PIC, FRASER10.PIC, FRASER15.PIC, and FRASER40.PIC give the regression of % males on age class for simulation years 1, 3, 5...40. Note that these regressions have to be recalculated as described above for each scenario; they are not automatically calculated.
KCOMP1.PIC1, KCOMP3.PIC3, KCOMP5.PIC5, KCOMP7.PIC10, KCOMP10.PIC, KCOMP15.PIC, AND KCOMP40.PIC40 give the composition of the harvest (No. of males and females age 2+) in each age class for the indicated simulation year (1, 3, ...40).

PCOMP1.PIC, PCOMP3.PIC, PCOMP5.PIC, PCOMP10.PIC, PCOMP15.PIC, AND PCOMP40.PIC give the composition of the population (No. of males and females age 2+) in each age class for the indicated simulation year (, 3, ...40).
MAFF2.PIC gives mean age in kill and in population of females age 2+
MAMM2.PIC gives mean age in kill and in population of males age 2+
MAKILL2.PIC gives mean age of males (2+) and females (2+) in kill
MAPOP2.PIC gives mean age of males (2+) and females (2+) in the population
SEXCOMP2.PIC gives % females in the population and the kill (bears 2+)
SEXCOMP5.PIC gives % females in the population and in the kill (bears 5+)

WILDLIFE RESTORATION

Federal Aid Project
funded by your purchase o
hunting equipment