Ranges

~~p. 3 new – Year?~~

~~p. Jack snipe? p. 14 new~~

~~p. 15 new – Zygadenus sp.~~

~~p. 16 new – Ripley – # 16 check~~

~~p. 19 delete?~~

p. 20 offspring of # 39

~~p 20 – # 38~~ explain – tab that this is conjecture based on observations of bear feeding habits composite picture

p. 22 ~~– Doronicum – stork's beak~~

p. 22 – whitebark – one word?

add concentrations – see orig range paper

Population

? add concentration figures p. 2 2nd para.

Retype orig page 12 & 13

p. 1. compare with preface 2nd para.

88 single nights

31 : 103 =

p. 10 mid pr check sex ratio in pop paper

p. 13 # 94 ♂ a ♀ (top)

See computer abstract 1973 – objectives & add to last chapt.

Rate that can be killed (abstract p. 5

Cooperation among agencies

Mortality

p.1 check 1st para with Preface

Abstract: <u>A Computer Analysis of the Yellowstone Grizzly Bear Population</u>

From a thirteen year study, the authors have accumulated demographic information to describe the behavior of the grizzly bear population in Yellowstone, and to relate this to the management of the species in the Yellowstone ecosystem. Objectives of this paper are; to summarize population statistics, describe computer simulation models, and to compare the growth characteristics of the population between 1959 and 1967 with growth characteristics for the period 1968 through 1972. Predictions are made of future population levels and trends, and these related to management practices.

Population statistics that could be developed into a model were acquired by recording age and sex specific mortalities from year to year and acquiring long term averages on such population parameters as population size and structure, sex ratios, reproductive rate and longevity. During a twelve year period, 256 grizzly bears were captured and individually color marked. Population size ranged from 154 animals in 1959 to 179 in 1970 with a peak of 202 in 1966. The 1970 population level of 179 grizzlies was used as a starting point from which to analyze changes that occured after that date. Our data indicated that the population of grizzlies we censu~~s~~sed represented a large proportion of the entire population of grizzly bears inhabiting the approximately five million acre Yellowstone ecosystem.

<u>Age Structure</u>

Age structure data were obtained by recording the age of individual animals on each of 367 censusses made from 1959 through 1967. A stable age structure prevailed from 1959 to 1967. The

Age Structure (continued)

average age composition was: 18.6 percent cubs, 13 percent yearlings, 10.2 percent two-year-olds, 14.7 percent three and four year-olds, and 43.7 percent adults.

Sex Ratios

Males predominated over females in all sub-adult age classes. Among adults the sex ratio was 53.7 percent females and 46.3 percent males. Among 78 cubs captured and sexed during a 12 year period, 59 percent were males and 41 percent females. A cub sex ratio of .59 males to .41 females was used in making population projections.

Reproductive Rates

Two different methods were used to calculate reproductive rates. The first consisted of making annual counts of cubs and adult females. (Those with cubs and those without) The second involved capturing and marking females and recording their reproductive histories over a period of years. Reproductive rate is the average number of cubs per female per year. Annual reproductive rates were obtained by dividing the number of cubs counted each year by the number of adult females recorded. From 1959 to 1967 an annual average of 33.2 adult females and 33 cubs were counted. This yielded a reproduction rate for the population of .99. From 1968 to 1970, 81 individual cubs and 122 adult females were counted, yielding a reproductive rate for the population of .66. Only 44.7 percent of the adult females produced cubs each year. This results in a relatively low reproductive rate for the species. Reproductive histories were compiled for 19 marked, female grizzlies. The average number of cubs per female per year for each of the 19 animals was obtained by dividing the number of cubs produced by each female by the

Reproductive Rates (continued)

observed reproductive period in years for each female. An average reproductive rate for the 19 marked females was then calculated by dividing the sum of the individual reproductive rates by the total number of females. This yielded a reproductive rate of 1.02 for the females during the 1959-67 period. The reproductive rate for 1967-70 period was .70. Similar reproductive rates were obtained by the two methods: .99 and 1.02 for the 1959-67 period, and .66 and .70 for the 1968-70 period. This indicates that a reproductive rate of one cub per one adult female per year is an accurate biological parameter for the grizzly bear population during the 1959-67 period. To present a best case situation, we used the higher reproductive rates of 1.02 for the 1959-67 period and .70 for the 1968-70 period. The average interval between litters for 22 marked females, each of which produced at least two litters, averaged 2.5. Reproductive rate is also dependent on litter size. This varied from one to four cubs, with an average of 2.22 for 22 marked females.

Mortality and Survivorship Rates

From 1959 to 1967 a total of 163 known deaths averaged 18.1 bears per year, or a ten percent known mortality in a population of 180 animals. The minimum age for producing a first litter of cubs was 5-1/2 years. From 1968 through 1972, a total of 160 known deaths averaged 32.0 bears per year. There were 46 and 45 grizzly deaths in 1970 and 1971 respectively.

Longevity

The oldest live bear recorded was 25.5 years. This age represents longevity for the population. The maximum reproductive age established for a female was 23.5 years. At this age she

Longevity (continued)

produced two cubs.

Population Estimates with Census Population

The projection from 1959 to 1970 agrees with the census data for 1970 within one bear (the census = 179; prediction = 178.3). The estimate for the most probable population at present, 1973, results in an estimated population in June, 1973, of 102 animals, a 42.7 percent reduction in population size in three years. Our data indicate that the census figures used in our computations represent at least 80 percent of the total ecosystem population. If we assume that only a 70 percent count was obtained during the 1959-1972 period, then the average population level would be 40 percent higher, or 250 rather than 178 animals. Assuming that the most recent census (179 animals in June of 1970) represents 70 percent of the total ecosystem population, results in an estimate for that year of 250 animals. Using this value results in an expected 1973 population of 177, a 29 percent reduction versus a 43 percent reduction. This figure of 177 is the most optomistic interpretation. In this analysis we have utilized only those grizzly bear mortalities that could be conclusively confirmed. The magnitude of suspected, but unrecorded and unconfirmed grizzly bear deaths could have been in excess of 30 percent of the known recorded deaths for each year.

If we assume that the known mortality remains at the 1972 level and the reproductive rate of 0.7 continues over a ten year period, the population declines sharply, reaching 23 plus or minus 5 animals in 1983. The population could be exterminated as early as 1990. If the known mortalities for 1973 dropped to 20 (they were 27 in 1972) then the population could not grow, even if it

Population Estimates with Census Population (continued)

could exhibit a reproductive rate as high as 2.0. Should the reproductive rate remain depressed at .70, the population would decline at a rate of 10 percent per year. Should known mortalities drop to ten grizzlies per year, the population would remain essentially static if the reproductive rate is .78. It would grow at about 2.5 percent per year with a reproductive rate of 1.0. For the grizzly population to grow at the same rate as 1959-67, it can sustain only ten known deaths during 1973 and must exhibit a reproductive rate of 1.0. The known permissable mortalities for 1973 if the population is to remain stabilized at 100 animals is only 13, 5 of which occur in the category of "Other Causes", in other words, mortality could be five control, three by hunters, or three control and five by hunters. The results of the study indicate that there must be complete cooperation among the agencies responsible for the management and preservation of grizzly bears in the Yellowstone ecosystem, and there must be a unified management program. The most responsible approach to take in future planning and management is for all agencies responsible for the welfare and preservation of Yellowstone grizzlies, to use our worst case population estimate for determining allowable annual mortality in order to leave some margin for error. The results of the analysis indicate that population levels in the Yellowstone ecosystem declined rapidly during the last three years and that the probable population in June, 1973 is 102 animals. Continued mortality at the level occuring during 1972 will result in further decline in population.

UNITED STATES GOVERNMENT

Memorandum

BUREAU OF SPORT FISHERIES AND WILDLIFE

TO : Charles Loveless, Ass't Director of Research DATE: October 15, 1973

FROM : John J. Craighead, Leader, Mont. Coop. Wildl. Res. Unit

SUBJECT: Permission to publish the report, "A Computer Analysis of the Yellowstone Grizzly Bear Population"

I would like to receive permission to proceed with publishing our report, "A Computer Analysis of the Yellowstone Grizzly Bear Population". There has been ample time for the report to be reviewed; and all of the reviews I have received, I have judged to be favorable.

In view of the controversy that exists with regard to the Yellowstone grizzly population and in view of the fact that Mr. Cole appears to be able to publish his data with little or no restrictions, I sincerely hope that our report can be quickly published and available to the scientific community. Only in this way can the situation be impartially judged and action taken to alter the management program, if it is judged that this is necessary in order to protect the grizzly.

JJC:gs

John Craighead

Age Structure Data was obtained from

367 censuses made from 1959-1967

av. age comp. 18.6% cubs, 13.0 yr., 10.2 2-yr, 14.7 3+4, 43.7 adults

Stable age structure prevailed from 1959-1967

♂ predominates over ♀ in sub-adult classes

among adults sex ratio 53.7% ♀ and 46.3% ♂

cubs - 59% ♂ + 41% ♀

Repr. rate - av. # of cubs produced per female per year

annual reprod. rate $\frac{\text{cubs counted}}{\text{adult females recorded}}$ $\frac{33}{33.2}$ = .99 reprod rate for pop.

.99 for 59-67 period + .66 for 68-70 period

only 44.7% of female produced cubs each year (relatively low reprod rate for species)

Used reprod. rate of 1.02 for 59-67 period + .70 for 68-70 period

1959-67 Mortality - 163 known deaths, 18.1 bears/year or a 10% known mortality

5½ yrs the min. age for producing a first litter

1968-72 Mortality - 160 known deaths, 32.0 bears/yr.

Longevity - oldest live bear 25.5 yrs., max reprod age of ♀ - 23.5

1970 census - 179, model prediction 178.3 bears

most probable pop. at present (1973) - June 102 animals, a 42.7% reduction in pop. size in 3 yrs.

Census figures represent at least 80% of the total ecosystem population

assuming that recent census of June 1970 represents 70% of the ecosystem pop. results in an estimated pop. of 250 animals (1970) and a projected 1973 pop. of 177 (most optimistic interpretation)

av. interval between litters 2.25 yrs.

av. litter size 2.22

suspected but unrecorded and unconfirmed grizzly bear deaths (1970-72 could have been in excess of 30% of the known recorded deaths for each year

Known mortalities permissible if pop. is to remain stabilized at about 100 animals (1973) — only 13 animals

Ex. 5 control, 3 hunter or 5 ~~other~~ hunter + 3 control
5 of 13 occur in "other category" (cannot be altered or manipulated)

Need for a unified management program
Use worst-case pop. estimate

MONTANA COOPERATIVE WILDLIFE RESEARCH UNIT

UNIVERSITY OF MONTANA
MONTANA FISH AND GAME COMMISSION
WILDLIFE MANAGEMENT INSTITUTE
FISH AND WILDLIFE SERVICE, UNITED STATES DEPARTMENT OF THE INTERIOR

UNIVERSITY OF MONTANA

MISSOULA, MONTANA 59801

Dr. Frank Craighead Jr.
Box 156
Moose, Wyoming

Dear Frank:

Enclosed is a report, "A Computer Analysis of the Yellowstone Grizzly Bear Population". This report is currently being reviewed by members of the Research Division of the Bureau of Sport Fisheries and Wildlife. Until this report has been officially cleared through proper channels for publication, the contents should be considered privileged information. The authors will appreciate comments and suggestions. Although this is basically a research report, management suggestions have been offered. Our data and our conclusions indicate that the Yellowstone grizzly bear population faces a critical situation and that immediate remedial action is in order. We especially solicit comments on our conclusions and request suggestions as to how our recommendations can be implemented into a harmonious, coordinated management program. Because of the sensitive nature of the subject and inter-agency ramifications, we will need your support. We are making this report available to a few selected individuals prior to publication because we believe the situation is critical, and we firmly believe that scientists have a responsibility to help translate basic research into responsible applied programs.

Sincerely,

John

Dr. John J. Craighead, Leader
Mont. Coop. Wildl. Res. Unit

JJC:gs

Encl:

Frank, please keep contents strictly confidential until I hear from Wash. This keeps me in the clear.

UNITED STATES GOVERNMENT

Memorandum

BUREAU OF SPORT FISHERIES AND WILDLIFE

TO : Charles M. Loveless,
Assistant Director of Research

DATE: September 19, 1973

FROM : Leader, Montana Cooperative Wildlife Research Unit

SUBJECT: Review of Cole's paper, "Management Involving Grizzly Bears in Yellowstone National Park 1970-72"

In the interest of the wildlife profession and a proper and rapid solution of the Yellowstone grizzly bear management problem, I am taking the liberty of suggesting that you request Gross and Peterson to review Cole's paper. This paper has been published and therefore, presumably, cleared by the National Park Service and other Interior Department personnel. Cole has taken unsupportable liberties with our data, Hornocker's data and his own. I make this suggestion not to discredit Cole; I intend to severely criticize his paper when I catch up with current work. I make the suggestion because if it cannot pass Bureau critics then Mr. Reed should be so informed.

Respectfully,

John Craighead

John J. Craighead

nh

UNITED STATES GOVERNMENT

Memorandum

BUREAU OF SPORT FISHERIES AND WILDLIFE

TO : Charles M. Loveless, Assistant Director of Research

DATE: September 19, 1973

FROM : Leader, Montana Cooperative Wildlife Research Unit

SUBJECT: Comments on the review of "A Computer Analysis of the Yellowstone Grizzly Bear Population" by Gross and Peterson

Enclosed you will find our comments. Appraisals made by other competent scientists from the University of Montana and other institutions have all been very favorable. We hope that we receive instructions in the very near future to release the report to interested parties and to submit the report for publication.

John Craighead

John J. Craighead

Enclosures

Comments on the Craighead paper: "A Computer Analysis of the Yellowstone Grizzly Bear Population"

The paper summarizes population statistics measured on the grizzly bear population for the period 1959-1972.

In 1968 the National Park Service began a rapid closure program involving all the open-pit garbage dumps in Yellowstone National Park. These dumps were evidently a valuable source of food for the grizzlies. The closure presumably resulted in more grizzly bears invading unsanitized campgrounds, more contacts with stockmen and more hunter kills outside the park.

The authors maintain that until 1968, the Yellowstone Park grizzly population was relatively stable, but after that date, the population steadily decreased. Consequently, the investigators have divided their data into two periods: the nine years prior to closure of the garbage dumps, and the three years immediately after closure. Various models are developed using population parameters to predict how the population would react under different sets of conditions. Their overall purpose is to show that current National Park policy is detrimental to the grizzly bear population and unless this policy is changed, the Yellowstone population may be extirpated.

The investigators attempt to show that reproductive rates started to change in 1968. Evidence is presented to support the hypothesis that during the nine-year period prior to 1968 the population was stable and experienced a relatively high reproductive rate (Table 7), but during the three-year period after the closure of the garbage pits, the population started to decline and experienced a relatively low reproductive rate (Table 8). If we examine Tables 7 and 8 together, we can see that "a stable population" is a little misleading. The 12-year period from 1959-1970 can be divided into four 3-year intervals (they divided it into 9 and 3). We can see that the second and third intervals had the same high reproductive rates (1.13 and 1.11), but the first and fourth periods were low (0.78 766 and 0.66). .666 The important point is that the reproductive rate for the last three-year period (after closure of the dumps) is very similar to the first three years during the "stable period." Actually the reproductive rates for the 12-year period form a nice bell-shaped curve!

was in stable age distribution

p-31

The authors also used the breeding histories for 15 marked females to show that reproductive rates in the last three years averaged lower than in the previous nine years (Tables 9 and 10). Again, I feel these tables are somewhat biased. First, the authors started observations on a marked grizzly only when she was first observed with a litter. This would be satisfactory if all observations started with bears that were 5 1/2 years old (year of first breeding). But surely some of the bears were older, and the first observations could be during those years when the female did not have a litter although previously she may have had one. These "zero years" would not be included in the column headed "reproductive period in years" because this equals the year of first recorded litter. If these non-productive years had been included, then the reproductive rate would be lower because the denominator in calculating the average number of cubs per female per year would be larger. To test this, I arbitrarily added 1 year to every other female that was observed in the two periods (7 of the 15 marked animals). This addition of 7 years to the reproductive period effectively lowered the reproductive rate from 1.03 for the 15 marked animals to 0.90--a decrease of 10%.

Table 10 is interesting in a similar way. Here, the authors use a reproductive period of three years (except one which was 2) for the marked females. If the females breed every other year, then the number of litters a female could bear would either be 1 or 2 depending on when the reproductive period was started for each female. As Table 10 indicates, only 1 or 0 litters were observed in the three-year period and this is probably one of the lowest reproductive rates that could be obtained. If one more year had been added to the reproductive period (e.g. 1971), the number of litters could very well have been doubled and the reproductive rate would be subsequently higher for the period that experienced a low reproductive rate.

I also compared the reproductive rates for the 1959-67 and 1968-70 periods by using a paired t-test on the 15 marked grizzlies presented in Tables 9 and 10. The test showed no significant difference in reproductive rates of the 15 marked females for the two periods (calculated "t" = 2.01 and tabular "t" for 14 d.f. = 2.14 @ the .05 level). Granted, the "t" values are very close, and if the species is really endangered, no biologist would "quibble" over a decimal point on a statistical test at that level. However, if we are to use statistical tests in formulating decisions in other "less touchy" wildlife problems, then we should at least give the test considerable thought in this problem.

After this discussion on reproductive rates, the authors discuss mortality and survivorship rates. These data are summarized in Tables 11, 12 and 13. I will not dwell long on a discussion of this section. The authors stress the point that mortality in subadult and adult bears increased after closure of the open-pit dumps in 1968. Presumably this increase in mortality was due to a dispersal out of the park where they were legally shot by hunters or a dispersal into unsanitized campgrounds where they were shot for control purposes. Tables 12 and 13 indicate almost twice as many grizzlies were killed each year, on the average, between 1968-1972 than between 1959-1967 (32.0 vs 18.1 respectively).

Known mortality is difficult to dispute, especially in an animal like a grizzly bear. However, due to the popularity of this animal in recent years, the increased "kill" could be due to more efficient reporting.

With that, I would like to end this rather lengthy discussion with a few closing remarks. <u>Intuitively</u>, I think the Craigheads are right. There is no doubt that (1) there are relatively few grizzly bears left in Yellowstone National Park and they are definitely worth saving, (2) the animal has a very low reproductive potential, (3) the population recovers slowly from excessive mortality, and (4) high mortality on adults could endanger the Yellowstone population and measures to prevent State hunting and National Park control by shooting may be necessary. I wish to point out that the models they developed, and the predictions that came from them, are only as good as the data that went in, namely, the sex and age ratios, reproductive rates, mortality rates, etc. If any one of these are a poor measure of a population parameter, then the prediction will likewise be poor. I feel the reproductive data, as they present it, are open to question.

Respectfully submitted,

Steven R. Peterson

Steven R. Peterson
Migratory Non-Game Bird Studies
Migratory Bird and Habitat
Research Laboratory

September 7, 1973

Steve penciled some notes in the margin of the report. I hope this was alright, if not, they can be erased without much effort.

Bob Smith

Comments on Jack Gross's Comments on:

"A Computer Analysis of the Yellowstone Grizzly Bear Population"

We have carefully reviewed Jack Gross's computer re-analysis and the computer printouts. Dr. Gross made a few changes in reproductive and mortality rates to match the behavior of one of his own programs to our census data, then made projections with it. His program shows lower population growth rates than ours, and the differences in results are all in the direction of faster declines.

Among nine statements evaluated by Dr. Gross, six were concluded to be valid, one partly valid and partly invalid, and two were invalid on the positive side---that is, his simulations indicated a more critical population situation than our models showed. No statements were concluded to be invalid.

The re-analysis was a very severe test of both our data and our computer programs. We were pleased to see them so rigorously tested and we believe that Dr. Gross's conclusions fully support our own.

John Craighead

John J. Craighead, Leader
Mont. Coop. Wildl. Res. Unit

Comments on Steve Peterson's Comments on:

"A Computer Analysis of the Yellowstone Grizzly Bear Population"

1st par. The dumps were not only a valuable source of food, but because they had been in existence for some 80 years they had profoundly affected the movements, size of home ranges, behavior patterns and seasonal distribution of grizzly bears throughout the 5,000,000 acre Yellowstone ecosystem. They had served to zone grizzlies from man during the visitor season and they had become an integral part of grizzly bear ecology. Data to support this will be presented in detail in future papers.

2nd par. We did not divide our data into pre- and post-1968 periods with an "overall purpose"..."to show that current National Park policy is detrimental...".

This is an assumption or a prejudice that the reviewer has accepted from other sources. It is nowhere stated in the paper. We would like to know how it is feasible to determine what occurred during the 1968-72 period unless data for that period can be compared with some ecological benchmark or norm of an earlier period? We concluded that the National Park Service policy is detrimental and should be changed. We did not set out to prove this or anything else. This attitude by the reviewer disturbs us and I think it deserves greater discussion than I can devote to it at this time.

3rd par. We did not present a hypothesis. Data showed that between 1959 and 1968 the population was in stable age distribution. Computer runs show that after that period it was not. See Appendix D. The reproductive rates are shown for each year. It is true that the reproductive rates for the first three years is .78 and .66 for the last three. Evidence was that it would have been considerably lower in 1971 and 1972 had we been able to remain in the Park and record data. The important point is that the reproductive rate was low (.66) at a time when mortality was excessively high. The results of such a combination are obvious without a computer. It could be theoretically argued that the low reproductive rate during 1968-70 was a normal population response and not due to stresses caused by closure of the dumps. Data which could not be included in the report indicate otherwise. This point is, however, academic. It is obvious from the data that the grizzly bear has a low reproductive rate, and that great caution should be exercised in formulating policies that increase the death rate. We believe the criticism offered in paragraph 3 is invalid.

4th par. Peterson's criticism essentially demonstrates that the reproductive rate could be lower than our calculations show and thus the population situation more critical.

If the reproductive rate is calculated from age 5½ (the earliest age that females produced litters) through 1967 for the 19 females recorded in table 9, then the average reproductive rate is .87.

If it is calculated from age 5½ to year of last observed litter, it is .93. We used the criterion - year of first recorded litter through 1967 as the reproductive period in order to be on the conservative side. This gave us the reproductive rate of 1.02.

<u>5th par</u>. We were consistent in treating the data in table 10 the same way data were treated in table 9, so there is no bias. More years of observation would have strengthened these data, but we were denied the privilege of doing this. There is no evidence that the reproductive rate would have been higher had we made such observations. Much indirect evidence indicates it would have been lower. Peterson fails to point out that the reproductive rate for that period (1968-70) shown in table 8 and obtained using an entirely different method is .664. Again, in order to be on the conservative side we used the reproductive rate of .70 (table 10) in our computer runs. We conclude that the criticism is not convincing.

<u>6th par</u>. If we understand the comment correctly, Peterson is saying that a sample size of 15 is too small to establish a significant difference in birth rate between the 1959-67 and 1968-70 periods. Method one, however, (page 14) used a much larger sample size and produced similar results. We are satisfied that the difference in birth rate between the two periods really exists.

7th par. No comment required.

8th par. Admittedly, it is difficult to standardize the efficiency and the amount of time and effort that goes into obtaining information on known deaths. We recognized this problem and we made special efforts to avoid bias. We believe there is bias but that it exists in under-recording rather than over-recording during the 1968-72 period. During 1959-68, we recorded all the known deaths in the Park, this included deaths from control as well as some deaths from "natural" causes. Since that time control deaths in the Park have been recorded only by Park biologists. We do not believe that deaths from natural causes have been adequately observed and recorded by Park biologists during 1970-73. We also believe we should have been permitted to verify and record control deaths in the Park during the 1968-73 period. This would have alleviated any suspicion as to whether all control deaths were recorded. For more detail on confirmed mortalities, see page 48 of the report.

9th par. I hardly know how to properly comment on an intuitive judgment made from long-term quantitative data. Essentially Peterson supports our basic conclusions. Perhaps what he is saying is that it doesn't take a computer analysis to demonstrate that in a species with a low reproductive rate, annual mortality cannot exceed annual recruitment for long without placing the population in jeopardy. If that is what he means, we are in agreement.

It is axiomatic that the conclusions made from any data are only as good as the data. Certainly this applies to population analyses and specifically to our analysis. If Peterson or anyone else can come up with more precise reproductive data for the grizzly bear, we would be glad to incorporate such data into our models. Actually, we believe our reproductive data are one of the strongest biological parameters we recorded.

John Craighead

John J. Craighead, Leader
Mont. Coop. Wildl. Res. Unit

Comments on Gross Report

Mr. Gross has apparently used the biological parameters and mortality data from our report in a harvest-type population model as an independent check on the performance of our model. The agreement between the results of the two simulations is very good in most respects, especially considering that the models may be quite different in construction. Moreover, in the cases where the results from the two models differ, those of Mr. Gross show (without exception) lower population growth rates and hence a more critical situation than described in our report.

It is not possible for us to resolve the discrepancies noted in Gross's report without complete information on his population model and program. It would probably require a considerable effort since both programs would need to be modified to print out intermediate calculation steps in order to identify the sources of differing growth rates. We don't feel that such effort is justified since the results of Gross's simulation show a uniformly bleaker situation than ours do.

J.V.

Joel Varney
Mont. Coop. Wildl. Res. Unit

John:

Here is part of the simulations. More material is following.

Joel.

9-4-73

John:

I looked over this material and the 6 lbs. of computer printouts that he sent along with it. He made a few changes in reproductive and mortality rates to match the behavior of one of his own programs to the census data, then made projections with it. His program shows lower growth rates than ours, and the differences in results are all in the direction of faster declines. Fine results! Makes us look very conservative.

Resolving differences as he mentions would be a large task and require much digging into the guts of both programs and making step-by-step comparisons. Also we don't have his program, only results printouts. Don't volunteer to get into it without making allowance for the time and effort that would be required (lots). Besides, I think such details are immaterial since his runs show a worse situation.

Joel

Send Jack - 2 copies.

A COMPUTER RE-ANALYSIS
by
Jack E. Gross
of
A COMPUTER ANALYSIS OF THE YELLOWSTONE GRIZZLY BEAR POPULATION
by
Craighead, Varney, and Craighead

I. FORMAT FOR SIMULATIONS NO. 1 THROUGH NO. 4

A. Annual cycle as described on page A-9 and A-10

1. Simulation begins with initial population size on June 1, 1959. Each subsequent simulation year begins with simulation population on June 1.

2. Natural mortality was distributed evely over the year, but controlled through three mortality periods.

3. Hunting and control mortalities were grouped into one classification (called harvest mortality) that was applied in mid-October.

4. Effective reproduction first appears in the simulations on June 1, as cubs per adult female.

B. Data input for simulations

1. Initial population size and age-class structure for males and females as reported on page 6 (less the last 5 age classes which carried negligible numbers of females).

2. Reproductive rates of 1.02 cubs per adult female on June 1 of each year from 1959 through 1967, and reproductive rates of 0.70 cubs per adult female on June 1 of each year from 1968 through 1973.

3. Age class and sex class mortality rates as reported on page 22 from June 1, 1959 through May 31, 1968.

4. Beginning on June 1, 1968 age class and sex class mortality rates were increased to correspond to the increased known-mortality rate as discussed on page 23. For example, known deaths from 1959-67 comprised 54.5 percent of total mortality. Thus, in age 5.5 males, the total mortality was 0.0556. The instantaneous rate was 0.0572. The instantaneous known mortality rate was 0.0312 (0.0572 x .545) and the instantaneous unknown mortality rate was 0.0260 (0.0572 x .455). Of the 76 percent increase in known mortality (page 23), adults increased by 218 percent (page 25). Thus the new instantaneous known mortality rate was 0.0992 (0.0312 x 3.18). The new total instantaneous mortality rate was 0.1252 (0.0260 + 0.0992). The new crude mortality rate was

0.1177, which represents the 5.5 year contribution to an unchanged unknown mortality and a 76 percent increase in known mortality. All other age classes were corrected in the same manner, the only difference being that ages 0.5 through 4.5 increased by only 33 percent (page 25).

5. Beginning on June 1, 1971, the known mortality portion of total mortality was separated and appears in the simulations specifically as harvest.

6. The harvest of 6 animals in October of year 15 (1973) is a dummy value and does not affect the implication of the simulations which only include data up to June 1, 1973.

II. RESULTS OF SIMULATIONS NO. 1 THROUGH NO. 4

A. SIMULATION 1 (years 1-9)

1. Number of adult females in TABLE 2 = 30.7

   30.7 times reproductive rate of 1.02 = 3.13

   This value of 31.3 agrees closely with the value of 32 in SIMULATION 1, TABLE 8, COLUMN F, YEAR 2.

   But the production of 32 young was offset by the total loss of 31.7 animals during the year (SIMULATION 1, NARRATIVE REPORT, YEAR 1, STATEMENT 33.

   Thus, the population density changed from 156.9 at the beginning (June 1) of year 1 to 157.2 at the beginning of year 2 (SIMULATION 1, NARRATIVE REPORT, YEAR 1, STATEMENT 33) and thus the population increase was only 0.2 percent (SIMULATION 1, TABLE 2, COLUMN E, YEAR 2 and SIMULATION 1, NARRATIVE REPORT, YEAR 1, STATEMENT 34).

   However, model Ib in Fig. 9 (p-40) exhibited a population growth of 8 percent by changing from 157 at the beginning of year 1 (1959) to 169.6 at the beginning of year 2 (1960).

2. The population in Model Ib (p-40) increased at an average rate of 3.6 percent per year during the first 9 years to a population high of 207.4 at the beginning of year 9 (1967).

   The population in SIMULATION 1 increased at an average rate of 1.5 percent (SIMULATION 1, TABLE 2, COLUMN E, YEARS 1-9) to a population high of 175.9 at the beginning of year 9 (SIMULATION 1, TABLE 2, COLUMN A).

Thus, the population high in Model Ib was 17.9 percent larger than the population high in SIMULATION 1, and the growth rate in Model Ib was 140 percent greater than the growth rate in SIMULATION 1.

B. SIMULATION 2 (years 1-9)

3. The first discrepancy to be cleared was the increase between year 1 and 2. By boosting the second year's cub crop to 1.41 cubs per female (SIMULATION 2, TABLE 7, COLUMN D, YEAR 2), the population increased from 156.9 to 169.5 between the beginning of the first year and the beginning of the second year (SIMULATION 2, TABLE 2, COLUMN A, YEARS 1 and 2) or an increase rate of 8.19 (SIMULATION 2, TABLE 2, COLUMN E, YEAR 2). Thus the 8 percent first year's growth rate in SIMULATION 2 matched the 8 percent growth rate of Model Ib.

4. However, the average growth rate of the population in SIMULATION 2 was only 1.9 percent for the first 9 years (SIMULATION 2, TABLE 2, COLUMN E, YEARS 1-9) as compared to the average growth rate of 3.6 percent for the first 9 years in Model Ib of Fig. 9. The low growth rate of SIMULATION 2 also allowed the population to reach a high of 181.9 (SIMULATION 2, TABLE 2, COLUMN A, YEAR 9). Thus the growth rate of Model Ib was still 89 percent greater than SIMULATION 2 and the high population of Model Ib was still 14 percent larger than SIMULATION 2.

C. SIMULATION 3 (years 1-9)

5. The second discrepancy to be cleared was the low growth rate of SIMULATION 2. The growth rate was changed by changing the cub mortality rate to a value 1/2 the reported. The adjusted cub mortality rate caused the population to grow at an average rate of 4.0 percent (SIMULATION 3, TABLE 2, COLUMN E, YEARS 1-9) a figure 10 percent larger than the 3.6 percent growth rate in Model Ib (p-40).

6. However, the new growth rate allowed the population in SIMULATION 3 to increase to a high of 214.2 (SIMULATION 3, TABLE 2, COLUMN A, YEAR 9 which was 2.5 percent larger than the population high in Model Ib. Likewise, the new growth rate caused the first year's growth to increase from 8.1 percent to 11 percent (SIMULATION 3, TABLE 2, COLUMN E, YEAR 2).

D. SIMULATION 4 (years 1-9)

7. The final discrepancy was to reduce the first year's growth rate to a better approximation of Model Ib. By decreasing the second

year's cub crop to 1.22 cubs per female (SIMULATION 4, TABLE 7, COLUMN D, YEAR 2), the first year's growth rate was reduced to 7.2 percent (SIMULATION 4, TABLE 2, COLUMN E, YEAR 2) as compared to 8.0 percent in Model Ib (p-40). The population's average growth rate in SIMULATION 4 was 3.7 percent (SIMULATION 4, TABLE 2, COLUMN E, YEARS 1-9) as compared to 3.6 percent average growth rate in Model Ib, and the population high was 210.3 (SIMULATION 4, TABLE 2, COLUMN A, YEAR 9) as compared to a population high of 207.4 in Model Ib.

8. Thus, the first 9 years of population size in SIMULATION 4 (SIMULATION 4, TABLE 2, COLUMN A, YEARS 1-9) are for practical purposes identical to the first 9 years of population size in Model Ib (p-40). However, the similarity was achieved by altering the following original data:

   1. The second year's reproductive rate was increased from 1.02 to 1.22.

   2. The cub mortality was reduced by 50 percent (from .2564 and .3704 on males and females, respectively to .1376 and .2065 on males and females, respectively.

The discrepancies should be resolved. In addition, the 8 percent increase between year 1 and year 2 in Model Ib does not appear to be possible with the stated female age structure and reproductive rate.

E. SIMULATION 4 (years 10-15)

9. Considerable discrepancies begin to appear in the population trend and sizes between Model Ib and SIMULATION 4 in years 10-15 (1968-73). In short, the population in SIMULATION 4 declines more rapidly than that in Model Ib. The population in SIMULATION 4 on June 1, 1973 is 83.8 animals (SIMULATION 4, TABLE 2, COLUMN A, YEAR 15) or 18.3 percent below the 102 shown by Model Ib. The most likely candidate for this discrepancy is the way mortality was applied during the period. This discrepancy should be clarified.

F. SIMULATIONS 5-13 (years 16-25 or 1974-83)

10. The following evaluations are all based on an extension of SIMULATION 4.

John:

The earlier material I sent picks up here.

JEG

Here is the rest of the material. I suppose
We will be in contact in the next few days.
The whole thing looks pretty good.

JEG

I. STATEMENT FOR EVALUATION
(Page 59, Paragraph 3, Sentence 6)

"For the population to grow at approximately the 1959-67 rate of 2.5% per year with a reproductive rate of .70 the known mortality per year could not exceed 6 or 7 animals."

II. SIMULATION FOR EVALUATION

No. 8, Alternative 1, Alternative 2

1. DATA ALIGNMENT WITH SOURCE

ALTERNATIVE 1

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	0.70	0.70	TABLE 7, COLUMN D, YEARS 16-25
KNOWN MORTALITIES	7	7	TABLE 5, COLUMN E, YEARS 16-25
POPULATION TREND	+2.5%/yr.	+1.5%/yr.	TABLE 2, COLUMN E, YEARS 16-25

ALTERNATIVE 2

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	0.70	0.70	TABLE 7, COLUMN D, YEARS 16-25
KNOWN MORTALITIES	6	6	TABLE 5, COLUMN E, YEARS 16-25
POPULATION TREND	+2.5%/yr.	+2.2%	TABLE 2, COLUMN E, YEARS 16-25

2. COMMENT

The known mortality of 7 animals (ALTERNATIVE 1, TABLE 5, COLUMN E, YEARS 16-25) caused the population to grow at a relatively constant rate of 1.5 percent per year during the project period (ALTERNATIVE 1, TABLE 2, COLUMN E, YEARS 16-25). The slightly lower known mortality of 6 animals (ALTERNATIVE 2, TABLE 5, COLUMN E, YEARS 16-25) caused the population to grow at a relatively constant rate of 2.2 percent per year during the projection period (ALTERNATIVE 2, TABLE 2, COLUMN E, YEARS 16-25.

III. CONCLUSION

1. The statement is valid.

I. STATEMENT FOR EVALUATION
(Page 62, Paragraph 2)

"Runs with Model I and standard calculations using the life table both show that for a stable population (R=.78) the total mortality and the recruitment must both be 18.5% per year. For the 1959-67 period, yearly recruitment was 21%, exceeding the 18.5% mortality by 2.5% and resulting in an average yearly growth of 2.5% for that period."

II. SIMULATION FOR EVALUATION

No. 10, Alternative 2

1. DATA ALIGNMENT WITH SOURCE

1959-67 PERIOD

		SOURCE	SIMULATION	LOCATION IN SIMULATION
A	AVERAGE NUMBER YOUNG		36.1	TABLE 8, COLUMN F, YEARS 2-10
B	AVERAGE SIZE BASE POP.		151.4	TABLE 2, COLUMN D, YEARS 1-9
C	AVERAGE RECRUITMENT	21%	24%	A/B (IN THIS TABLE)
D	AVERAGE NUMBER LOST		30.5	TABLE 1, COLUMN A-D, YEARS 1-9
E	AVERAGE TOTAL MORTALITY	18.5	16.8%	TABLE 2, $\frac{A-D}{A}$, YEARS 1-9
F	POPULATION TREND	+2.5%	+3.0%	TABLE 2, COLUMN E, YEARS 1-9

1974-83 PERIOD PROJECTION

		SOURCE	SIMULATION	LOCATION IN SIMULATION
A	AVERAGE NUMBER YOUNG		16.5	TABLE 8, COLUMN F, YEARS 16-25
B	AVERAGE SIZE BASE POP.		68.3	TABLE 2, COLUMN D, YEARS 16-25
C	AVERAGE RECRUITMENT	18.5	24%	A/B (IN THIS TABLE)
D	AVERAGE NUMBER LOST		16.5	TABLE 2, COLUMN A-D, YEARS 16-25
E	AVERAGE TOTAL MORTALITY	18.5	19.5%	TABLE 2, $\frac{A-D}{A}$, YEARS 16-25
F	POPULATION TREND	level	level	TABLE 2, COLUMN E, YEARS 16-25

2. COMMENTS

Simulation number 10 (ALTERNATIVE 2) agrees with the statement only in terms of the growth rates during the 1959-67 and 1974-83 periods. The general patterns of average recruitment and average total mortality differ between the source and simulation. The recruitment for both periods in the simulation was equal, but the average total mortality increased in the 1974-83 period. Thus, recruitment changed in the source information while mortality changed in the simulation. In addition, the implications of equal recruitment and equal mortality on population stability may not be valid, depending on how they were calculated. For example:

1. Consider a base population of 100 animals with 18.5% recruitment the first of the year

2. There would be 18.5 young produced and the population size would be 118.5

3. Consider that the population exhibited 18.5% total mortality

4. The total number of animals lost during the year would be 21.9 and the end-of-year population would be 96.6, for a population decline of 3.4%

5. Thus, this example, which is comparable with the stated stable conditions, does not agree with the statement ?

6. If the population exhibited 15.6% total mortality, the total number of animals lost would be 18.5, and the end-of-year population would be 100, for a stable density. This example is comparable to the simulation.

III. CONCLUSION

1. The statement appears to be partly valid and partly invalid.

3 I. STATEMENT FOR EVALUATION
(Page 61, Paragraph 1, Sentence 1)

"Should known mortalities drop to 10 grizzlies per year, the population would remain essentially static if the reproductive rate is .78."

II. SIMULATION FOR EVALUATION

No. 10, Alternative 1, Alternative 2

1. DATA ALIGNMENT WITH SOURCE

ALTERNATIVE 1

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	.78	.78	TABLE 7, COLUMN D, YEARS 16-25
KNOWN MORTALITIES	10	10	TABLE 5, COLUMN E, YEARS 16-25
POPULATION TREND	level	-1.8%/yr.	TABLE 2, COLUMN E, YEARS 16-25

ALTERNATIVE 2

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	.78	.85	TABLE 7, COLUMN D, YEARS 16-25
KNOWN MORTALITIES	10	10	TABLE 5, COLUMN E, YEARS 16-25
POPULATION TREND	level	level	TABLE 2, COLUMN E, YEARS 16-25

2. COMMENTS

The stated reproductive rate of .78 (ALTERNATIVE 1, TABLE 7, COLUMN D, YEARS 16-25) required to create population stability does allow little change in the population in 1974 (ALTERNATIVE 1, TABLE 2, COLUMN E, YEAR 16), but does create a population that declines at an average rate of -1.8 percent, with the rate increasing in the latter years of the projection period (ALTERNATIVE 1, TABLE 2, COLUMN E, YEARS 16-25). An increase of the reproductive rate to .85 (ALTERNATIVE 2, TABLE 7, COLUMN D, YEARS 16-25) essentially creates long-term stability in the population (ALTERNATIVE 2, TABLE 2, COLUMN E AND A, YEARS 16-25).

III. CONCLUSION

1. The statement of required reproductive rate is slightly low but essentially valid.

I. STATEMENT FOR EVALUATION
(Page 74, TABLE 20)

"Allowable known mortalities in 1973 for stable population level."

(Page 73, Paragraph 1, Sentence 4)

"A permissable total known mortality of only 13 animals, 5 of which occur in the category of "other causes", leaves no leeway for trial and error management.

II. SIMULATION FOR EVALUATION

No. 12, Alternative 1, Alternative 2

1. DATA ALIGNMENT WITH SOURCE

ALTERNATIVE 1

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	1.0	1.0	TABLE 7, COLUMN D, YEAR 16
KNOWN MORTALITIES	13	13	TABLE 5, COLUMN E, YEAR 16
1974 POPULATION TREND	level	+0.1%	TABLE 2, COLUMN E, YEAR 16

ALTERNATIVE 2

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	1.0	1.0	TABLE 7, COLUMN D, YEARS 16-25
KNOWN MORTALITIES	13	11	TABLE 5, COLUMN E, YEARS 16-25
POPULATION TREND	level	-1.1%	TABLE 2, COLUMN E, YEARS 16-25

2. COMMENTS

The 13 known mortalities (ALTERNATIVE 1, TABLE 5, COLUMN E, YEAR 15) do hold the 1973 population size of 83.8 to a 1974 population size of 83.9 (ALTERNATIVE 1, TABLE 2, COLUMN A, YEARS 15 and 16), but the continued application of 13 known mortalities (ALTERNATIVE 1, TABLE 5, COLUMN E, YEARS 16-25) cause the population to decline at an increasing rate during the final 9 years of the projection period (ALTERNATIVE 1, TABLE 2, COLUMN E, YEARS 16-25). However, a known mortality of 11 animals (ALTERNATIVE 2, TABLE 5, COLUMN E, YEARS 15-25) cause the population to assume a more level population trend of -1.1% during the projection period (ALTERNATIVE 2, TABLE 2, COLUMN E, YEARS 16-25). Actually, the known mortality would have to be slightly less than 11 per year.

III. CONCLUSION

1. The statement of allowable known mortalities to stabilize the population is valid for 1973, but is 18 percent too high for long-term stabilization.

I. STATEMENT FOR EVALUATION
(Page 61, Paragraph 1, Sentence 2 and 3)

"It would grow at about 2.5 percent per year with a reproductive rate of 1.0. Thus for the population of grizzlies in 1973 to grow at about the same rate that characterized it during the 1959-67 period, it can sustain only 10 known deaths during 1973 and must exhibit a reproductive rate of 1.0."

II. SIMULATION FOR EVALUATION

No. 11

1. DATA ALIGNMENT WITH SOURCE

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	1.0	1.0	TABLE 7, COLUMN D, YEARS 16-25
KNOWN MORTALITIES	10	10	TABLE 5, COLUMN E, YEARS 16-25
POPULATION TREND	+2.5%/yr.	+3.2%/yr.	TABLE 2, COLUMN E, YEARS 16-25

2. COMMENTS

The simulation population trend of 3.2 percent annual growth is reasonably close to the stated 2.5 percent annual growth. However, the simulation growth of 3.2 percent in years 16-25 (TABLE 2, COLUMN E) almost duplicates the simulation growth of 3.3 percent in years 1-9 (TABLE 2, COLUMN E). Thus, the stated reproductive rate and known mortalities for the projection do cause the population to grow at a similar rate observed in 1959-67.

III. CONCLUSION

1. The statement is valid.

6 I. STATEMENT FOR EVALUATION
(Page 59, Paragraph 4, Sentence 1)

"If known mortalities per year drop to 15, the reproductive rate must be 1.5 to effect a 2.0 percent population growth."

II. SIMULATION FOR EVALUATION

No. 9, Alternative 1, Alternative 2

1. DATA ALIGNMENT WITH SOURCE

ALTERNATIVE 1

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	1.5	1.5	TABLE 7,COLUMN D,YEARS 16-25
KNOWN MORTALITIES	15	15	TABLE 5,COLUMN E,YEARS 16-25
POPULATION TREND	+2.0%/yr.	-3.5%/yr.	TABLE 2,COLUMN E,YERAS 16-25

ALTERNATIVE 2

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	1.5	1.8	TABLE 7,COLUMN D,YEARS 16-25
KNOWN MORTALITIES	15	15	TABLE 5,COLUMN E,YEARS 16-25
POPULATION TREND	+2.0%/yr.	+2.2%/yr.	TABLE 2,COLUMN E,YEARS 16-25

2. COMMENTS

The stated reproductive rate of 1.5 is not sufficient to maintain a 2.0 percent population growth over the entire projection period. Although a fairly level population is maintained for the first 4 years of the projection (ALTERNATIVE 1, TABLE 2, COLUMN A, YEARS 16-19), the average population trend is -3.5 percent (ALTERNATIVE 1, TABLE 2, COLUMN E, YEARS 16-25). The population will increase at an average rate of 2.2 percent over the projection period (ALTERNATIVE 2, TABLE 2, COLUMN E, YEARS 16-25) with a reproductive rate of 1.8 (ALTERNATIVE 2, TABLE 7, COLUMN D, YEARS 16-25), or 20 percent higher than the stated rate.

III. CONCLUSION.

1. The stated reproductive rate is 17 percent too low to achieve the stated results.

I. STATEMENT FOR EVALUATION
(Page 59, Paragraph 3, Sentence 4)

"If the known mortalities for 1973 drop to 20 (they were 27 in 1972) then the population cannot grow even if it should exhibit a reproductive rate as high as 2.0."

II. SIMULATION FOR EVALUATION

No. 6

1. DATA ALIGNMENT WITH SOURCE

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	2.0	2.0	TABLE 7, COLUMN D, YEARS 16-23
KNOWN MORTALITIES	20	20	TABLE 5, COLUMN E, YEARS 15-23
POPULATION TREND	DOWN	DOWN	TABLE 2, COLUMN A, YEARS 16-23

2. COMMENTS

Although the population increased by 10.9% (TABLE 2, COLUMN E, YEAR 16) in the first projection year (due to a sudden change from a reproductive rate of 0.70 to 2.00 (TABLE 7, COLUMN D, YEARS 15-16)), the increase is temporary and is soon cancelled (TABLE 2, COLUMN E, YEAR 18) by the fixed known mortality that takes an increasingly large percentage of the total population (TABLE 5, COLUMN F, YEARS 16-23), and the population size continues to decline (TABLE 2, COLUMN A, YEARS 16-23).

III. CONCLUSION

1. The statement is invalid if the single year 1973 is the reference point.

2. The statement is valid if the 10-year trend 1973-1983 is the reference point.

8 I. STATEMENT FOR EVALUATION
(Page 59, Paragraph 3, Sentence 5)

"Should the reproductive rate remain depressed at .70, the population would decline at a rate of 10% per year."

II. SIMULATION FOR EVALUATION

No. 7

1. DATA ALIGNMENT WITH SOURCE

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	0.70	0.70	TABLE 7, COLUMN D, YEARS 16-17
KNOWN MORTALITIES	20	20	TABLE 5, COLUMN E, YEARS 15-17
POPULATION TREND	-10%/yr.	-19%/yr.	TABLE 2, COLUMN E, YEARS 16-17

2. COMMENTS

For the 6-year period immediately prior to the projection period, during which the population exhibited a reproduction rate of .70 (TABLE 7, COLUMN D, YEARS 10-15), the population declined from 206 to 83 (TABLE 2, COLUMN A, YEARS 10-15) for an average decline rate of 14% per year (TABLE 2, COLUMN E, YEARS 10-15). Since the fixed known mortality of 20 animals (TABLE 5, COLUMN E, YEARS 15-17) takes an increasingly larger percentage of the total population (TABLE 5, COLUMN F, YEARS 15-17), the application of a .70 reproductive rate to the population projection (TABLE 7, COLUMN D, YEARS 16-17) continues to depress the population size.

III. CONCLUSION

1. The general implication of the statement is correct.
2. The magnitude of the decline is greater than the statement indicates.

9

I. STATEMENT FOR EVALUATION
(Page 56, Paragraph 2, Sentence 2)

"At the 1972 level (rate 1), the reproductive rate must be 2.8 for a stable population."

II. SIMULATION FOR EVALUATION

No. 13, Alternative 1, Alternative 2

1. DATA ALIGNMENT WITH SOURCE

ALTERNATIVE 1

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	2.8	2.8	TABLE 7,COLUMN D,YEARS 16-19
KNOWN MORTALITIES	27	26*	TABLE 5,COLUMN E,YEARS 16-19
POPULATION TREND	LEVEL	-6.7%	TABLE 2,COLUMN E,YEARS 16-19

*Actually 27 but rounding error shows 26

ALTERNATIVE 2

	SOURCE	SIMULATION	LOCATION IN SIMULATION
REPRODUCTIVE RATE	2.8	4.5	TABLE 7,COLUMN D,YEARS 16-25
KNOWN MORTALITIES	27	26*	TABLE 5,COLUMN E,YEARS 16-25
POPULATION TREND	LEVEL	+0.4%	TABLE 2,COLUMN E,YEARS 17-25

*Actually 27 but rounding error shows 26

2. COMMENTS

Although the application of the 2.8 reproductive rate caused the population to increase by 13.8% in the first year of the projection (ALTERNATIVE 1, TABLE 2, COLUMN E, YEAR 16), the application of the same reproductive rate to the population in following years caused the population to decline at an increasing rate (ALTERNATIVE 1, TABLE 2, COLUMN E, YEARS 17-19). A reproductive rate of 4.5 applied in ALTERNATIVE 2 produced a population with a practically level trend of 0.4% annual increase (TABLE 2, COLUMN E, YEARS 17-25) and with a mean density of 127.5 (TABLE 2, COLUMN A, YEARS 17-25).

III. CONCLUSION

1. The stated reproductive rate for population stability at 1972 mortality levels is a considerable underestimate.