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

IMPACTS OF INCREASED HUNTING PRESSURE ON THE DENSITY, STRUCTURE, AND DYNAMICS OF BROWN BEAR POPULATIONS IN ALASKA'S GAME MANAGEMENT UNIT 13

by
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Project W-23-2
Studies 4.18 and 4.21
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4.18 (see Appendix H)

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SUMMARY

During this reporting period progress was made in a number of somewhat disconnected areas related to this project. Three manuscripts were prepared and presented at the 8th International Conference of Bear Research and Management (Victoria, BC, Canada, Feb. 1989). Abstracts of two of these manuscripts ("Detection of Differences in Brown Bear Density Caused by Hunting in GMU 13" and "Denning Ecology of Brown Bear in Southcentral Alaska") are presented in Appendices A and B of this report. The abstract of the third manuscript ("Population Management of Bears in North America") is presented in Appendix G.

The timing of female harvests during spring and fall seasons in Unit 13 was examined to determine when a closure would protect the most females from hunting. The first 2 weeks of the fall season would be the best period to close. A comparison of information on harvest densities in areas accessible by road to those accessible primarily by airplane supported earlier conclusions (Miller 1988) that there has been a long history of overharvesting along the Denali Highway. Brown bear harvests throughout southcentral Alaska have increased 50% during the last 5 years, compared with the period 1975-1979; seasons in most areas became more liberal during this period. This pattern raises concerns that harvests in excess of sustainable levels could become widespread throughout the region.

Simulation studies were conducted to illustrate sample size and term of study required to estimate reproductive parameters; i.e., litter size, reproductive interval, and age of first reproduction for brown bears (Appendix C). Sensitivity analyses were conducted to indicate impacts of error in estimating these reproductive parameters on estimating sustainable harvest rates of brown bear populations (Appendix C). Simulation studies were also conducted to evaluate the impact of violating the independent observation assumption in making capture-recapture estimates of bear populations (Appendix D). Returns from a mail survey of brown

bears hunters were analyzed to estimate resident and nonresident hunter success rates in each Alaskan Game Management Unit (Appendix E).

Key words: Alaska, brown bear, *Ursus arctos*, density estimate, capture-recapture, Lincoln index, independent observation assumption violation, population trend, simulation studies, bear reproductive rate estimation, bear hunter success rates.

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OBJECTIVES

To document changes in density and in the sex and age composition in a brown bear population subjected to heavy rates of harvest by hunters.

To monitor changes in individual bear reproductive performance and survivorship in a population subjected to heavy harvest rates.

To investigate the hypothesis that brown bear cub survivorship is inversely related to the proportion of adult males in the population.

RESULTS AND DISCUSSION

A final report on objective 1 was presented by Miller (1988). A progress report on objectives 2 and 3 was also presented by Miller (1988). Data on objectives 2 and 3 accumulate slowly and will be compiled and analyzed in next year's progress report. Objectives

2 and 3 represent continuation of bear studies begun in 1980 as part of Su-hydro bear investigations (Miller 1987).

During this reporting period, 3 manuscripts related to this project were prepared and presented at the "8th International Conference for Bear Research and Management." These draft manuscripts will be published in 1990. The first of these was a comparison of brown bear densities in intensively and less-intensively hunted portions of Unit 13. This manuscript describes the results obtained for objective 1 of this project that were reported by Miller (1988). The abstract for this manuscript is presented in Appendix A. The 2nd manuscript discussed aspects of population management of bears in North America. The abstract of this manuscript is presented in Miller and Miller (1990; Appendix G). The 3rd manuscript described denning ecology of brown bears in Unit 13, including the chronology of sex ratio in harvested animals (<u>see</u> abstract in Appendix B).

Modified capture-recapture techniques were used to document a decline in brown bear density between 1979 and 1987 in a study area along the Denali Highway following liberalization of hunting regulations (Miller 1988). Lower brown bear densities were also documented between this study area along the Denali Highway and a nearby area with similar habitat (Miller 1988).

Hunting was indicated as the cause of the differences in density between these 2 areas by a comparison of kill densities (i.e., number of bears killed/unit area) in these 2 areas (Fig. 2). Since the early 1970s, kill density has been over twice as high in the accessible areas along the Denali Highway as in the nearby areas where most hunting access is by airplane (Fig. 1). Harvests have been declining along the Denali Highway since 1984 and in the more remote area since 1985 (Fig. 1). It appears probable that high harvests along the Denali Highway were sustained largely by immigration of bears from areas with less hunting pressure. However, the increased hunting pressure in these remote areas since regulation liberalization began in 1980 has reduced the capability of the formerly lightly hunted areas to restock, through immigration, the more heavily hunted areas. This interpretation is also supported by information on population composition in these 2 study areas (Miller 1988).

<u>Effects of Harvest in Unit 13</u>

The reduction in brown bear density in accessible portions of Unit 13 (Miller 1988), which includes Subunits 13A, 13B, and 13E, may require a reduction in the harvest in order to prevent further declines in density. Chronology of changes in sex ratio in harvested animals has management implications. More adult females are harvested during the early portion of the fall season than during any other period of spring or fall seasons (Fig. 1--taken from the denning ecology manuscript, Appendix B). This suggests that elimination of the early portion of the fall season may be the most effective way to prevent further declines in Unit 13 brown bear populations.

Brown Bear Management in Southcentral Alaska

During the 1980's increases in brown bear harvests observed in Unit 13 have been paralleled by increases in harvest elsewhere in southcentral Alaska. Harvests during 1975-1979 were lower in every portion of southcentral Alaska than they were during 1984-1988 (Table 1). Increases ranged from a relatively modest 27% in Unit 9 to 149% in Unit 16 (Table 1). In the region as a whole, harvests increased by 50% (Table 1). Except in Unit 8 (Kodiak) seasons were longer in every unit in the Southcentral region in 1988 than they were in 1979 (Table 1). Although information is lacking for specific areas, hunter effort is probably also increasing; there were over twice as many brown bear tags sold by 1987 (8,046) as in 1979 (3,779) (Table 1, Appendix E). These changes, do not mean that any of these areas are being overharvested. They do suggest, however, that a geographically widespread shift has occurred from conservative management of brown bears to more aggressive strategies in which the potential for overharvests is higher. This shift has occurred in the absence of any new direct information on the status of bear populations anywhere in this region, except in Unit 13 where the population is declining at least in accessible areas (Miller 1988) and in Unit 8 where field studies (Smith and Van Daele 1988, Barnes 1986) demonstrate the population is stable (ADF&G files). Because the increases in harvest are geographically widespread across many units, there is a risk of simultaneous reductions in several areas. Marked reductions in the regional harvest would be required to remedy this situation.

Estimating Reproductive Rates

In 1988 an intraagency workshop on bear management was held in Anchorage. Following this meeting I was assigned the task of preparing recommendations on

> . . .the value of reproductive data collected from radio-collared animals and recommend priorities on where such data should be collected. This would include an evaluation of which parameters are most important, a review of the potential uses of such data, and a desired sample size for each use, a review of the currently available database and recommendations on areas where an increase in the database is most important. Illustrations of how rapidly data on each parameter accumulate (e.g. the pattern of accumulation of breeding interval data over a period of years) should be included. (1 April 1988 memo from Karl Schneider on bear workshop results).

The initial effort on this assignment is presented in Appendix C. This work will be redone incorporating some needed improvements in procedures, additional simulations will be run for black bear reproductive parameters, and the results will be prepared for publication.

Mark-Recapture Density Estimation Technique

The mark-recapture procedures used to estimate bear density in Unit 13 and elsewhere require making a number of assumptions which may or may not be valid (Miller et al. 1987). It is important to continue to examine these assumptions to evaluate the sensitivity of the underlying model to assumption violations. One of these assumptions is that observations are independent of each other. This assumption is violated when bears occur in groups. Most commonly these groups are families of a female with her offspring, but they may also include breeding aggregations in the spring.

Miller et al. (1987) recommended a procedure where family groups recaptured during density estimation procedures would be considered all marked or unmarked depending on whether the mother was marked. Because this procedure was clearly a violation of the independent observation assumption, we also recommended calculating a separate density estimate for the population of bears 2.0 years old, the age when young separate from their mothers in Unit 13 (Miller et al. 1987). This estimate could be converted to a total population estimate if the proportion of the population consisting of cubs and yearlings was known. During capture-recapture density estimation procedures on Kodiak Island, the population estimate was calculated for the population of "independent" bears, excluding offspring still with their mothers (Barnes et al. 1988). This procedure is, like the population >2.0 estimate recommended by Miller et al. (1987), preferable from a statistical standpoint because it reduces a source of error derived from violation of the independent observation assumption. It has the disadvantages, however, of requiring a correction factor to derive a total population estimate which includes dependent offspring and of not permitting density comparisons between areas where age of independence is different. For these reasons, a simulation study was conducted to evaluate the significance of violating the independent observation assumption in making estimates of total population size following the procedure recommended by Miller et al. (1987). The results of this work are presented in Appendix D.

Hunter Questionnaire

A questionnaire was sent to all persons who purchased a brown bear hunting tag in either 1985 or 1986. The objectives of this questionnaire were to establish levels of hunting effort by unsuccessful hunters in different Units (only successful hunters are required to report effort and other data) and to estimate the economic value of bear hunting in Alaska. Most of these data have yet to be analyzed. However, a preliminary analysis of success rate by resident and nonresident hunters in each unit in the state has been completed. Success rates reported by hunters responding to the questionnaire were compared with those from the permit reports required from all bear hunters in Unit 8 (Appendix E).

Maximum Sustainable Harvest and Population Recovery

Simulation studies indicate that the maximum sustainable harvest for highly productive populations is 5.7% for brown bears and 14.2% for black bears (Appendix F). Overharvested populations of grizzly bears and black bears will require decades to recover if hunted during the period of recovery (Appendix F).

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Table 1. Change in number of brown bear harvested in different GMUs in Region II from the 5 year period prior to 1979 to the 5 year period ending in 1988 and corresponding changes in seasons.

Mean Harvest By GMU	6	7 & 15	8	9	13	14	16	17	All Region II
'75-79	26.6	5.4	124.6	183.4	63.4	5.4	28.2	35.8	472.8
'84-88	47.8	12.4	173.6	233.4	115.6	11.2	70.2	47	711.2
% increase	79.7	129.6	39.3	27.3	82.3	107.4	148.9	31.3	50.4
Seasons									
Spring '79	5/10-5/25	5/15-5/25	4/1-5/31	5/10-5/25*	closed	closed	5/10-5/25	5/10-5/25	
Spring '88	1/1-5/31	5/10-5/25	4/1-5/15	5/10-5/25*	1/1-5/31	5/10-5/25	1/1-5/25	4/10-5/25	
Spring Increase (days)	+135	+5	-16	0	+151	+16	+129	+30	
Fall '79	10/10-11/30	9/10-9/30	10/1-11/30	10/7-10/21*	9/1-10/10	9/10-10/10	9/1-10/10	10/7-10/21	
Fall '88	9/1-12/31	9/1-10/15	10/25-11/30	10/1-10/21*	9/1-12/31	9/1-10/31	9/1-12/31	9/10-10/10	
Fall Increase (days)	+70	+24	-24	+7	+82	+30	+82	+16	
Total increase	+205	+29	-40	+7	+233	+46	+211	+46	

* Alt. years

Figure 1. Number of female brown bear killed during each week of the open season. Percentage of kill during week that is female is indicated in parenthesis. Data are from Alaska's Game Management Unit 13 during period 1980-1987. Figure is from report on denning ecology of brown bears in south-central Alaska (Appendix B.).

Figure 2. Annual brown bear kill densities (kill/1000 km^2) reported in road accessible (the Denali Highway area) and inaccessible (remote central) portions of Alaska's Game Management Unit 13 during 1970-1988. Coding areas included in each area are presented in Appendix A of Miller (1988). Bag limit was 1/year from fall 1982 through spring 1987, 1/4 years before and after this period. Spring season was added in 1980 and remains in effect. Figure is from manuscript described in Appendix A.

Figure 1.

Chronology of female brown bear kill

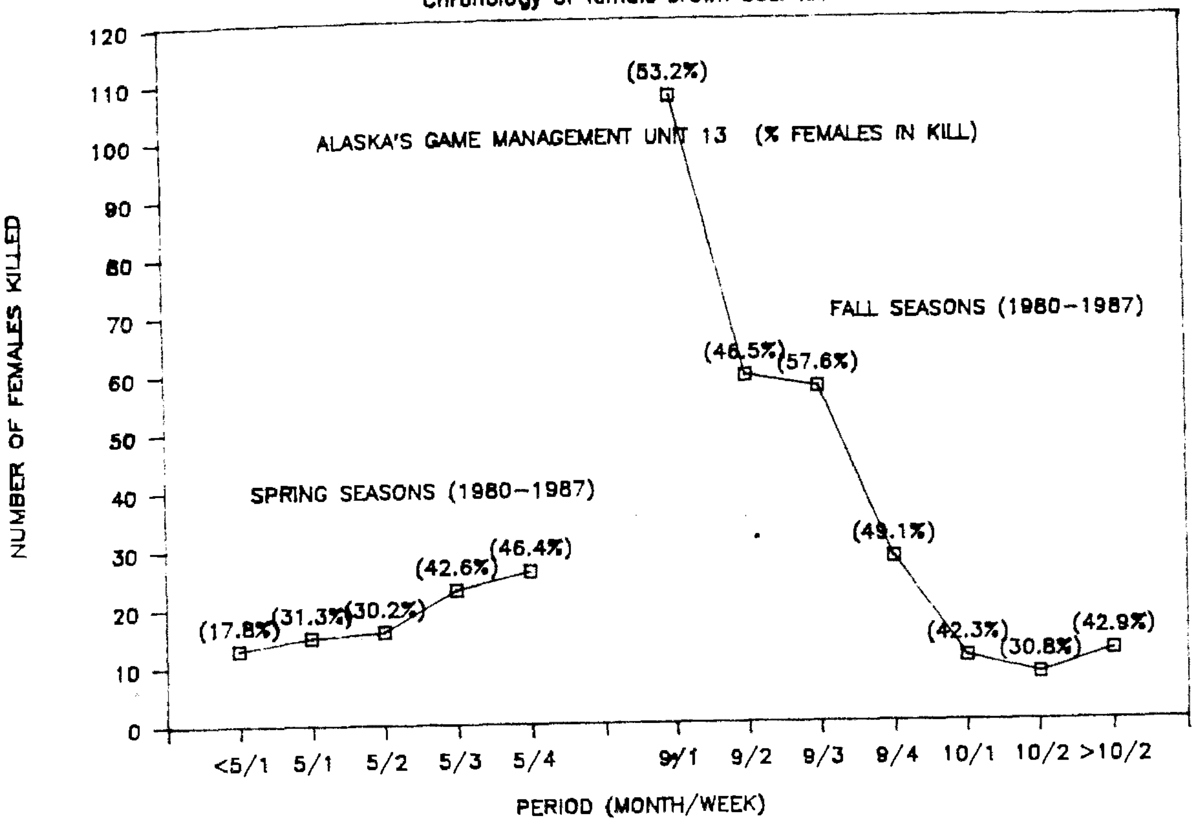
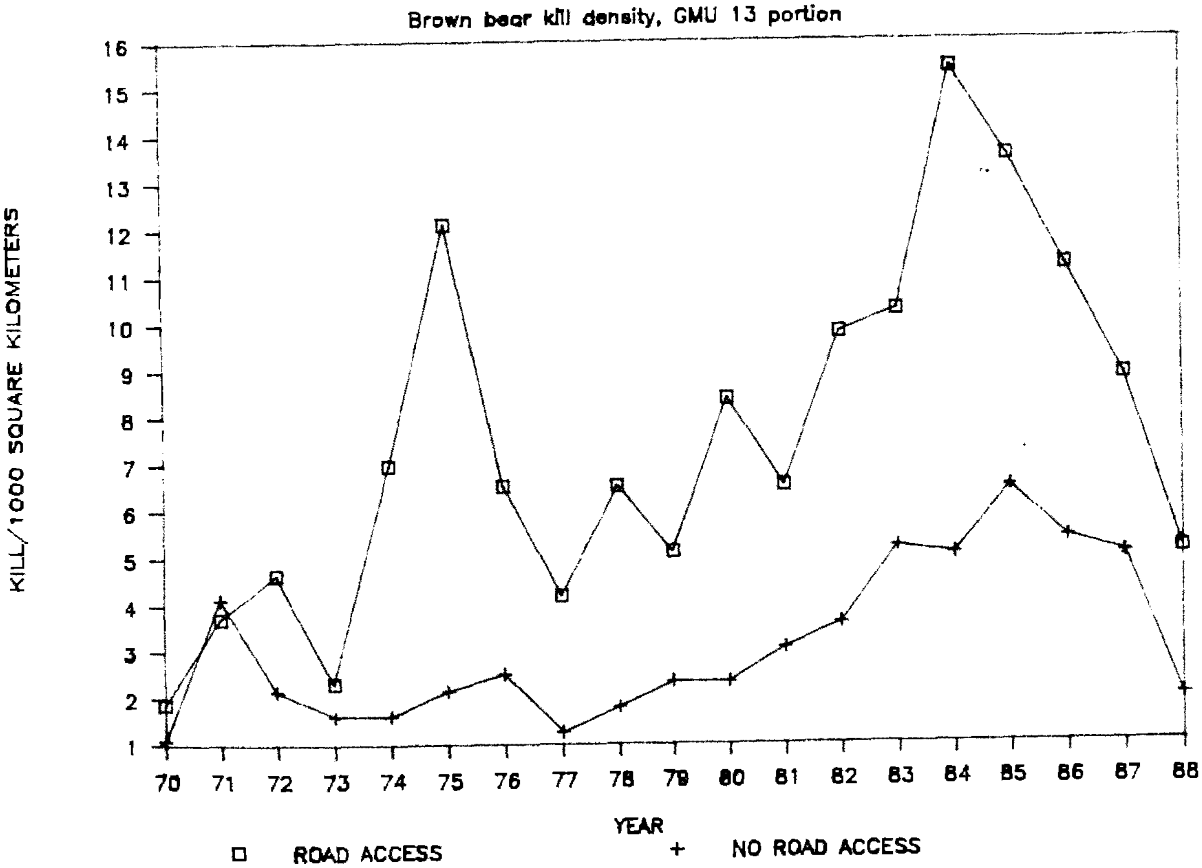


Figure 2.

Brown bear kill density, GMU 13 portion



Appendix A. Detection of Differences in Brown Bear Density and Population Composition Caused by Hunting.

STERLING D. MILLER. Alaska Dept. of Fish and Game. 333 Raspberry Rd. Anchorage, AK 99518-1599.

Abstract: Liberalized hunting regulations in a portion of southcentral Alaska resulted in an increased sport-harvest of brown bears (Ursus arctos). A reduction in population density caused by increased hunter harvest was demonstrated using modified capture-recapture techniques. Density differences were documented between 2 areas of generally equivalent habitats but different patterns of hunter access as well as in the same area at 2 different times. Density estimates (for bears >2.0 years old) were 6.7 bears/1000 km^2 (95% CI = 5.2- 10.1) in the intensively hunted area compared to 12.9 (95% CI = 7.3-31.5) in the same area 8 years earlier, and 19.1 (95% CI = 16.7-23.2) in the less intensively hunted area. The total population density estimate was 10.51 bears/1000 km^2 in the intensively hunted area. Males constituted a smaller proportion of the population in the heavily hunted area compared to the less intensively hunted area and to the same area studied prior to onset of increased hunting pressure. There were relatively more younger males and more older females in the heavily hunted population.

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Appendix B. Denning Ecology of Brown Bears in Southcentral Alaska and Comparisons with a Sympatric Black Bear Population.

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Abstract: Brown bears (Ursus arctos) in southcentral Alaska spent an average of 201 days in winter dens. Males spent the least time in dens (mean = 189 days) and parturient females the most (mean = 217 days). Females with newborn cubs and females that were pregnant at den entry spent the least amount of time out of dens (158 and 164 days respectively) and males the most (180 days). No differences in den entrance date based on sex or reproductive status was observed. Mean den entrance date was 14 October. Entrance date differed between years, early entrance appeared associated with berry crop failures and colder weather. Mean date of exit from dens was earliest for males (23 April) and latest for females with newborn cubs (15 May). Exit dates also varied between years with late exits correlated with colder weather and persistent snow cover.

Dens used by brown bears in this area were almost all excavated, no unmodified natural cavities were used. These dens collapsed during spring and summer precluding reuse. Some individuals dug dens in the same general area from year to year; mean distance between den sites used in successive years by all bears was 6.1 km. Characteristics of den sites and sizes of dens are described. Typically dens were dug at higher elevations and on the periphery of home ranges used during summer and fall. Upon exit most bears moved to lower elevations but females with newborn cubs tended to remain in the vicinity of den sites. Available data suggest this behavior reduces loss of newborn cubs to predation by other bears.

Compared to a sympatric population of black bears (Ursus americanus), brown bears denned at higher elevations, spent less time in dens, emerged from dens earlier, and spent less time in dens. Dimensions of brown bear dens were not significantly larger than for excavated black bear dens and mean dates of emergence from dens were about the same. A proposed hydroelectric project in this study area would likely have reduced black bear populations through impacts on black bear denning habitat. The project would have had only indirect impacts on brown bear denning habitats.

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Appendix C. Factors of sample size and study term to consider in designing studies to estimate brown bear reproductive rates.

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Estimating reproductive rates of brown bears

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Abstract: Simulation studies were conducted to estimate length of study period and sample size of marked animals required to estimate reproductive parameters (reproductive interval, litter size, age at first reproduction). Simulations were analogous to investigations where a number of female bears are radio- marked in the first year of study and subsequently followed for many years to determine reproductive rates. For each parameter, complex (heterogeneous) and simple (homogeneous) scenarios that were thought to bound the range biologically feasible for brown bears (Ursus arctos) were modeled. Simulations were conducted as if 10, 25, 50, and 75 radio-marked females were available for each scenario.

Ten marked females were not adequate to estimate any reproductive parameter to the point where 90% of the samples drawn from the same population correctly estimated (within +/- 5%) the true value of the reproductive parameter in the complex scenario. This sample size was also inadequate to estimate litter size or age at first reproduction even for simple scenarios regardless of length of study; it did estimate reproductive interval for the simple scenario after 7 years of study. For sample sizes > 25 females, age at first reproduction was correctly estimated within +/- 5% of the true value in > 90% of the samples in year 3 of the study for the simple scenario and in year 5 for the complex scenario. For estimation of litter size this level of precision was reached for samples > 50 in year 11 of the complex scenario and in year 6 of the simple scenario.

Sensitivity analyses on the significance of error in estimating these reproductive parameters indicated that reproductive interval was the most significant. However, no reproductive parameter was very significant in affecting growth rate of populations, a 25% overestimate of each of these 3 parameters resulted in only an 8.08% increase in population growth rate.

INTRODUCTION

Biologists planning studies on reproductive parameters of animals with low reproductive rates like brown bear (Ursus arctos) know that many years of study will be necessary to accurately estimate reproductive parameters. It is difficult, however, to evaluate in advance how many years will be needed and how many animals should be marked to accomplish the objectives. It is frequently necessary to make such evaluations in order to justify budget requests, assure adequate long-term financing for studies, and to avoid studies that are too short-term or that have too few marked animals to accomplish meaningful estimates. Avoidance of inadequately designed studies is especially important in areas where the status of bears is threatened and, frequently, it is precisely in these areas where studies are most in demand. Also, reproductive data, which are frequently cited as justification for studies of small or declining bear populations, may not be needed at all if these parameters can be adequately approximated by comparisons with other areas.

This study is designed to assist investigators planning studies designed to estimate grizzly bear reproductive parameters (litter size, age at first reproduction, reproductive interval) to design their studies in a way which will maximize the utility of their efforts. This may also help avoid experimental designs which could ultimately prove fruitless in accomplishing desired objectives. In addition to the answers provided in this study, the approach used should prove useful in designing studies for other species with low reproductive rates.

Different investigators may have different designs in terms of when marks are applied. In the simulations described here, I used a model where all marks were applied simultaneously in the first year of study and where marked animals were followed with no mortality, radio-failures, or missing data. Since in real studies, information gaps from these causes do occur, the simulations underestimate the number of marks and the period of time required to obtain the necessary level of precision in making estimates of reproductive rates. The approach described here could be adapted by investigators who desired to incorporate these factors in estimating the necessary term for studies.

In addition, an effort is made to evaluate the significance of error in estimates of each of the 3 reproductive parameters in making estimates of population growth rates. These results should assist in design of reproductive rate studies and help avoid studies which are too short or have too few marked bears to achieve meaningful estimates of reproductive rates.

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METHODS

Eight simulations were conducted for each of the three reproductive parameters (reproductive interval, age at first reproduction, litter size). For each reproductive parameter an effort was made to simulate from the basis of the most complex as well as from the least complex scenarios that might exist in the real world. This would establish the outer limits within which real-world investigations would occur. A complex situation was one in which there was large variation in the parameter between different individuals and the mean value for the parameter was large. A simple scenario had little variability between individuals and the mean value for the parameter was relatively small. The simulations were conducted from the standpoint of an investigator following radio-marked females to determine their reproductive status. For both the complex and simple scenarios, simulations were run as if 4 different sample sizes (N = 10, 25, 50, and 75) of individuals were radio-marked. These changes in sample size progressively represent increases of 250%, 100%, and 50% from the preceding sample.

For each reproductive parameter and scenario, a population of individuals with known reproductive traits was established. Random samples of (N) individuals were repetitively drawn from these populations and the corresponding reproductive rate parameter based on this sample was calculated for each replication. Values use for (N) were 10, 25, 50, or 75. A minimum of 300 replicate samples were drawn for simulation of reproductive interval estimation, 500 for each simulation of age at first reproduction, and 300 for each simulation of litter size. Variability in this derived from the speed of the computer running the simulations overnight. The base population was 1000 individuals for reproductive interval, 500 for litter size and age at first reproduction. [xxx note to readers of this draft, 1000 is too many, each run was taking 50 hours on a Compac Deskpro so I cut back to 500 individuals in the population and to fewer replications in subsequent runs--still have plenty, but will probably try to standardize this for the ultimate publication].

For each scenario, the true value of the reproductive parameter for the whole population was calculated. For each year of study in each simulation, the proportion of all replicates that produced results within +/- 5% of the true value was calculated and presented graphically. All simulations were run using DBASE III (Ashton-Tate).

Reproductive interval estimation was based on the period between production of a litter and production of the subsequent litter (excluding subsequent litters which suffer premature, pre-weaning, mortality). In estimating recruitment rates for brown bears, this is a more meaningful calculation as frequently whole litters can be lost very early. When this happens the female can breed again and produce a litter the following year; this would yield a meaningless interval of 1 year. Inclusion of such meaningless "intervals" would yield overestimates of reproductive capability. This method of calculating reproductive data was used for real populations of brown and black (Ursus americanus) bears (Miller 1987 and unpubl. data). The frequency of interval lengths used for simulations of simple and complex scenarios is presented in Table 1.

In the simple scenario data for reproductive interval (Table 1), 75% of the reproductive intervals were 3 years and 25% were 4 years. A "list" consisting of 750 records each with the value of 3 and 250 records with the value 4 was created to run simulations for this scenario. Random numbers were assigned to each record and records were then ordered by random number. These records were read into a sampling file of 1000 individuals as the interval length values for interval number 1. Random numbers were then reassigned to the list, the list was re-ordered and appended into the sampling file as interval lengths for interval number 2 of the 1000 individuals in the sampling file. This process was repeated for interval numbers 3 through 9 so that each interval for each individual in the sampling file was independently assigned. Subsequently, for each individual in the sampling file, the year each interval (1 through 9) was completed was calculated. In the simple scenario where all intervals were either 3 or 4, for example, no intervals would be completed in years 1 or 2, but some would be included in year 3. In a case where an individual had completed 2 intervals of 3 years followed by one of 4 years, all three intervals would be included in calculation of mean interval length in the tenth year of the study (3+3+4), the first 2 in the sixth year of study (3+3), and only the first interval in the third year of study.

Repeated random samples were drawn from this sampling file and the mean of all intervals that had been completed in each year since year 1 of the study was calculated and entered into a results file for each year (1-30) of each replication. Finally, this results file was examined to see what proportion of the replications in each year of study provided a calculated reproductive interval that was within +/- 5% of the true reproductive interval for that scenario.

A similar process was followed for the litter size simulations. For the simple scenario, 80% of the litters had 2 cubs and 20% had 3, therefore the "list" for this scenario contained 400 records of 2 and 100 records of 3 (values for the complex scenario are presented in Table 3). Each individual in the sampling file could have up to 6 litters and the size of each of these litters was randomly assigned in the same manner as for reproductive interval (6 independent random sortings of the list of litter sizes). In order to evaluate length of study needed to obtain an adequate estimate of mean litter size, the period between litters must also be know. Values used for the period between litter 1 and 2, between 2 and 3, and so on, were identical to the values previously derived for estimating reproductive interval in the simple scenario (80% of intervals were 3 years and 20% 4 years). Sampling was conducted as if the first assigned litter (litter 1) was observed in the first year of study.

For age at first reproduction the situation modeled was analogous to one where animals were marked in the year following the one during which they separated ("weaned") from their mothers. These marked animals are then followed until they produced their first litter. For these simulations, both age at weaning and age at first reproduction were randomly assigned to each individual in the sampling file according to the proportions presented in Table 3. Using the simple scenario, for example, 80% of the sample weaned at age 2 and 10% of bears had first litters at age 4 (Table 3). In each replication, then, individuals with these characteristics would have their age at first reproduction (4) included in calculations during the second year of the study (age at first litter[4] - age at weaning[2] = 2).

Sensitivity analyses were done on the significance of error in estimating reproductive parameters on population growth rates. For these analyses, a deterministic population model based in LOTUS 1-2-3, release 2 (Lotus Development Co., Cambridge MA.) was used. The population used in this model is that of bears 2 years of age or older. Sensitivity to error was evaluated by changing one reproductive parameter at a time in increments and recording the resulting change in population growth rate once the model has restabilized to a stable age distribution. Increments use for each parameter were 1%, 5%, 10%, 15%, 20%, and 25%.

Initially, the population used in this model was configured so that population growth rate was zero. Subsequently litter size (of 2-year-old offspring) was increased in increments and the population growth rate for each increment was observed recorded. Subsequently, litter size was reset to the original value and mean reproductive interval (interval between production of one litter which is successfully weaned and the production of the next litter which also does not suffer pre-weaning mortality) was decreased in the same increments. Values used in these manipulations are presented in Table 4. Finally, litter size and reproductive interval were reset to original values and mean age at first reproduction was decreased in the same increments. Since this model uses a matrix of proportion of the population which is adult at each age, an iterative process was used to obtain the correct increment used to decrease mean age; the resulting proportions used for each increment are illustrated in Table 5. Finally, all three parameters were changed at the same time to evaluate the total effect of a certain incremental error in estimating each parameter (Table 4).

RESULTS AND DISCUSSION

Reproductive Interval Estimation: In the simple scenario where all reproductive intervals were 3 or 4 years in length, as would be the case when there were few losses of complete litters, 7 years of study were adequate to assure that over 90% of the replicates samples drawn were within +/- 5% of the true interval even with a sample size of 10 females (Figure 1). Six years were adequate for sample sizes > 25 females (Figure 1).

Comparable level of precision using the complex scenario were not reached even after 30 years of study with a sample size of 10 females (Figure 2). With larger samples of bears, 90% of the samples were within +/- 5% of the true interval after 15 years (N = 25 females), 11 years (N = 50), and 10 years (N = 75) (Figure 2). Clearly investigators cannot expect to precisely estimate reproductive interval in situations where this parameter is variable and large with small samples (<25) or with short studies (<10 years) regardless of sample size. Also, in nature a large proportion of the initial sample of females would die before completing the necessary number of intervals to estimate this parameter precisely.

Litter Size: Similar results were found for litter size. With a sample of 10 females number of litters obtained even after 18 years of study was inadequate to obtain more than about 75% of the replicate samples within +/- 5% of the true value even for the simple scenario (Figure 3). This level of precision was obtained after 8 years of study with N = 25, after 5 and 2 years respectively for N = 50 and 75 females, respectively (Figure 3).

For the complex scenario of litter sizes, 90% of the samples were not within +/- 5% of the true value even after 18 years for N = 10 and N = 25 (Figure 4). For N = 50 and 75, this level of precision was reached in years 7 and 6 respectively (Figure 4).

Age at First Reproduction: Similarly, age at first reproduction could not be accurately (90 % within +/- 5% of true value) estimated with a sample of 10 bears even with the simple scenario (Figure 5). For samples > 25, this level of precision was reached in year 3 for the simple scenario (Figure 5) and in year 5 for the complex scenario (Figure 6). This suggests that 10 is not enough to estimate this parameter, 25 is adequate and that samples much larger than 25 are larger than necessary.

Anomalies: For reproductive interval and age at first reproduction the smaller samples appeared to produce "better" results in the early years of study than did the larger samples. The samples of 10 individuals in the early years, for example, had a larger proportion of their replicates within +/- 5% of the true value than did the samples of 50 individuals (Figures 1-4). This result appears counter-intuitive but has an explanation. In the early years, the full array of possible intervals between litters or intervals between weaning and first birth has not occurred, only the shorter intervals have occurred. Therefore, the mean calculated on the basis of just the shorter intervals (xbar early) will always be less than the true population mean (xbar true). The distribution of results in these early years will be a normal distribution centered over (xbar early). For small samples this distribution will have a broader base and, as a result, a larger proportion of the points will fall within +/- 5% of (xbar true) than will be the case for the larger samples which have more narrowly-based distributions.

Sensitivity Analyses: Reproductive interval was the most significant of these three parameters in influencing population growth rate. Reproductive interval in these calculations includes loss of whole litters of cubs and yearlings. If importance of reproductive interval is scaled to 1, then the relative importance of litter size is 0.62 and age at first reproduction is 0.46 (Table 4 using values for 25% error).

Similar results were reported for polar bear by Taylor et al. (1987) although these authors reported litter survival rate (for both cub and yearling litters) and litter production rate as 3 separate parameters and did not consider age at first reproduction. Scaling the sum of their 3 parameters to 1, litter size ranked 0.46 compared to 0.62 for brown bears using my model.

Overall the growth rate of the modeled population seemed largely unaffected by large errors in estimating reproductive rates. If all three rates are overestimated by 25%, the resulting "error" in estimating annual population growth would only be 8.08%. This, of course, is not an insignificant error for a species that can typically sustain harvests of < 5%/year, but it is relatively insignificant compared to the large error in estimating all 3 of the reproductive parameters. Errors in estimating reproductive parameters translate into errors in estimating sustainable levels of mortality of wild populations. This estimate, in turn, requires an estimate of population size. When compared to likely levels of error in estimating bear population size using field techniques (Harris 1986, Miller et al. 1987), the wisdom of allocating of large amounts of funds to obtain precise estimates of reproductive parameters is questionable. Similar conclusions were reached by Taylor et al. (1987) who noted that adult female mortality rates were much more significant in estimating sustainable harvest levels for polar bears than were reproductive parameters.

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________________. 1987. Susitna Hydroelectric Project Final Report, Big Game Studies, Vol. VI Black Bear and Brown Bear. ADF&G report submitted to Alaska Power Authority.

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

Table 1. Parameters used in simulation designed to estimate length of study and sample size required to estimate mean reproductive interval.

Interval Length (years)	Proportion of population with intervals of indicated length (%): Simple Scenario	Complex Scenario
2	0	5
3	75	20
4	25	35
5	0	30
6	0	10
Mean =	3.25	4.15

Table 2. Parameters used in simulations designed to estimate length of study and sample size required to estimate mean litter size. Litter frequency is identical to the simple scenario for reproductive interval (Table 1).

Mean litter size	Proportion of population with litters of indicated size (%): Simple Scenario	Complex Scenario
1	15	15
2	75	30
3	10	30
4	0	25
Mean =	1.95	2.65

Table 3. Parameters used in simulations designed to estimate length of study and sample size required to estimate age at first litter.

Age	Portion of population weaning at indicated age: Simple Scenario	Complex Scenario	Portion of population having first litter at indicated age (%): Simple Scenario	Complex Scenario
2	80	40		
3	20	40		
4		20	10	
5			.80	10
6			10	50
7				30
8				10
Mean =			5.0	6.4

Table 4. Effect on population growth rate of incremental increases (for litter size) or decreases (for mean reproductive interval and age at first reproduction) of a modeled brown bear population. Actual values used are given in parenthesis.

Resultant growth rate in percent resulting from change in:

Incremental change	Litter Size		Reproductive Interval		Mean Age @ 1st litter		All 3 parameters
Initial conditions	0	(1.7)	0	(4.5)	0	(5.2)	0
1%	0.10	(1.72)	0	(4.46)	0.07	(5.15)	0.25
5%	0.45	(1.79)	0.48	(4.28)	0.32	(4.94)	1.27
10%	0.89	(1.87)	0.98	(4.05)	0.98	(4.68)	2.64
15%	1.30	(1.96)	1.52	(3.83)	0.98	(4.42)	4.12
20%	1.71	(2.04)	2.74	(3.38)	1.27	(4.16)	6.34
25%	2.13	(2.13)	3.42	(3.15)	1.58	(3.90)	8.08

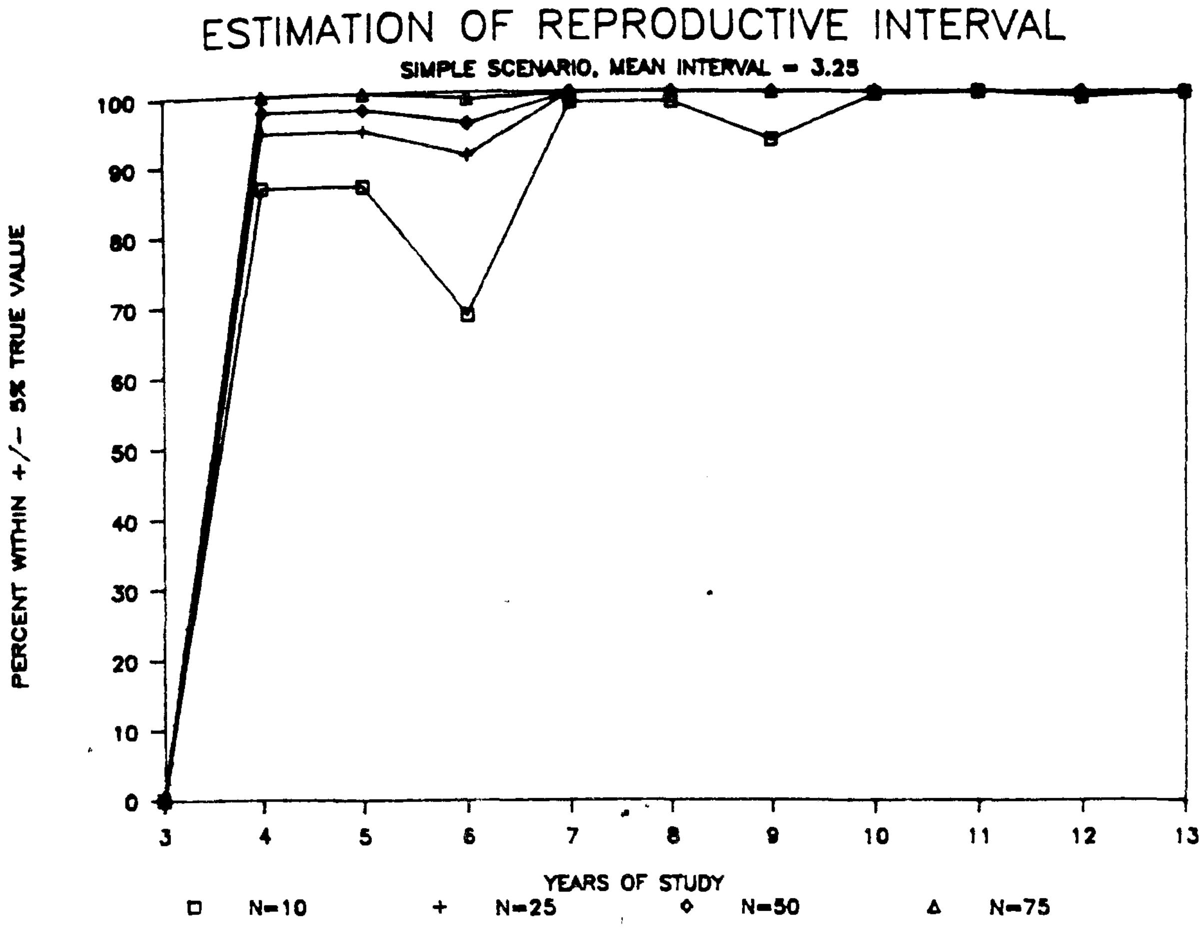
Table 5. Values used in estimating mean age at first reproduction based on increments above original (stable) population. Values are percentage of the population that is adult (has produced a litter at indicated age or earlier).

Percentage of population that is adult at age:

Increment	3	4	5	6	7	8+	Mean Age
Original value	0	20	70	90	100	100	5.2
1%	0	25	70	90	100	100	5.15
5%	0	46	70	90	100	100	4.94
10%	12	60	70	90	100	100	4.68
15%	38	60	70	90	100	100	4.42
20%	38	60	86	100	100	100	4.16
25%	40	70	100	100	100	100	3.90

Figure 1. Relationship between the percentage of replicate samples that provided estimates of brown bear reproductive interval that were within +/- 5% of the true value and the number of years of study for the simple scenario outlined in Table 1.

Figure 2. Relationship between the percentage of replicate samples that provided estimates of brown bear reproductive interval that were within +/- 5% of the true value and the number of years of study for the complex scenario outlined in Table 1.


ESTIMATION OF REPRODUCTIVE INTERVAL
SIMPLE SCENARIO, MEAN INTERVAL = 3.25
PERCENT WITHIN +/- 5% TRUE VALUE
0
10
20
30
40
50
60
70
80
90
100
3
4
5
6
7
8
9
10
11
12
13
YEARS OF STUDY
N=10
N=25
N=50
N=75

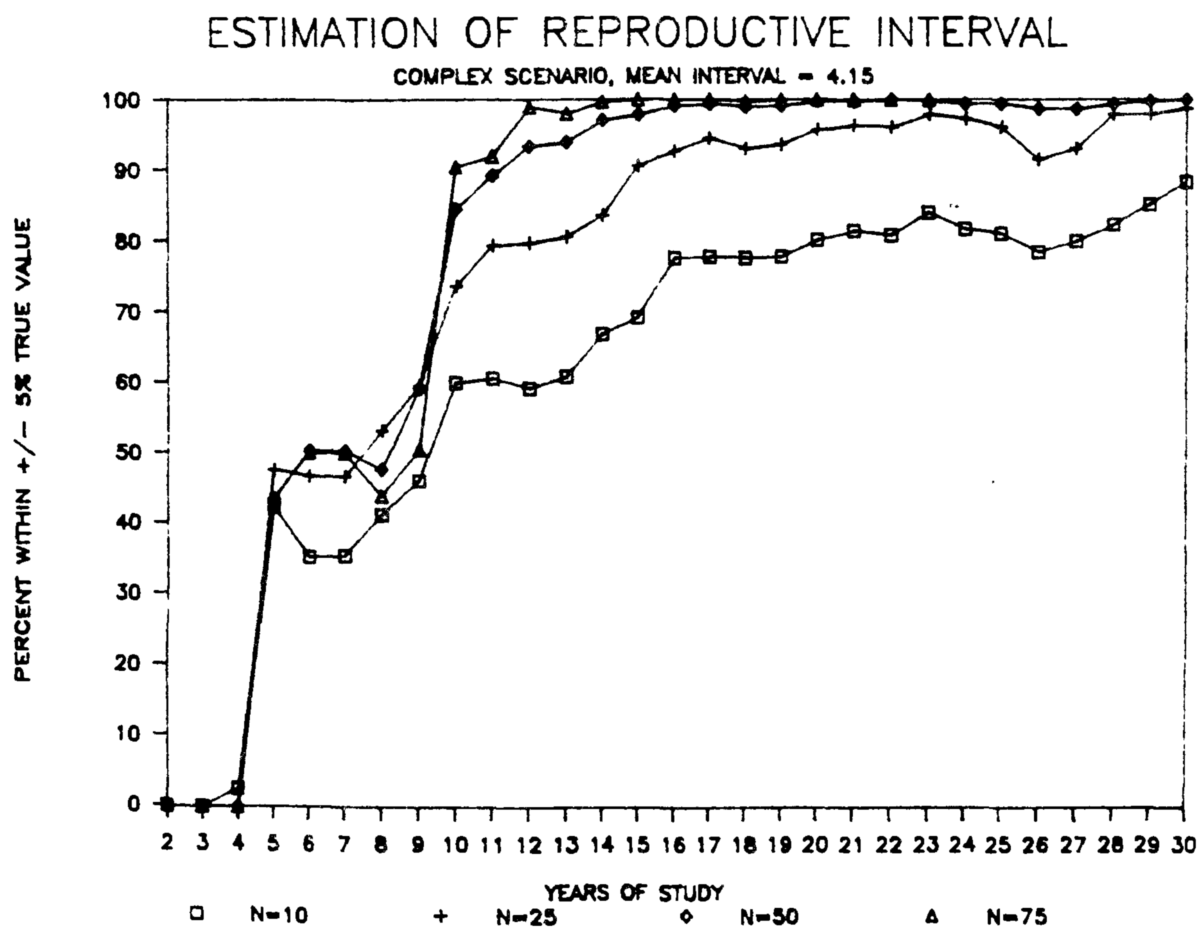
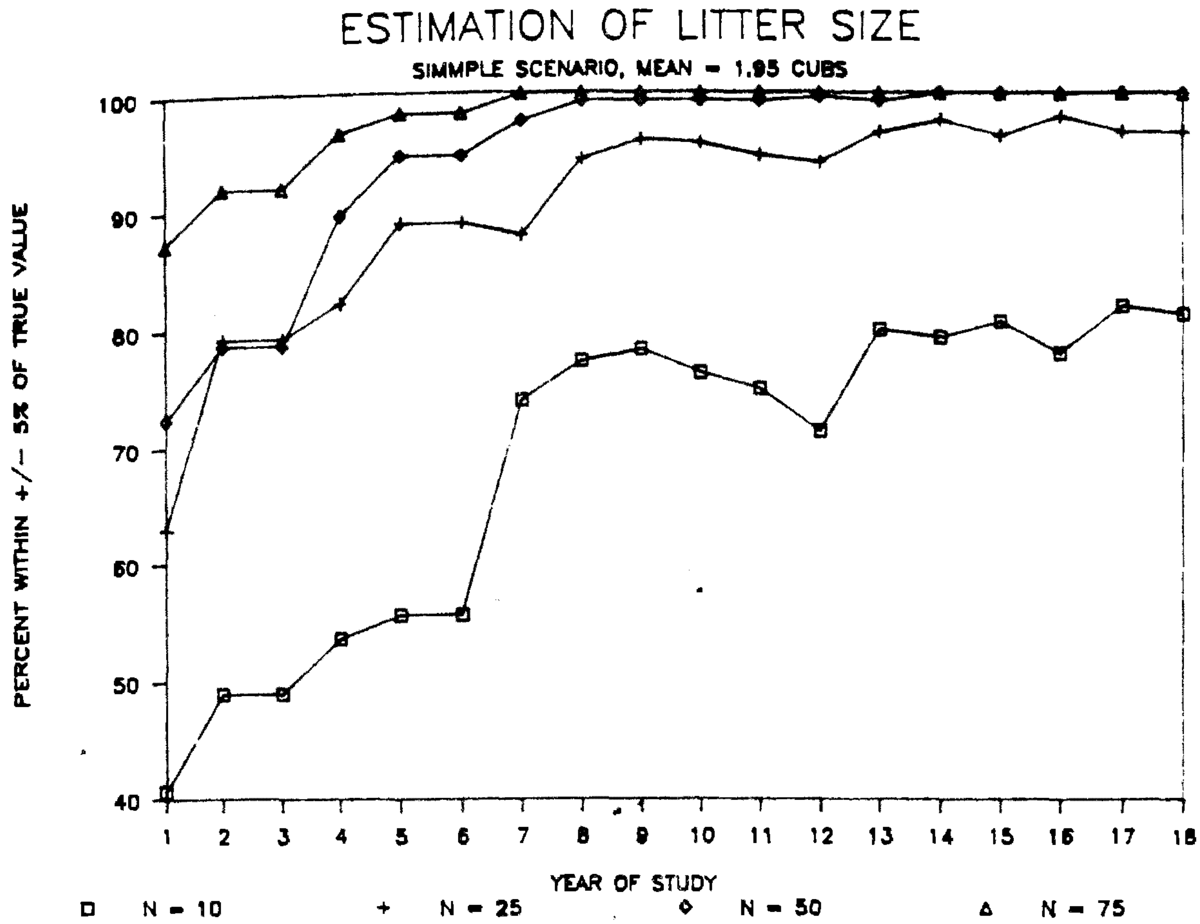

ESTIMATION OF REPRODUCTIVE INTERVAL
COMPLEX SCENARIO, MEAN INTERVAL = 4.15
PERCENT WITHIN +/- 5% TRUE VALUE
0
10
20
30
40
50
60
70
80
90
100
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
YEARS OF STUDY
N=10
N=25
N=50
N=75

Figure 3. Relationship between the percentage of replicate samples that provided estimates of brown bear litter size that were within +/- 5% of the true value and the number of years of study for the simple scenario outlined in Table 2.

Figure 4. Relationship between the percentage of replicate samples that provided estimates of brown bear litter size that were within +/- 5% of the true value and the number of years of study for the complex scenario outlined in Table 2.


ESTIMATION OF LITTER SIZE
SIMMPLE SCENARIO, MEAN = 1.95 CUBS
PERCENT WITHIN +/- 5% OF TRUE VALUE
100
90
80
70
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
YEAR OF STUDY
N = 10
N = 25
N = 50
N = 75

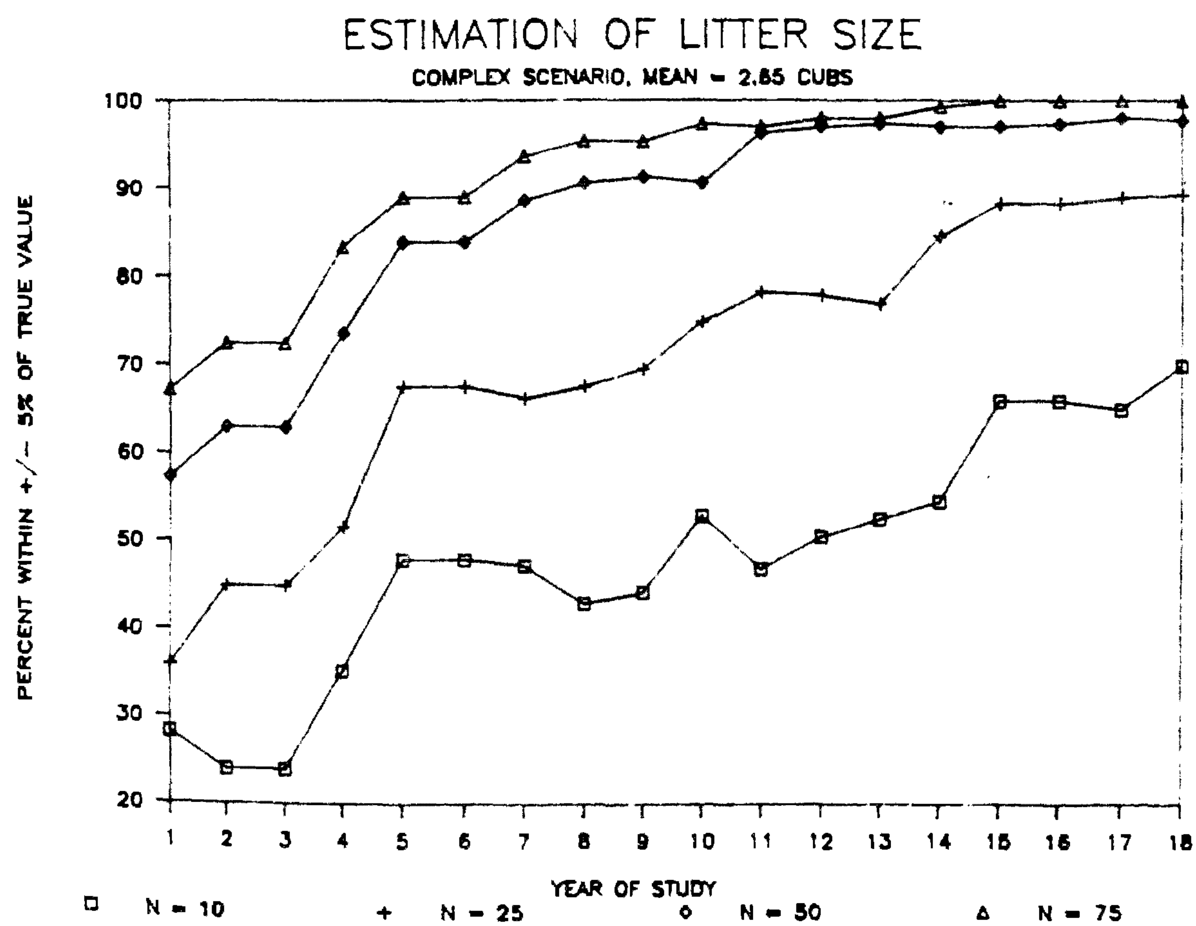
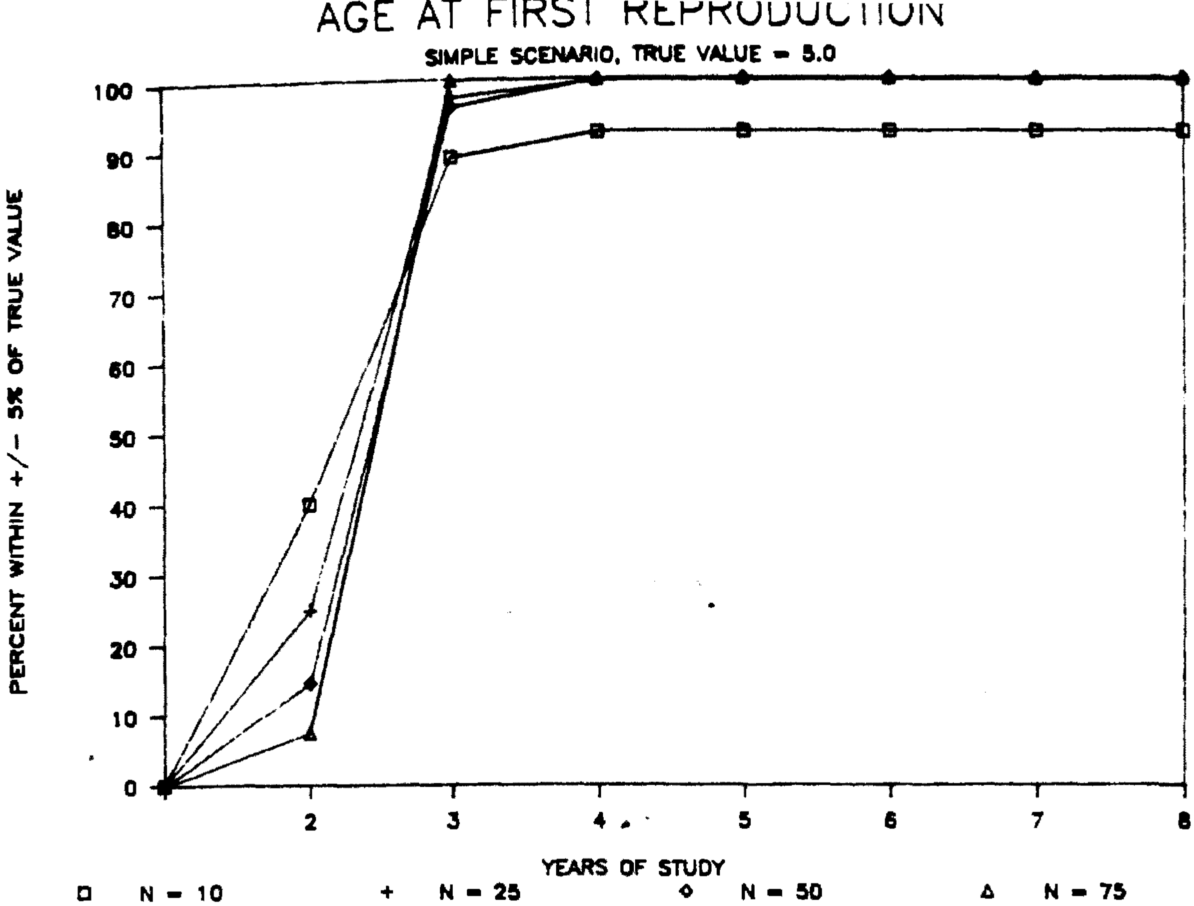
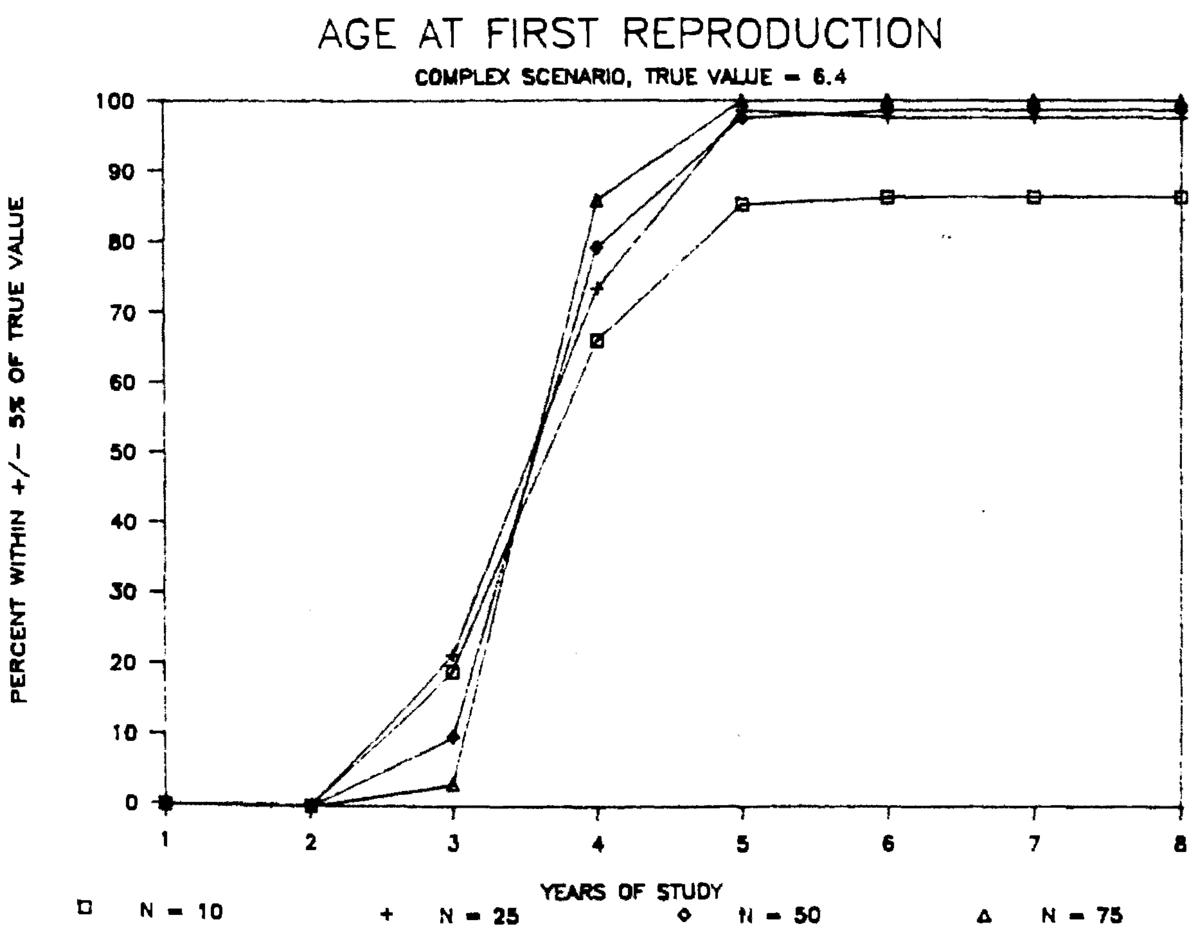

ESTIMATION OF LITTER SIZE
COMPLEX SCENARIO, MEAN = 2.65 CUBS
PERCENT WITHIN +/- 5% OF TRUE VALUE
100
90
80
70
60
50
40
30
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
YEAR OF STUDY
N = 10
N = 25
N = 50
N = 75

Figure 5. Relationship between the percentage of replicate samples that provided estimates of brown bear age at first reproduction that were within +/- 5% of the true value and the number of years of study for the simple scenario outlined in Table 3.

Figure 6. Relationship between the percentage of replicate samples that provided estimates of brown bear age at first reproduction that were within +/- 5% of the true value and the number of years of study for the complex scenario outlined in Table 3.



AGE AT FIRST REPRODUCTION
SIMPLE SCENARIO, TRUE VALUE = 5.0
PERCENT WITHIN +/- 5% OF TRUE VALUE
YEARS OF STUDY
N = 10
N = 25
N = 50
N = 75



AGE AT FIRST REPRODUCTION
COMPLEX SCENARIO, TRUE VALUE = 6.4
PERCENT WITHIN +/- 5% OF TRUE VALUE
YEARS OF STUDY
N = 10
N = 25
N = 50
N = 75

Appendix D. Impact of violating independent observation assumption in making bear capture-recapture estimates--preliminary results for the point estimate. (from Sterling Miller's ADF&G memo dated January 13, 1989)

During our bear workshop we had some discussion on the impacts of violating the assumption that all captures were independent of each other in making population estimates for bears using capture-recapture techniques. This is pertinent to the question of whether we should attempt estimates of total population size where we assume that bears in family groups were sighted independently when, in fact, they were not. The alternative is to calculate estimates for independent bears (as was done in Kodiak) or for bears older than some set age (as has been done in other applications of these techniques on bears in Alaska). Rob DeLong has recently written some software for me which will permit evaluation, through simulation, of the impact of violating this assumption--let me or Rob know if you'd like a copy. This software calculates the mean of Lincoln-Peterson estimates for (n) days (n = 10 in the simulations discussed below).

I did 3 simulations to look at this problem. In all cases I tried to estimate a "population" of 150 individuals, all of which had a capture probability of 0.3 (including groups), with a third of groups/individuals being marked (slight variations on this were made necessary by the necessity for groups and singles to add up to a total of 150 individuals). Tabular results are presented in Table 1 and illustrated in Figures 1-3.

In the first situation modeled, all 150 individuals were independent (group size = 1 for everyone) (Fig. 1). Fifty of these individuals are marked.

In the second simulation 51% of bears were in groups. This is about as groupie a situation as you are likely to find in bears--all adult females were in groups with from 1 to 3 offspring (Fig. 2). In this simulation there were 99 groups of from 1-4 individuals (Table 1). Although there were 48 individuals treated as "marked" in this scenario (instead of 50 as above), this represents only 32 radio-collars because the other 16 "marked" bears would be in litters with a radio-marked female and are just "treated" as marked (Table 1).

In the third situation I also had 150 bears, only 19% of which were in groups; this is analogous to a situation where you are trying to estimate the population of bears age 2.0 or older and some females are still with their 2- or 3-year-old offspring. In other words in the third situation you are making a relatively minor violation of the independence assumption (Fig. 3). In this simulation 56 bears were "marked", 44 with radio-collars and the rest by association with radio-marked mothers (Table 1).

In comparison to situation 1 where all 150 bears were in groups of 1, treating individuals in groups as independent sightings resulted in a minor shift of the distribution to the right (overestimation).

The degree of shift was somewhat larger when the violation of the assumption was more significant. The distribution of results was broader and more skewed towards overestimation when violation of the independence assumption was more pronounced; this indicates that your calculated confidence interval almost certainly will be an underestimate of the true confidence interval, and the upper limit is more underestimated than the lower limit.

In a situation where a relatively small proportion of the population you are trying to estimate is in groups (as when you are estimating the population age 2.0 or above and some adult females still have 2-3 year old cubs with them which you treat as "independent" sightings), the distribution of <u>point estimates</u> is only slightly wider and more skewed to the right than when there is no violation of the assumption (Table 1).

These results do not simulate effect of assumption violation on confidence intervals, however, there is doubtless a direct relationship between increased variance of point estimates and size of the confidence interval for any particular estimate. These results suggest that you should be cautious in interpreting calculated confidence intervals for population estimates of bears in circumstances where a large proportion of the bear population being estimated occurs in groups. In these circumstances you may wish to report the point estimate but not the confidence interval.

In conclusion these results suggest that in circumstances where a relatively small proportion of the population being estimated occurs in groups (as when estimating population of bears >2.0 years-old) you may wish to include a brief cautionary statement that the actual confidence interval for your result may be wider than you have calculated (or that the percent coverage of the CI is less than indicated). In such circumstances it would probably be a good idea to provide readers with the percentage of your "population" that occurred in groups.

You may also wish to make a calculation for "independent" bears for use in comparing trends over time in the same area. Making the calculation for bears >2.0 year-old <u>in addition</u>, however, permits making density comparisons between areas (as will be done in the joint paper we're planning), as well as converting the estimate (for bears >2.0 years, for example) to total population size based on your assumptions about the proportion of population younger than 2.0. In my view these are significant advantages at almost no additional cost.

Although the pattern resulting from failure to meet the independence assumption would be similar, I expect that the results illustrated here would be worse (broader-based distributions) when estimating smaller populations; the points where 5% of the trials were in upper and lower tails would be a larger percentage of the true population size. Also, the results would be worse if fewer days were included in making the estimate or if a smaller proportion of the population were marked.

In response to a suggestion from Earl during his review of this memo, I repeated the simulation discussed above using 5 days of effort to calculate each estimate instead of 10 and I've added these results to Table 1. These simulations were done to see whether fewer days effort would have the result of increasing the amount of variability between simulations where observations were independent and those where they were clumped. If so, the hypothesis is that the ratio of the standard deviations would be larger in the case where 5 days were used than where 10 days were used. In other words:

$$\frac{SDc5}{SDi5} \qquad \frac{SDc10}{SDi10}$$

where SDi5 is the standard deviation of the 1000 results where observations were independent and simulations were run for 5 days; and

where SDc5 is the standard deviation of the 1000 results where observations were clumped and simulations were run for 5 days; and

SDi10 and SDc10 are the standard deviations where simulations were run for 10 days.

In this case, Earl's concerns were unsupported by the additional simulations and, in fact, the reverse situation was noted (data are in Table 1). The ratio of the standard deviations when clumping was at the maximum was:

15.48:8.93 or 1.7:1 for 10 day experiments; and

10.26:12.58 or 1.6:1 for 5 day experiments.

In other word the ratio was less, not greater, for the 5 day experiments. I suspect that, in fact, these ratios were equal and this difference is just noise but the same pattern was observed in a comparison of the minor violation standard deviations when the ratios of clumped to unclumped was:

10.80:8.93 or 1.21:1 for 10 day experiments; and

14.61:12.58 or 1.16:1 for 5 day experiments.

I am still hopeful that Earl Becker will get involved in quantifying the impacts of assumption violations on confidence intervals. Please let me know if you have comments or suggestions on additional ways of looking at this problem. Thanks again to Rob and Dan for their help in making this software.

Table 1. Results of simulations designed to test violation of independence-of-observation assumption on brown bear capture-recapture population estimation experiments. For each scenario population being estimated was 150 individual, 1000 replications were run, probability of capture for all groups or individuals was 0.3, a third of the population was marked, and calculated statistic was mean of daily Lincoln-Petersen estimates over a period of 10 days.

For 10 day experiments:	No violation (Fig. 1)	Massive violation (Fig. 2)	Minor violation (Fig. 3)
True population size	150	150	150
Mean of 1000 replications	149.5	155.6	151.4
Median of 1000 replications	149	154	151
Standard deviation of 100 reps.	8.93	15.48	10.80
S.D. ratio (violation/no violation	1.1	1.73:1	1.21:1
Minimum estimate(% from true)	127 (-15%)	117 (-22%)	118 (-21%)
Maximum estimate(% from true)	187 (+25%)	238 (+59%)	196 (+31%)
Value where 10% of reps. are:			
in lower tail(% from true)	133 (-11%)	129 (-14%)	133 (-11%)
in upper tail(% from true)	171 (+14%)	193 (+29%)	177 (+18%)
Value where 5% of reps. are:			
in lower tail(% from true)	131 (-13%)	127 (-15%)	131 (-13%)
in upper tail(% from true)	172 (+15%)	202 (+35%)	178 (+19%)
POPULATION PARAMETERS			
% in groups of 1	100	49	81
% in groups of 2	0	5	5
% in groups of 3	0	38	14
% in groups of 4	0	8	0
TOTALS	100	100	100
Total No. bears	150	150	150
	No. unmarked (No. marked)		
Number of groups of 1	100 (50)	49 (24)	81 (40)
Number of groups of 2	--	3 (1)	2 (2)
Number of groups of 3	--	13 (6)	5 (4)
Number of groups of 4	--	2 (1)	--
Total No. of groups	100 (50)	67 (32)	88(44)
Total No. groups (records)	150	99	132

For 5 day experiments:	No violation	Massive violation	Minor violation
True population size	150	150	150
Mean of 1000 replications	150.68	155.47	151.49
Median of 1000 replications	150	153	150
Standard deviation of 1000 reps.	12.58	20.26	14.61
S.D. ratio (violation/no violation)	1:1	1.61:1	1.16:1
Minimum estimate (% from true)	119 (-21%)	113 (-25%)	104 (-31%)
Maximum estimate (% from true)	217 (+45%)	267 (+78%)	248 (+65)

Fig. 1. NO VIOLATION OF ASSUMPTION

POP = 150, 1000 TRIALS, MEAN = 149.62

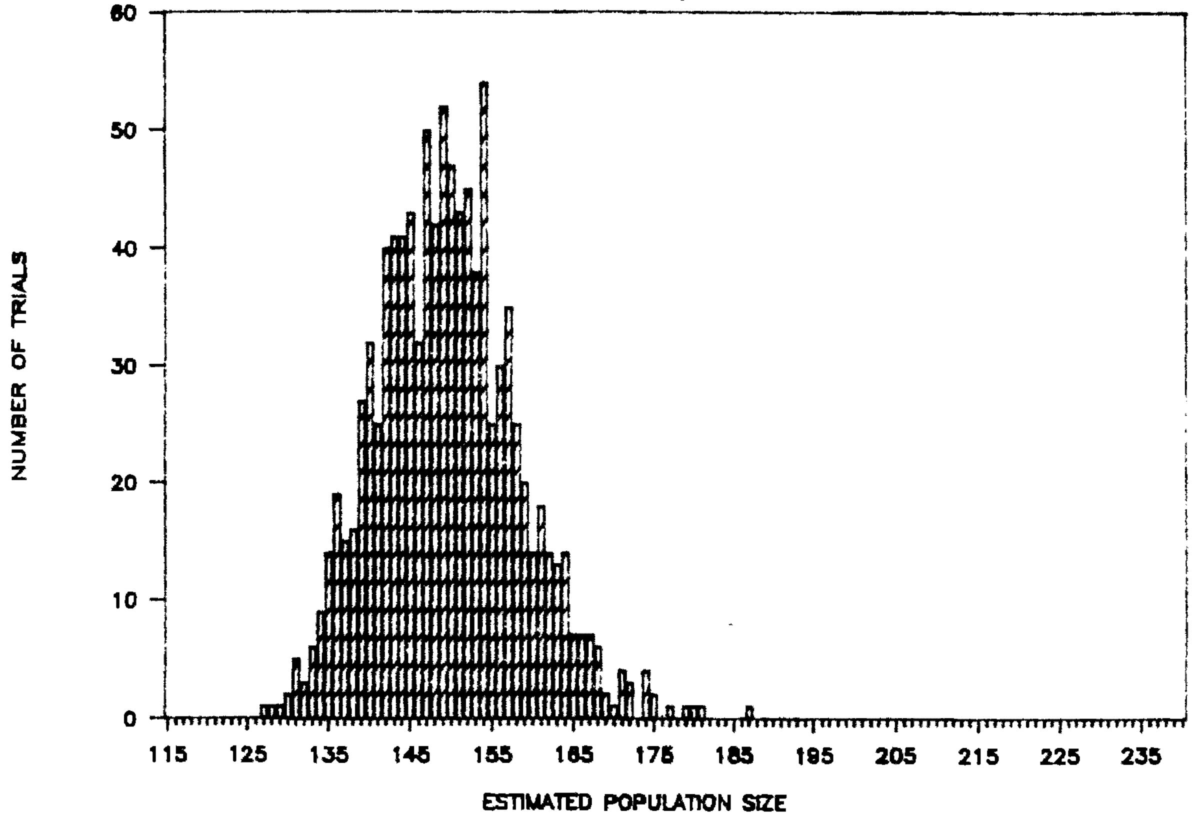


Fig. 2. MASSIVE ASSUMPTION VIOLATION

Total population = 150, Mean = 155.62

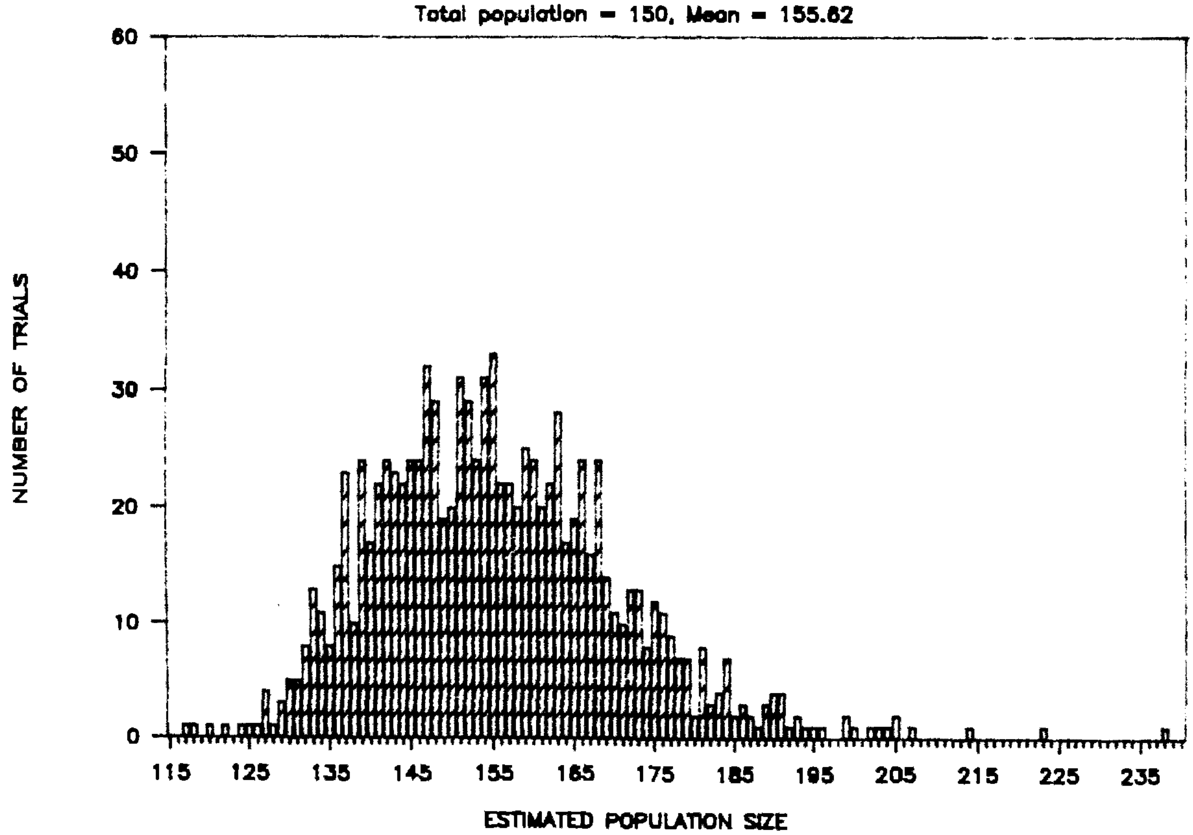
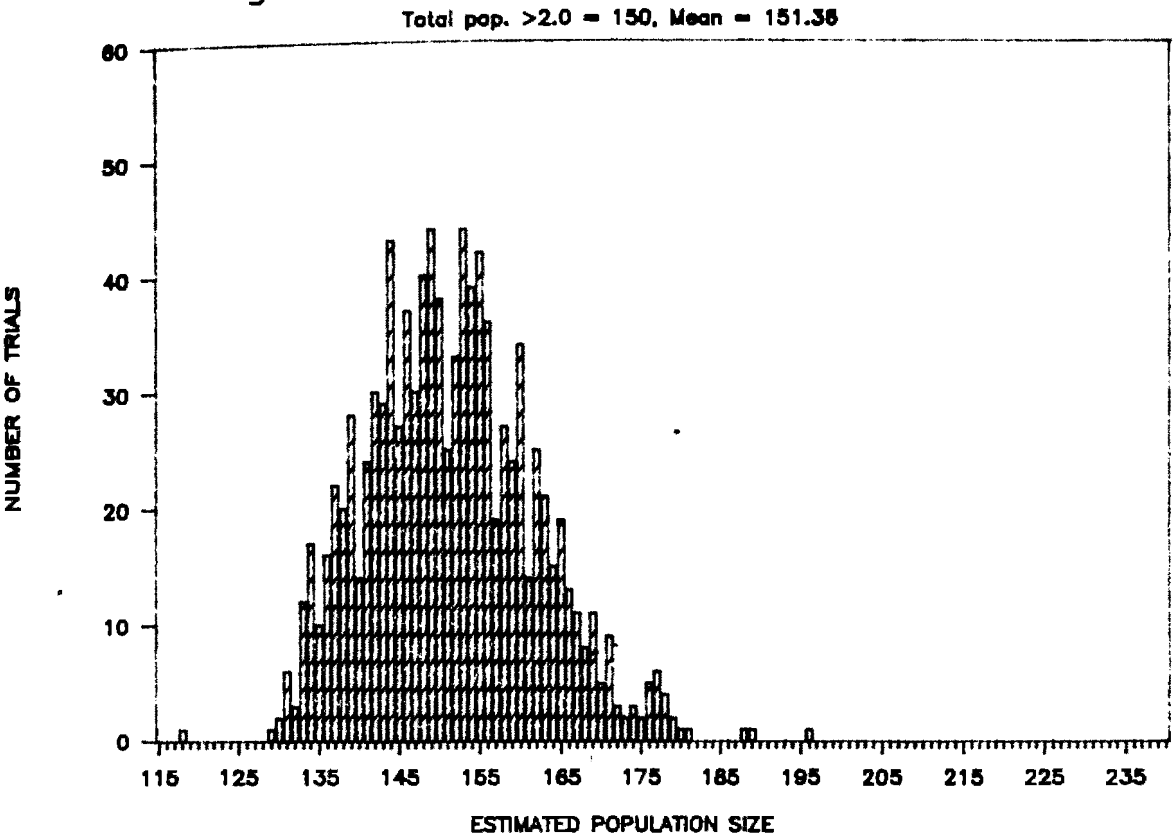


Fig. 3. MINOR ASSUMPTION VIOLATION



Appendix E. Questionnaire analysis, success rate by GMU.

TO: Distribution

DATE: December 5, 1988- (rev.6/89)

THRU: Dan Timm
Regional Supervisor
Southcentral Alaska

TELEPHONE NO: 267-2203

FROM: Sterling Miller
Wildlife Biologist
Div. of Wildlife Conservation

SUBJECT: Brown bear hunter success by residency and success by GMU--results from questionnaire returns

In light of the recent court decision on exclusive guide areas, some of you are considering possible changes in bear hunting regulations in some areas. One of the pieces of information we don't have from bear hunters that is pertinent to these considerations is success rate by residency in different areas. Estimates of this parameter are available in the returns from the brown bear hunter questionnaire we sent out last year and these data are attached for your use as you see fit. Management coordinators may wish to distribute these data to their area staff.

The questionnaire was sent to persons who purchased brown bear tags in 1985 and/or in 1986 and asked them to report on their effort, success, and expenditures in both of those years. Financial considerations precluded sending reminder letters to persons who did not respond to the initial mailing. Becky Strauch in Statistics Section has compiled all of these data and has produced some preliminary tabulations. I have recently been assigned the job of analyzing these questionnaire returns and I hope to get to it early next year. Until then I can offer little to assist in your interpretation of the attached results except for the following comparisons.

On a statewide basis the apparent success rate can be estimated by dividing the number of bears sealed by the number of tags sold (Table 1). These data can be compared with the questionnaire returns to assist in evaluation of these returns. In 1985 and 1986, respectively non-residents had success rates of 51.9% and 50.7% based on sealing and tag sale data (Table 1) compared to 52.5% and 53.5% based on questionnaire returns (Table 2). There is little here to suggest bias in the questionnaire returns for non-residents. For residents the sealing and tag sale data provide success rates of 10.2% and 8.5% in 1985 and 1986, respectively (Table 1), compared to 5.9% and 5.8% based on questionnaire returns (Table 2). Greg Bos pointed out to me that some or all of this difference, for residents, may result from hunting by residents in more than 1 GMU (a hunter could be unsuccessful in J1 GMU, and be counted as unsuccessful more than once in this tabulation, but for the statewide data he was successful or unsuccessful only once). Regardless, these data may the statewide data he was successful or unsuccessful only once). Regardless, these data may indicate that the questionnaire responses may underestimate the success rate of residents, however, this pattern was not found in the following comparison in GMU 8.

In Kodiak, Roger Smith has independent data on success rate of residents and non-resident brown bear hunters as all hunters in GMU 8 must have a drawing or registration permit. Therefore, I have compared reported success rates from Roger's permit data in the BGDIF for Drawing Hunts #201-226 and Registration Hunt #250 combined, with data on success rates in GMU 8 from the questionnaire responses (Table 5). Although there was some variation in individual years, lumping the 1985 and 1986 permit data and comparing it with the lumped data for both years from the questionnaire returns suggested there was little difference in these data sets for either spring or fall or for either residents or non-residents (Table 5). Based on these comparisons, there is little reason to suspect systematic bias in the hunter success rates reported by those answering the questionnaire. Unit 8 hunters may differ in reporting patterns from hunters in other areas but I know of no way to evaluate this.

For spring seasons the raw data for each GMU for 1985, 1986, and both years lumped, and for residents and non-residents are presented in Table 3, equivalent data for fall seasons are presented in Table 4. Looking at these tables I see few surprises which tends to add credence to the data. In fall seasons in southeast, non-residents are very successful as they are in Kodiak and Unit 9 (>50%). In Units 11-14 and 20 non-residents are relatively less successful (<30%), probably because fewer are hunting with guides and more with relatives and because hunting conditions in these areas are harder. In most areas with spring seasons, success rates are higher during spring seasons than during fall seasons, probably because many fall hunters are hunting bears incidental to hunts for other species.

Data which would make these points more clear are in the questionnaire data but I don't have time to break it out now. If you need more information now, I'll be glad to send you the raw data which are in DBASE III files (send me 3 high density-formatted diskettes and you'll get all the data back).

I hope these data are useful to you. If you have observations or thoughts on these data, I'd like to hear them. Mike Thomas is analyzing the economic data from the questionnaire.

Table 1. STATEWIDE BROWN BEAR HARVEST AND TAG SALE HISTORICAL SUMMARY FOR 1961-87.

	RESIDENTS					NONRESIDENTS				
Year	No. Tags Sold	% Change	No. Bears Taken	% Change	% "Success"	No. Tags Sold	% Change	No. Bears Taken	% Change	% "Success"
1961	-		213		-	437		258		59.0
1962	-		249		-	446		287		64.3
1963	-		260		-	475		296		62.3
1964	-		315		-	551		321		58.3
1965	-		381		-	746		401		53.8
1966	-		368		-	968		503		52.0
1967	-		333		-	881		458		52.0
1968	-		274		-	930		369		39.7
1969*	-		259		-	797		253		31.7
1970	-		261		-	697		368		52.8
1971	-		308		-	967		432		44.7
1972	-		323		-	905		511		56.5
1973	-		363		-	932[1]		564		60.5
1974	-		292		-	940		487		51.8
1975	-		338		-	843		489		58.0
1976	-		385		-	853		447		52.4
1977	2,903[3]		327		11.3	876[2]		446		50.9
1978	3,431	+18	350	+7	10.2	843	-4	470	+5	55.8
1979	3,533	+3	342	-2	9.7	1,036	+23	541	+15	52.2
1980	3,894	+10	371	+9	9.5	1,006	-3	509	-6	50.6
1981	4,437	+14	392	+6	8.8	970	-4	492	-3	50.7
1982**	5,049	+14	376	-4	7.4	813	-16	435	-12	53.5
1983	6,076	+20	492	+30	8.1	870[4]	+7	482	+11	55.4
1984***	6,322	+4	593	+21	9.3	883	+1	525	+9	59.5
1985	6,054	-4	615	+2	10.2	1,043	+18	541	+3	51.9
1986	6,986	+15	596	-3	8.5	1,031	-1	523	-3	50.7
1987	6,811	-3	569	-5	8.4	1,235	+20	643	+23	52.1
1988	6,703	-2	492	-14	7.3	1,288	+4	600	-7	46.6
1989	6,759	+1	479	-3	7.1	1,268	-1	598	0	47.2

[1] Fee increase from $75 to $150 in 1973.

[2] Fee increase from $150 to $250 in 1977.

[3] Resident tag fee of $25 initiated in 1977.

[4] Fee increase to $350 in 1983.

* Bag limit change from 1/year to 1/every 4 years in 1969.

** Bag limit increased to 1/year effective for fall season in GMUs 12, 13, and 20E in 1982.

*** The $25 resident tag fee requirement was deleted for GMUs 12, 20E, 22, and 23 effective in January 1984, and in 21(D) in July 1985.

Prepared by: Sterling Miller, 10/88

Table 2. Brown bear questionnaire results. Percent success reported by respondents in different GMUs in Alaska based on residency. Spring and Fall results lumped.

	1985 SPRING AND FALL SEASONS LUMPED					
Year Class Result GMU	1985 Resident # Suc. RES85 S	1985 Resident # Unsuc. RES85 U	1995 Non-Resident # Suc. NON85 S	1985 Non-Resident # Unsuc. NON85 U	1985 Resident % SUCC	1985 Non-Resident %SUCC
1	6	54	2	3	10.0	40.0
2	0	1	1	0	0.0	100.0
3	0	0	1	1	ERR	50.0
4	8	89	19	12	8.2	61.3
5	1	10	6	13	9.1	31.6
6	5	121	5	11	4.0	31.3
7	2	26	0	1	7.1	0.0
8	25	191	34	21	11.6	61.8
9	19	86	54	30	18.1	64.3
10	4	1	1	0	80.0	100.0
11	0	29	2	3	0.0	40.0
12	0	37	2	7	0.0	22.2
13	21	492	5	18	4.1	21.7
14	1	116	1	3	0.9	25.0
15	3	112	0	2	2.6	0.0
16	8	157	6	3	4.8	66.7
17	3	37	7	2	7.5	77.8
18	0	0	0	0	ERR	ERR
19	5	46	7	8	9.8	46.7
20	6	266	1	10	2.2	9.1
21	0	29	1	2	0.0	33.3
22	0	3	10	2	0.0	83.3
23	2	17	4	3	10.5	57.1
24	1	13	0	1	7.1	0.0
25	0	18	1	0	0.0	100.0
26	3	19	4	0	13.6	100.0
27	0	4	2	3	0.0	40.0
TOTALS	123	1974	176	159	5.9	52.5

Table 2. Continued.

	1986 SPRING & FALL SEASONS LUMPED							
Year Class Result GMU	1986 Resident # Suc. RES86 S	1986 Resident # Unsuc. RES86 U	1986 Non-Res. # Suc. NON86 S	1986 Non-Res. # Unsuc. NON86 U	1986 Resident % SUCC	1986 Non-Res. % SUCC	85+86 Resident % SUCC	85+86 Non-Res. % SUCC
1	4	127	2	4	3.1	33.3	5.2	36.4
2	0	2	0	0	0.0	ERR	0.0	100.0
3	0	1	1	0	0.0	100.0	0.0	66.7
4	18	212	28	10	7.8	73.7	8.0	68.1
5	5	17	8	9	22.7	47.1	18.2	38.9
6	9	201	11	5	4.3	68.8	4.2	50.0
7	0	60	0	3	0.0	0.0	2.3	0.0
8	36	208	42	16	14.8	72.4	13.3	67.3
9	24	124	63	36	16.2	63.6	17.0	63.9
10	2	0	0	0	100.0	ERR	85.7	100.0
11	3	33	0	2	8.3	0.0	4.6	28.6
12	1	55	3	9	1.8	25.0	1.1	23.8
13	37	767	12	16	4.6	42.9	4.4	33.3
14	5	199	1	5	2.5	16.7	1.9	20.0
15	5	156	1	1	3.1	50.0	2.9	25.0
16	9	263	7	7	3.3	50.0	3.9	56.5
17	2	50	8	7	3.8	53.3	5.4	62.5
18	0	4	0	1	0.0	0.0	0.0	0.0
19	3	59	9	21	4.8	30.0	7.1	35.6
20	17	422	2	12	3.9	14.3	3.2	12.0
21	1	29	2	1	3.3	66.7	1.7	50.0
22	1	6	10	12	14.3	45.5	10.0	58.8
23	3	22	5	2	12.0	71.4	11.4	64.3
24	2	21	0	1	8.7	0.0	8.1	0.0
25	1	29	0	3	3.3	0.0	2.1	25.0
26	4	29	6	2	12.1	75.0	12.7	83.3
27	0	7	0	1	0.0	0.0	0.0	33.3
TOTALS	192	3103	221	186	5.8	54.3	5.8	53.5

Table 3. Brown bear questionnaire results. Percent success reported by respondents in different GMUs in Alaska based on residency. Spring seasons only.

Year Class Result GMU	1985 Resid. # Suc. RES85S_SP	1986 Resid. # Suc. RES86S_SP	1985 Resid. # Unsuc. RES85U_SP	1986 Resid. # Unsuc. RES86U_SP	85 & 86 Resid. % Success.	1985 Non-resid. # Suc. NON85S_SP	1986 Non-resid. # Suc. NON86S_SP	1985 Non-resid. # Unsuc. NON85U_SP	1986 Non-resid. # Unsuc. NON86U_SP	85 & 86 Non-resid. % Success.
1	3	3	26	51	7.2	2	1	3	2	37.5
2	0	0	0	0	ERR	0	0	0	0	ERR
3	0	0	0	1	0.0	0	1	0	0	100.0
4	4	13	24	73	14.9	12	17	10	5	65.9
5	1	0	2	8	9.1	2	2	6	6	25.0
6	3	3	44	79	4.7	1	8	7	2	50.0
7	0	0	13	26	0.0	0	0	1	1	0.0
8	12	19	33	45	28.4	19	31	13	12	66.7
9	0	23	5	86	20.2	2	57	6	28	63.4
10	1	0	0	0	100.0	0	0	0	0	ERR
11	0	1	1	4	16.7	1	0	0	0	100.0
12	0	0	6	19	0.0	0	0	0	2	0.0
13	7	13	99	182	6.6	0	6	6	1	46.2
14	0	0	6	24	0.0	1	0	0	2	33.3
15	1	1	32	39	2.7	0	1	1	0	50.0
16	4	5	29	56	9.6	1	2	0	2	60.0
17	0	0	3	3	0.0	1	0	0	0	100.0
18	0	0	0	0	ERR	0	0	0	0	ERR
19	0	1	2	1	25.0	3	1	0	1	80.0
20	1	4	57	61	4.1	0	0	5	2	0.0
21	0	0	0	1	0.0	0	1	0	0	100.0
22	0	1	1	0	50.0	6	6	0	4	75.0
23	0	0	1	0	0.0	2	0	0	0	100.0
24	0	1	7	7	6.7	0	0	0	1	0.0
25	0	0	6	5	0.0	0	0	0	0	ERR
26	0	1	0	1	50.0	1	2	0	0	100.0
27	0	0	0	2	0.0	1	0	2	0	33.3
TOTALS	37	89	397	774	9.7	55	136	60	71	59.3

Table 4. Brown bear questionnaire results. Percent success reported by respondents in different GMUs in Alaska based on residency. Fall seasons only.

Year Class Result GMU	1985 Resid. # Suc. RES85S_FL	1986 Resid. # Suc. RES86S_FL	1985 Resid. # Unsuc. RES85U_FL	1986 Resid. # Unsuc. RES86U_FL	85 & 86 Resid. % Success.	1985 Non-resid. # Suc. NON85S_FL	1986 Non-resid. # Suc. NON86S_FL	1985 Non-resid. # Unsuc. NON85U_FL	1986 Non-resid. # Unsuc. NON86U_FL	85 & 86 Non-resid. % Success.
1	3	1	28	76	3.7	0	1	0	2	33.3
2	0	0	1	2	0.0	1	0	0	0	100.0
3	0	0	0	0	ERR	1	0	1	0	50.0
4	4	5	65	139	4.2	7	11	1	5	75.0
5	0	5	8	9	22.7	4	6	7	3	50.0
6	2	6	77	122	3.9	4	3	4	3	50.0
7	2	0	13	33	4.2	0	0	0	2	0.0
8	12	17	157	156	8.5	15	11	8	4	68.4
9	18	1	79	38	14.0	51	5	24	8	63.6
10	3	2	0	0	100.0	1	0	0	0	100.0
11	0	2	28	29	3.4	1	0	3	2	16.7
12	0	1	31	36	1.5	2	3	7	7	26.3
13	13	23	392	582	3.6	5	5	12	13	28.6
14	1	5	109	175	2.1	0	1	3	3	14.3
15	2	4	80	117	3.0	0	0	1	1	0.0
16	4	4	128	207	2.3	5	5	3	5	55.6
17	3	2	34	45	6.0	6	8	2	7	60.9
18	0	0	0	4	0.0	0	0	0	1	0.0
19	5	2	44	58	6.4	4	8	8	20	30.0
20	5	13	208	355	3.1	1	2	5	9	17.6
21	0	1	29	28	1.7	1	1	2	1	40.0
22	0	0	2	6	0.0	4	4	2	8	44.4
23	2	3	15	22	11.9	2	5	3	2	58.3
24	1	1	6	14	9.1	0	0	1	0	0.0
25	0	1	12	23	2.8	1	0	0	3	25.0
26	3	3	19	28	11.3	3	4	0	2	77.8
27	0	0	4	4	0.0	1	0	1	1	33.3
TOTALS	83	102	1569	2308	4.6	120	83	98	112	49.2

Table 5. Comparison of % success in brown bear questionnaire results with permit return results in GMU 8 (Kodiak Island). Permit results based on drawing hunts 201-226 and registration hunt 250 combined, data from BGDIF.

	AK. RESIDENTS			ALASKAN NON-RESIDENTS		
PERMIT RESULTS	No. reports Returned	# Success. hunters	Percent success	No. reports Returned	# Success. hunters	Percent success
Spring 1985	244	46	18.9	99	55	55.6
Spring 1986	292	103	35.3	77	60	77.9
Total	536	149	27.8	176	115	65.3
QUESTIONAIRE RESULTS						
Spring 1985	45	12	26.7	32	19	59.4
Spring 1986	64	19	29.7	43	31	72.1
Total	109	31	28.4	75	50	66.7

	AK. RESIDENTS			ALASKAN NON-RESIDENTS		
PERMIT RESULTS	No. reports Returned	# Success. hunters	Percent success	No. reports Returned	# Success. hunters	Percent success
Fall 1985	529	52	9.8	49	30	61.2
Fall 1986	424	31	7.3	48	33	68.8
Total	953	83	8.7	97	63	64.9
QUESTIONAIRE RESULTS						
Fall 1985	169	12	7.1	23	15	65.2
Fall 1986	173	17	9.8	15	11	73.3
Total	342	29	8.5	38	26	68.4

Appendix F. Simulation results designed to estimate, under optimal conditions, maximum sustainable harvest results for black bears and brown bears and period of recovery for overharvested bear populations.

As part of a review of bear population management in North America (Appendix G), simulation studies were conducted to estimate maximum sustainable harvest rates for black and brown bears and minimum period required for population recovery following overharvest. These simulation utilised a deterministic LOTUS model (Miller and Miller 1988).

Recovery Period

The population recovery period was simulated using maximally-productive populations of black and brown bears. This was done to illustrate the best case scenario, more realistic simulations may be done using input parameters derived directly from the population being managed.

Exploitation rates were adjusted until the modeled population was stabilized. Hunting rates were set so that they were twice as high for males as for females in each age class (Table 1). This stabilized population was abruptly overharvested by doubling the exploitation rate. When the population declined to half of its original size, hunting was restricted and the period required for the population to recover to its initial size was noted. When no hunting occurred during the recovery period, the grizzly bear population recovered in 10 years compared to 6 years for black bears (Table 2). When hunting rate during the recovery period was half the initial rate at which populations were stable, population recovery occurred in 19 years for grizzly bears and 9 years for black bears (Table 2). When hunting during the recovery period was 75% of the initial rate, grizzly bear populations recovered in 40 years and black bear populations in 17 years (Table 2).

This kind of exercise may be useful for managers to conduct when needed to demonstrate the consequences of overharvest to persons or groups that frequently agitate for increased hunting opportunities. When overharvests occur, recovery will require decades unless hunting is eliminated altogether.

Changes in mortality from hunting rates used in these simulations are illustrated for 2-year old female grizzly bears. Under initial stable conditions mortality from hunting for 2-year old females was set at 0.07 (Table 1). During the overhunting period mortality from hunting was set at 0.14 (twice the stabilized mortality rate), during recovery with hunting at half the initial rate mortality rate was 0.35, and during recovery with hunting at 75% of initial rate mortality was set at 0.0525. Corresponding changes from initial conditions (Table 1) were made for the other sex-aged classes. The LOTUS model requires input of survivorship rather than mortality rates so actual inputs used were (1- these mortality rates).

Maximum Harvest Rate

The high reproductive and low natural mortality rates in the above simulations were set at maximally optimistic levels. The harvest rate that occurred when populations were stabilized at initial conditions was an estimate of maximum harvest rate sustainable without causing a population decline for these species under these conditions. These hunting rates were derived by dividing the number killed annually by the "post-weaning" population size for grizzly bears >2.0 and black bears >1.0 (Table 3). The LOTUS model used in these simulations does not directly deal with grizzlies younger than 2 or black bears younger than 1 (the "pre-weaning" population). However, the pre-weaning population can be estimated and this value added to the post-weaning population to derive a total population number. Number killed divided by this total population may be a preferred way of expressing maximum sustainable kill rate in some cases. Pre-weaning population size was estimated by back-calculating from the first age class used in the model (yearling black bears and 2-year old grizzly bears). Conservative estimates of mortality rates for pre-weaning age classes were used (Table 3).

Table 1. Input parameters used for simulating recovery rates for overexploited black and brown bear populations (Table 2 & 3).

Age Class	Brown Bears: Stabilized Harvest rates, Males	Brown Bears: Stabilized Harvest rates, Females	Brown Bears: Natural Mortality Rate both sexes	Black Bears: Stabilized Harvest rates, Males	Black Bears: Stabilized Harvest rates, Females	Black Bears: Natural Mortality Rate both sexes
1	--	--	--	0.3	0.15	0.1
2	0.14	0.07	0.06	0.3	0.15	0.06
3-4	0.14	0.07	0.06	0.3	0.15	0.04
5	0.14	0.07	0.03	0.3	0.15	0.04
6-17	0.1	0.05	0.03	0.28	0.14	0.04
18-20	0.1	0.05	0.06	0.28	0.14	0.06
21-22	0.1	0.05	0.1	0.27	0.135	0.1
23-24	0.1	0.05	0.2	0.27	0.135	0.2
25+	0.1	0.05	0.5	0.27	0.135	0.5

		Brown Bears	Black Bears
Reproductive Interval[1]		4.5	2.4
Litter size[2]		1.7	2
Proportion of females that are adult[3] at age:	3	0	0
	4	0.22	0.3
	5	0.44	0.7
	6	0.89	0.9
	7	0.94	1
	8	1	1

[1] Interval between production of successive litters that survive until age 2 (brown bears) or age 1 (black bears).

[2] Litter size when litter is 2-years old (brown bears) or 1-year old (black bears).

[3] First successful litter produced at indicated age or earlier.

Table 2. Simulation results for estimating period required to recover from overhunting which caused a 50% reduction in maximally productive grizzly bear and black bear populations. During recovery period production was subject to hunting rates of 0, 50, and 75% of the initial rates at which populations were stable.

	Grizzly Bear	Black Bear
Years required to recover from reduction when hunting is held at following fractions of initial hunting rate:		
(No hunting)	10	6
50%	19	9
75%	40	17

Table 3. Estimated sustainable yield from maximally productive populations of grizzly and black bears (input parameters reported in Miller [1989]).

	Grizzly Bear	Black Bear
Annual hunting rate for initial stabilized population of grizzly bears (>2.0 years-old) and black bears (>1.0 years-old)	7.8%	15.9%
Equivalent hunting rate for total population (all ages)	5.7[1]	14.2%[2]

[1] Total population estiamted from number of 2-year olds by assuming yearling and cub mortality rates of 0.20 and 0.35, respectively for each sex.

[2] Total population estimated from number of yearlings by assuming cub mortality rates of 0.22 for each sex.

APPENDIX G

Abstract of draft manuscript presented at 8th Intl. Conference of Bear Res. and Manage. (Victoria B. C., Canada, Feb. 1989).

POPULATION MANAGEMENT OF BEARS IN NORTH AMERICA. Sterling D. Miller. Alaska Dept. of Fish and Game. 333 Raspberry Rd., Anchorage, AK. 99518-1599.

Abstract: Aspects of bear population management are examined from the perspective of managers of North American bear populations that are healthy enough to produce a sustainable surplus for harvest by humans. The importance of planning is emphasized; management objectives should be established in quantitative terms that will serve as benchmarks to success or failure. Because of the low reproductive potential of bears, the consequence of error resulting in overharvest of bear populations is high. Simulation results where reproductive rates are generous, natural mortality rates are low, and harvests are 25% below sustained yield, suggest that populations reduced by half require >40 years to recover for brown bears (Ursus arctos) and >17 years for black bears (U. americanus). Under these optimal conditions for reproduction and natural mortality, maximal sustainable hunting mortality was estimated as 5.7% of total population for brown bears and 14.2% for black bears. Managers have little ability to directly measure trends in bear demographics except with intensive, multi-year studies in areas which are typically small compared to the area occupied by managed populations. The best technology is too expensive for routine use by bear managers and, even this, lacks sensitivity to detect moderate changes in populations. Consequently, managers usually rely on deductive or inferential reasoning to establish management objectives. Simulations studies reported here suggest that statistics like mean or median age in harvest, or sex ratio in harvest, are poor indicators of population trend. Stability over time in these statistics reflects stability in relative vulnerabilities among the different sexes and ages rather than population trend; changes in these statistics reflect changes in vulnerability. Although there is no single perscription for all situations, a generally preferable way to set management objectives is to balance the total number of bears killed by humans with the estimated sustainable yield of bears. This requires estimates of (1) population size, (2) reproductive or recruitment rate, (3) natural mortality rates, and (4) a means of integrating these parameters in a population model. Managers can bracket the sustainable harvest rate by making conservative and liberal estimates of demographic inputs. This process and additional information from hunter effort, hunter success rates, and environmental variables, will usually provide managers with an ambiguous interpretation of population trend. The number of bears taken can be influenced with a wide variety of management tools including: methods and means of take, season or area restrictions or closures, and limited entry hunts. The difficulties faced by

bear managers are not surprising; bears have received the protection of "game animal" classification only recently in many areas of North America, so the lack of technology is understandable. Given the nature of bear biology, it is likely that management of exploited bear populations will continue to retain a high level of uncertainty requiring conservative management to avoid overharvests.

APPENDIX H

State: Alaska

Cooperator: None

Project No. W-23-2 Project Title: Wildlife Research and Management

Study No. 4.18R Study Title: Interpretation of Bear Harvest Data

Period Covered: 1 July 1988 - 30 June 1989

SUMMARY

Progress in this reporting period was limited to preparation of a manuscript on "Population management of bears, some considerations" and information presented in a separate report on a closely-related project. The abstract of the population management manuscript is presented in Appendix G.

BACKGROUND AND OBJECTIVES

Background and objectives for this project were outlined by Miller and Miller (1986, 1988). In brief this project is designed to inprove understanding of the relationship between the sex and age composition of harvested bears and trends in bear populations.

METHODS

A deterministic population simulation model was developed and tested as one approach towards improving understanding of the relationship between bear harvest data and population trend. These results were reported by Miller and Miller (1988). Data on the sex and age composition of harvested bears in an area where bear populations were determined to be declining, using independent population monitoring techniques, were examined for indicators indicating a decline by Miller (1988). During this reporting period wildlife management agencies in different states and provinces in North America were contacted to determine the techniques they used to assess status of exploited bear populations.

RESULTS AND DISCUSSION

During this reporting period, a paper was prepared and presented at the 8th International Conference for Bear Research and Management (i.e., "Population management of bears: Some considerations"). The abstract of this manuscript, currently undergoing peer review, is presented in Appendix G of Miller (1990). This paper presents the results of the simulations reported in last year's progress report (Miller and Miller 1988) and includes insights into bear population management gained from the survey on bear population management in other states and provinces. No progress was made on converting the harvest data interpretation model developed by Tait (1983) into a form where it could be evaluated using Alaska harvest data.

Other activities related to this job are reported in Miller (1990). These activities include an analysis of brown bear harvest trend in all Units in Southcentral Alaska, an abstract of a manuscript on detection of differences in brown bear density caused by hunting (Appendix A of Miller 1990), and success rates of hunters in all Alaska Units based on questionnaire responses (Appendix E of Miller 1990).

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WILDLIFE RESTORATION

Federal Aid Project
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