PART 2

Population Dynamics of Arctic Grayling in the Upper Susitna Basin

POPULATION DYNAMICS OF ARCTIC GRAYLING IN THE UPPER SUSITNA BASIN

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ABSTRACT

The effects of an anticipated sport fishery for Arctic grayling on the tributary streams of the upper Susitna basin is examined by modelling the effects of hypothetical harvest. The increased levels of mortality created by a sport fishery cause a rapid shift in the age structure and consequently the size of the fish caught. To maintain a "trophy" fishery on a sustained yield basis, a catch and release fishery appears to be warranted. Under the assumptions of the model, the total number of all fish caught is not substantially reduced with comparatively high levels of fishing. Possible explanations of the differences in population structures of the Deadman Creek drainage and the impoundment tributaries are discussed.

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1.0 INTRODUCTION

During the 1983 studies on the upper Susitna basin Arctic grayling populations, data were obtained that are useful in revision of the population dynamics model which was constructed from 1982 data (ADF&G 1983a). We obtained refined data on age estimates by examination of otoliths in addition to a broader sample of spawners during the spring of 1983. In addition, a study was conducted on Deadman Creek outside of the proposed impoundment boundaries (see Part 1 of this volume). In this report, we examine the effects of reclassification of the ages of fish collected during 1982 on the conclusions of the earlier model. We also explore effects of various levels of exploitation on the reproduction of these populations. The effects of catch and release management strategies on harvest of these fish and comparisons of the Deadman Creek population with the other tributaries are included. The information presented should be useful in developing a mitigation plan for dealing with the effects of increased exploitation of the fish stocks associated with improved access.

2.0 METHODS

2.1 Study Locations

The approximate location of the sampling sites are depicted in Figure 1. The data collected for the tributaries within the impoundment zone were primarily obtained during the summer of 1982, with spawning data and otoliths obtained from these tributaries during late May and early June of 1983. Detailed descriptions of the sampling sites and study locations were described in ADF&G (1983b) and in Appendix I of ADF&G (1983a). The remainder of the data were obtained from the Deadman Creek drainage during the summer of 1983. These data are reported in Part 1 of this report.

2.2 Fish Data Collection

All data collection methods are described in ADF&G (1983a, 1983b) and in Part 1 of this report. The only data not previously described are the otolith collections from tributaries within the impoundment zone. These otoliths were collected along with scales, in an identical method with the collection procedures employed on Deadman Creek (Part 1). In addition, length, sex, and spawning condition were also recorded.

2.3 Data Analysis

Data summaries from the collection efforts of the open water field season of 1982 and 1983 were used to estimate different parameters of

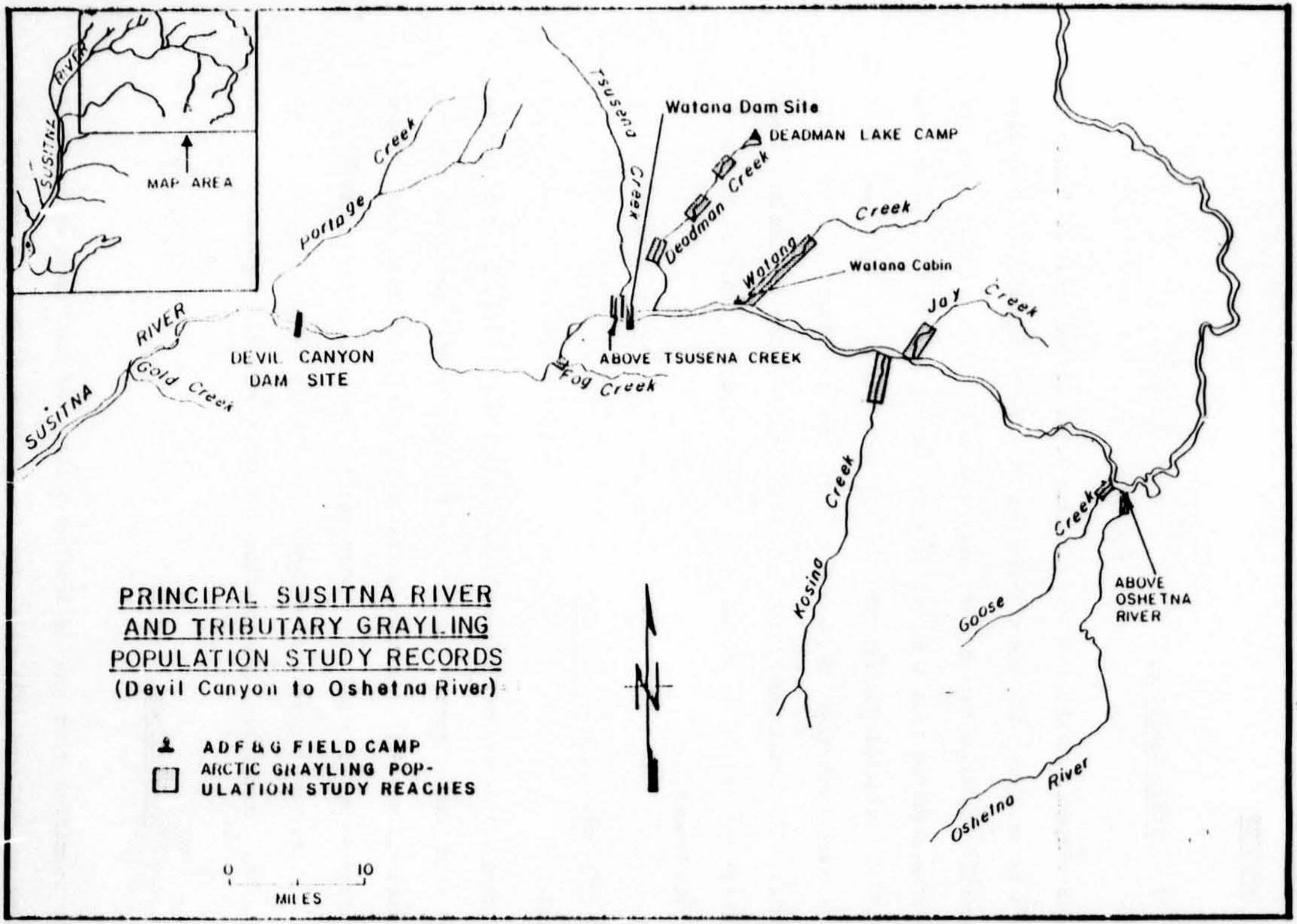

Figure 1. Study reaches used for modelling the population and harvest of Arctic grayling in the upper Susitna Basin.

the Arctic grayling populations under study. These parameters include length-age relationships using scales or otoliths, instantaneous rates of natural mortality from catch curves, density estimates from mark and recapture studies, instantaneous rates of mortality from fishing pressure, and percentage spawners of each age class. We independently calculated these estimates from the Deadman Creek drainage study sites and from the impoundment tributary studies, with the exception of the instantaneous mortality rates from sportfishing. The sportfishing mortality rates measured from the impoundment tributaries in 1982 were used to describe projected fishing pressure mortality for both Deadman Creek and the impoundment tributaries.

Fecundity estimates were derived from Tack(1974) which reflected fecundity rates from Arctic grayling on the Goodpaster River.

$$E = 28.676 \times L - 4254.537$$

Where:

E = number of eggs

L = length in millimeters.

These relationships were applied to both the impoundment tributary and the Deadman Creek fish populations.

A population model which included incremental sport fishing exploitation as a component was developed using the approach described by Clark (1983) and also used by Allen (1955a, 1955b), Beverton and Holt (1957), and Jensen (1981). The methods duplicated Clark's study except that differential mortality rates were assigned to each of the age classes of the populations. Equations used in the model are listed in Appendix 1. The equations were entered into a commercial spreadsheet program which features interactive graphics (1-2-3 by Lotus Inc.). Most of the illustrations of output of the model in this report are produced directly from this program.

This model does not address density dependent mortality of the egg to recruit portion of the life cycle. Constant recruitment was assumed.

3.0 RESULTS

3.1 Population Dynamics of Arctic Grayling

During the spring of 1983, we obtained additional information on the age to maturity of the Arctic grayling populations within the tributary streams adjacent to the reach of river to be inundated by the Watana and Devil Canyon impoundments. Otoliths were obtained from a range of sizes of Arctic grayling and were compared to scale analysis (Figure 2). This figure illustrates the consistent pattern of underestimating age by scale analysis after age V. The otolith readings are assumed to be the most accurate of the two. This shift in age structure has altered the estimates of the populations previously recorded from the 1982 study (ADF&G 1983a). Figure 3 illustrates the differences using both scales and otoliths for estimating populations of the impoundment grayling. The population estimates for the youngest aged fish considered as part of the catchable population have shifted one year with the four year old fish now the youngest cohort of the population. The new population estimate for each age class using the revised age structure information is depicted in Figure 4. This adjustment was made to consider spring-caught fish to be beginning the year rather than ending the year. Although the shift in age structure is quite large, the total estimate of the population after accounting for this change is similar to the 1983 report (14,174 versus 13,750). The natural survival rate for the age VI and older fish was estimated to be 0.56 by using a least squares fit to the catch curve data. For purposes of modelling the population, a survival rate of 0.75 was used for the age III, IV, and V cohorts of this population. These values were obtained iteratively so that the

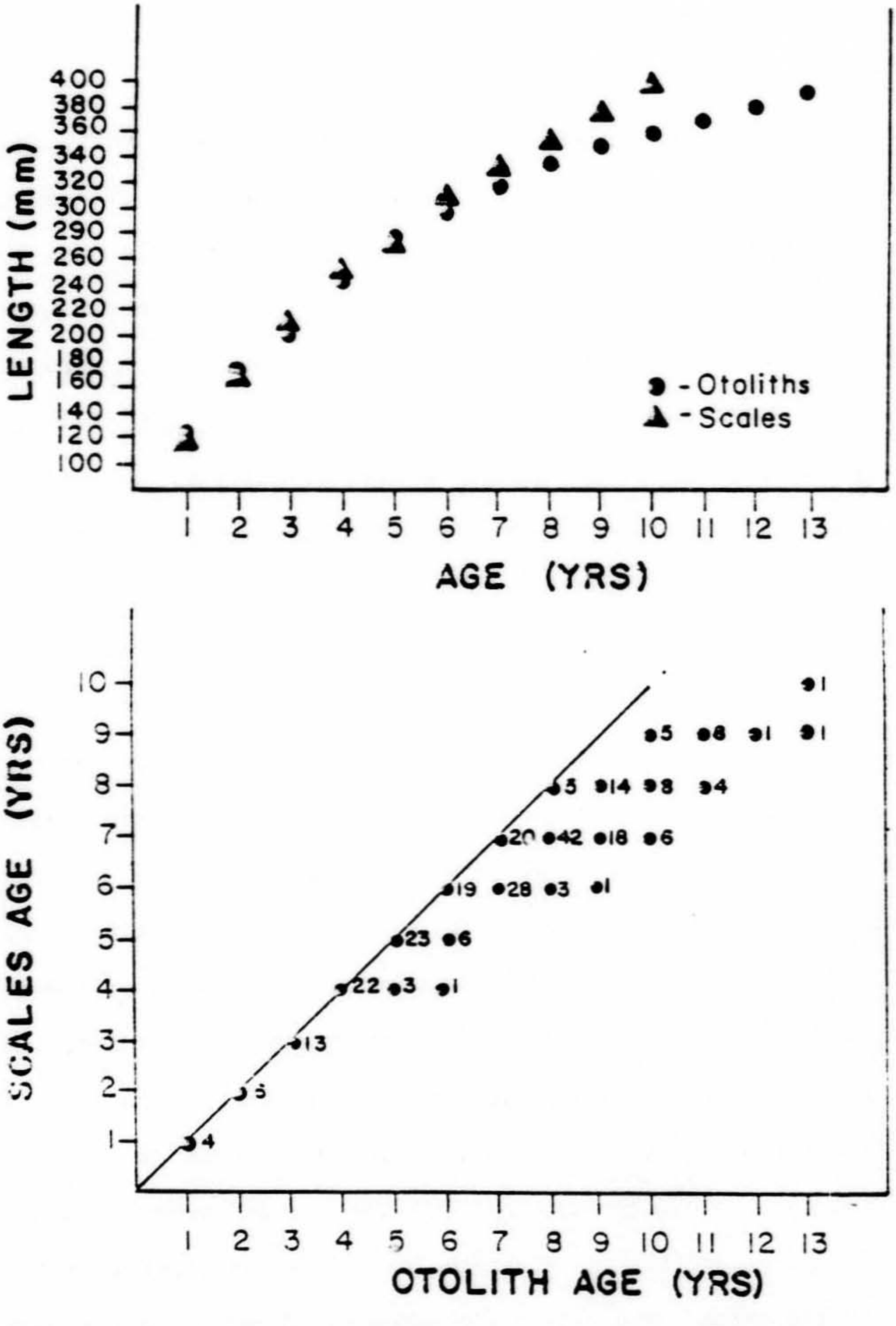

Figure 2. Comparison of age estimates obtained from the same fish using otoliths and scales. Numbers of fish are indicated next to the dots in the lower figure. The upper figure illustrates the effect of correction for age by otolith analysis on growth determinations.

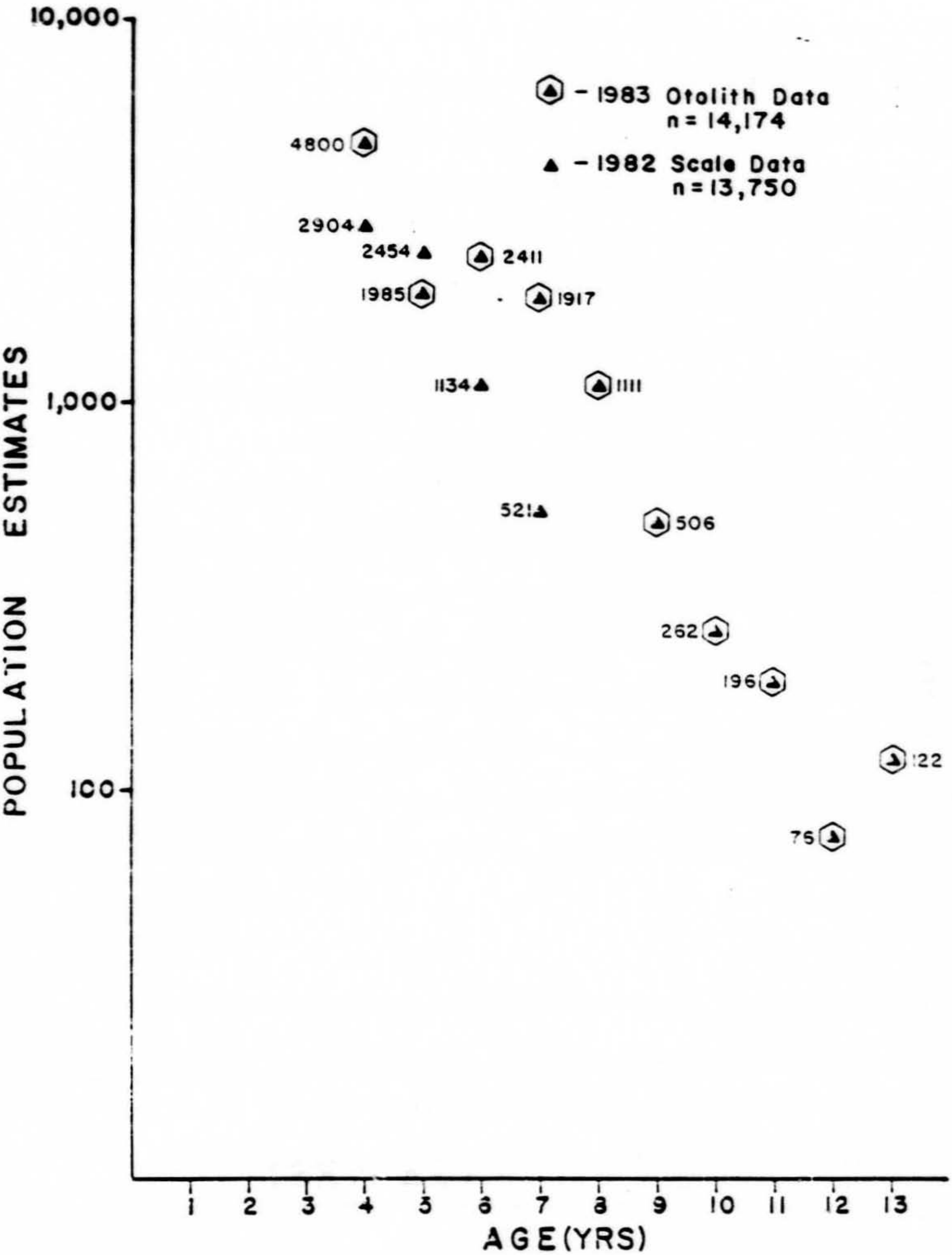

Figure 3. Comparison of the age specific populations when length data were used to estimate age from the length/age relationships developed from scale data and from otolith data. Total population estimates of age 4 and older fish are included.

model approximated the age class specific populations observed in the field. The model reached a steady state after simulation of approximately 13 generations. This method of estimation of natural survival rates replaced the estimates used in the previous report which relied on population differentials between each age class for survival estimates. The revised population estimates suggested the constant recruitment assumptions were sufficiently violated that actual population estimates of the younger cohorts could not be used to estimate age specific survival rates.

The contribution of each age cohort to the spawning population is depicted in Figure 5. This analysis suggests some four year old females became sexually mature and a higher percentage of females remained mature until age VII. The three fish collected over Age XII were all males. Because otolith aging required killing the fish, we did not sample large numbers of the older age classes. The larger Arctic grayling captured in both the impoundment tributaries and in Deadman Creek were usually males, which suggests higher mortality rates for females.

The population parameters of the representative reaches of Deadman Creek have been reported in Part 1 of this report. The presence of Deadman Creek falls provides a barrier that has isolated this population from the Arctic grayling population of the tributaries within the proposed impoundment boundaries. Population estimates by age class were not possible because of the comparatively small numbers of fish that were marked and recaptured in the population estimates conducted on specific

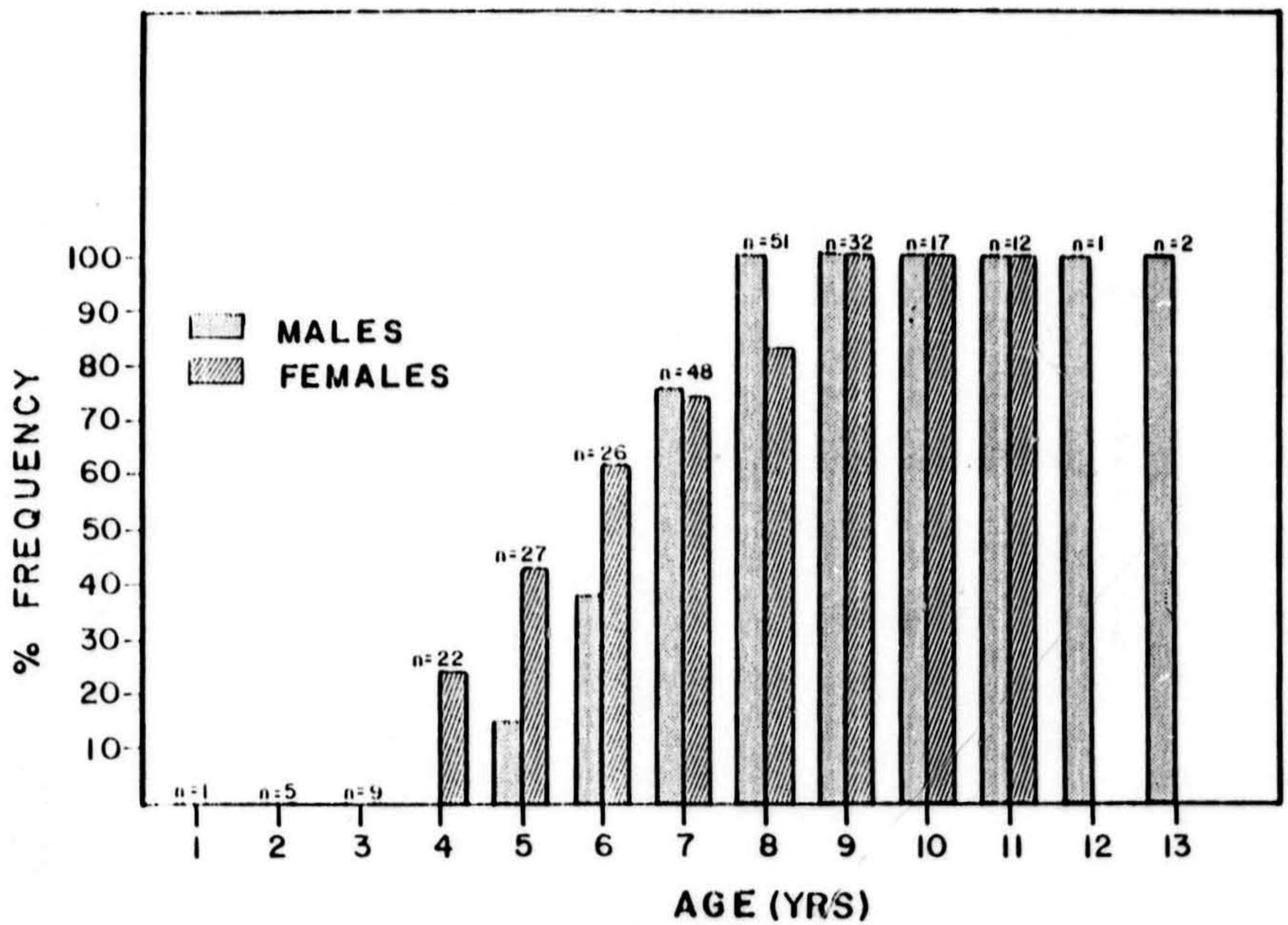

Figure 5. Percentages of sexually mature Arctic grayling of each age class. All ages were determined by otolith examination.

reaches. Survival rates calculated from the least squares fit of the catch curve data were 0.76. This value was applied to the age VI and older cohorts of this population. This value was also applied to the age III, IV, and V cohorts for simulation of the population by the model. The population estimates for the baseline year of each age class were approximated by choosing an initial recruitment of age III fish that would provide a population estimate of age IV and older fish similar to the number estimated by the mark and recapture methods reported in Part 1. This value is approximately 8000 fish for the reach of Deadman Creek that is under consideration in this study.

3.2 Sport Fishing Harvest Model

The sport fishing model originally reported (ADF&G 1983a) has had minor modifications to incorporate catch and release fishing. Also, we used the egg production and percent spawner data developed from field data obtained during 1983 and from the literature sources described earlier as input to the model. The model has been operated independently for the impoundment tributaries and for Deadman Creek. In all cases, the numbers of fish harvested refer to populations within the reaches of all of the tributaries within the boundaries of the proposed Devil Canyon and Watana impoundments or, in the case of Deadman Creek, the reach between Deadman Creek falls and Deadman Lake. Under the constant recruitment assumption of the models, sustained yield projections were obtained after ten generations of constant natural mortality accompanied with the type of fishing mortality being examined. Comparison of the effects on egg production of sustained harvest (assuming 100% mortality of all caught fish) with a catch and release fishery that produces only 10% mortality (90% survival) of the fish that were captured is depicted on Figure 6. Because of the average larger size and older age of the Deadman Creek fish, a more rapid decrease in the spawning cohort (and consequently, egg production) occurs than under similar harvests in the impoundment tributaries. The simulations of harvests of Deadman Creek and the impoundment tributaries demonstrated similar trends so only the Deadman Creek simulation plots for numbers caught under alternative catch and release strategies are provided.

Figure 7 illustrates the effect of increased harvest pressure on grayling assuming 100% mortality of all caught fish in the Deadman Creek study area. Note that the maximum sustained yield of all fish occurs at about 40 hours per mile annually whereas the maximum yield of age IX and older fish occurs at less than 10 hours per mile. The effects of catch and release of sport caught fish of 90, 80, 70, 60, 50, and 0% of the numbers actually caught (assuming releases of fish without mortality) is illustrated in the simulation output plot on Figure 8. The optimal catch rate is clearly a function of the percentage of the caught fish successfully returned.

Finally, Figure 9 depicts the number of fish of each age class caught each year beginning at the present (and assuming negligible fishing pressure prior to the present) and continuing for the next ten years, assuming 100 hours of fishing per mile of stream. Figure 9 also illustrates the effects of assuming 90%, 50% and no successful return on the catch over this period.

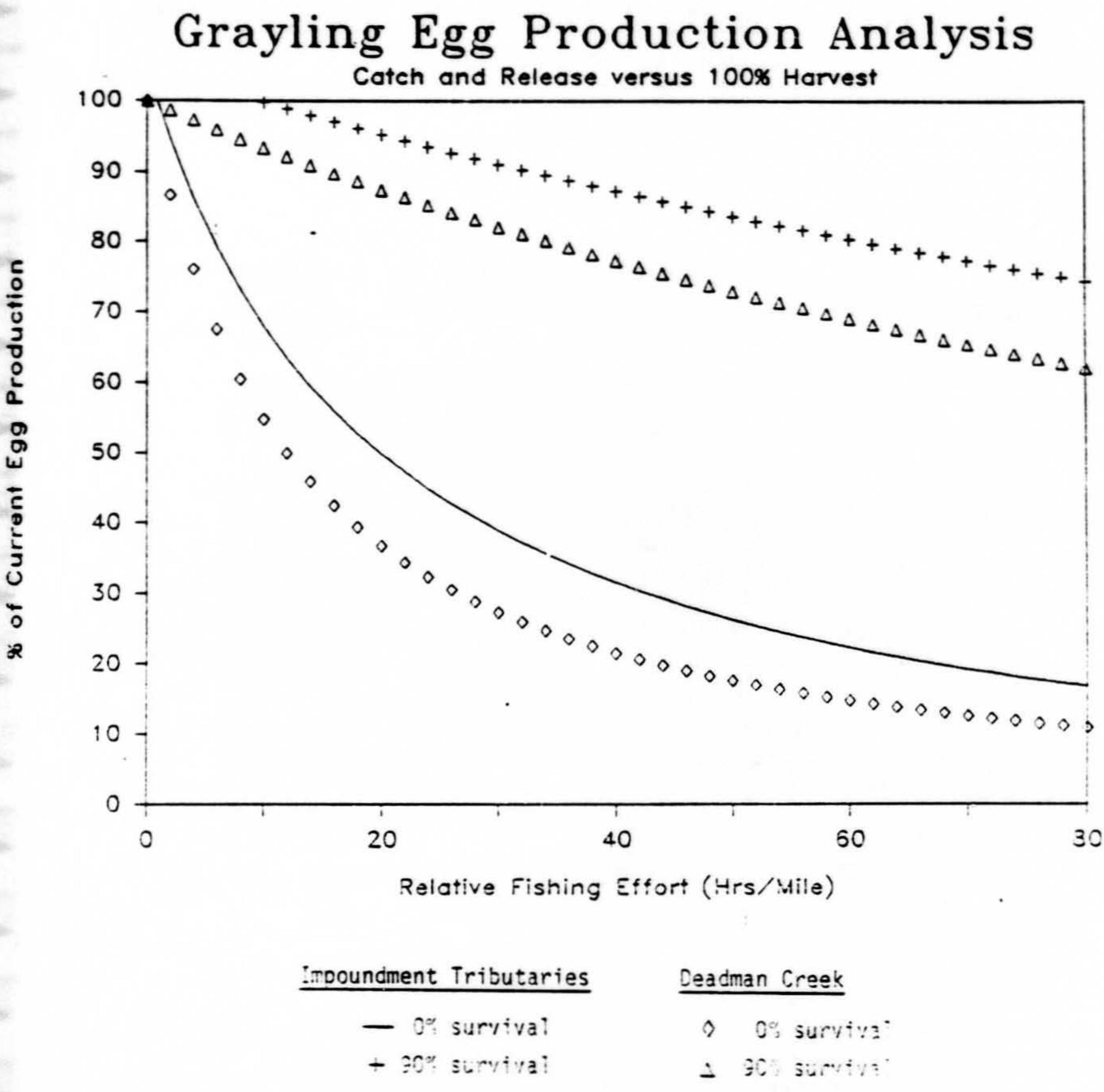

Figure 6. Percentage change in total egg production of Arctic grayling populations of the impoundment tributaries and the Deadman Creek drainage with and without simulated catch and release fisheries. The catch and release fishery assumed 10% mortality of the captured fish.

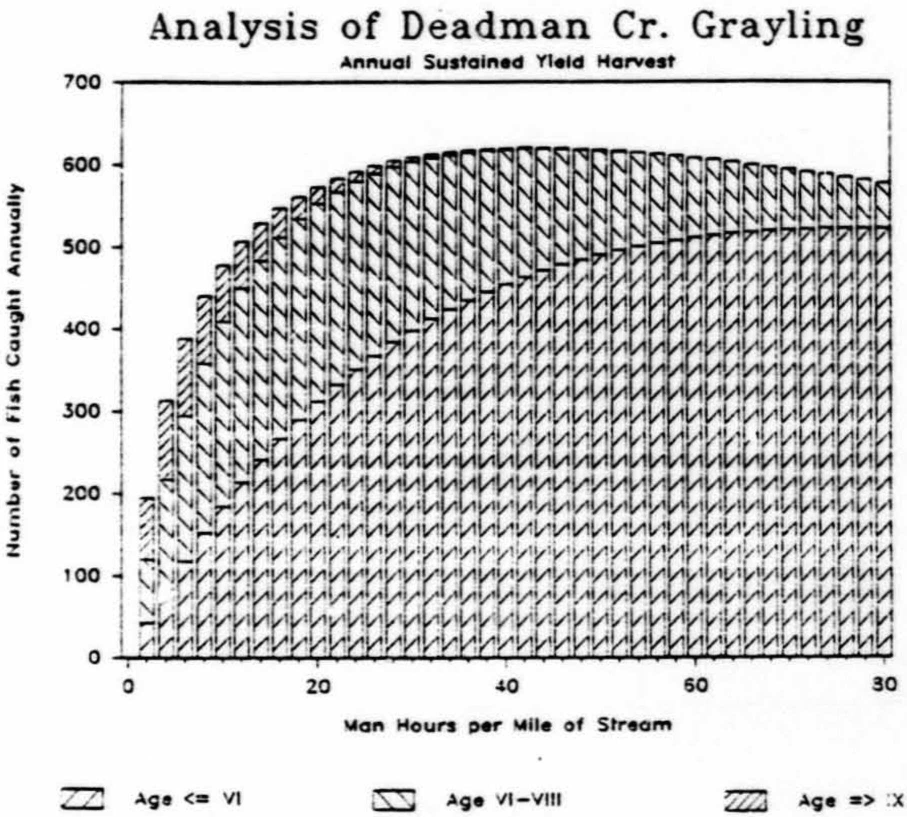

Figure 7. Effects of increasing sportfish harvests (100% mortality) on the sustained yield catch of various age cohorts of the Deadman Creek grayling population.

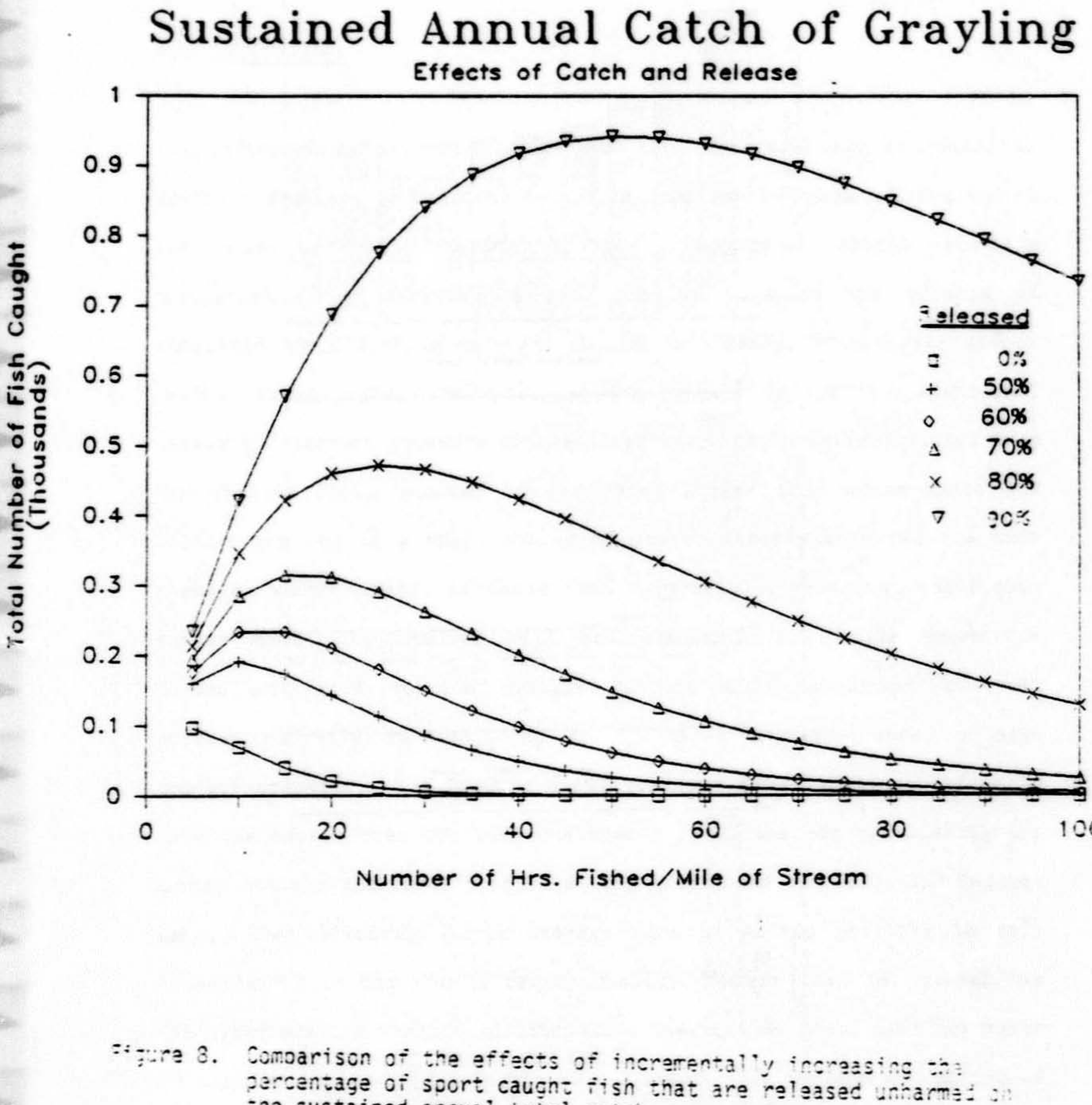

Figure 8. Comparison of the effects of incrementally increasing the percentage of sport caught fish that are released unharmed on the sustained annual total catch.

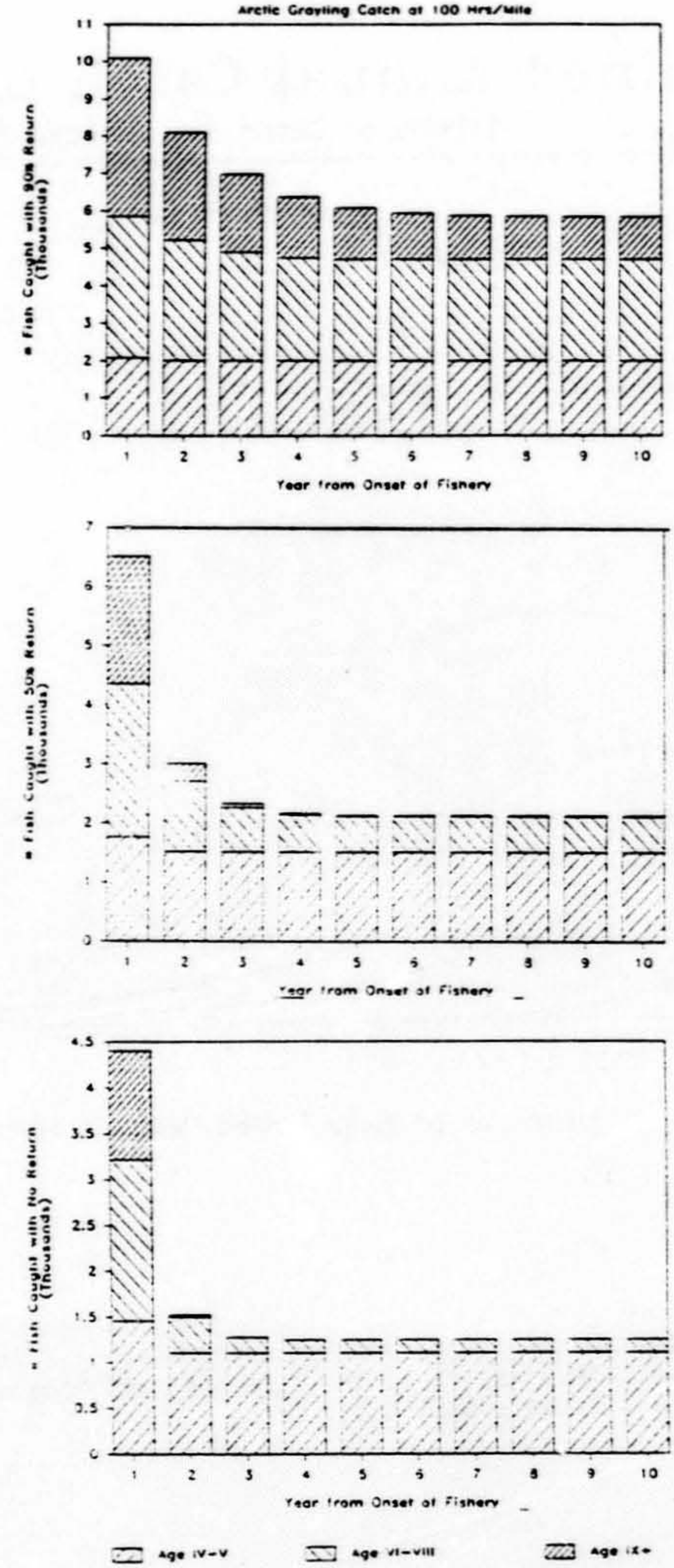

Figure 9. The effect of sport harvest on the Deadman Creek grayling population for a ten year period after the onset of a fishery with 90%, 50%, and no return catch and release.

4.0 DISCUSSION

The refinement of the population and age structure data presented in previous studies, in addition to new information on Deadman Creek and on the spawning and maturity of the impoundment Arctic grayling populations, has provided a more precise look at the effects of simulated sport fishing harvests on the impoundment tributaries and on Deadman Creek. The development of the project may provide additional access and harvest pressure on the clear water tributaries draining into the Susitna River because of easy boat access into areas where now helicopters or, in a small number of areas, float planes are the only means by which harvest of these fish is possible. Although the tributaries that were studied will be inundated, the areas above the impoundment zone provide similar habitat and, consequently, these populations will be subjected to increased harvests under a post project scenario. The Deadman Creek drainage is a likely candidate to have the access road for the development of Watana dam paralleling its length between the lower portion of the creek near the falls and Deadman Lake. The relatively large average size of Arctic grayling in this creek currently provides a trophy quality fishery that is unusual for the upper Susitna basin. Additionally, the barrier falls near the mouth of Deadman Creek will be inundated, allowing free passage and mixing of the populations of the impoundment tributaries and Deadman Creek.

The analysis presented and the following discussion will attempt to estimate the results of various management alternatives on the long term sport fishery within these streams. In addition, we will explore the possible reasons why Deadman Creek produces larger Arctic grayling than other impoundment tributaries and how the removal of passage barriers may affect this population.

The effects of sport fishing harvests on the population structure of Arctic grayling has been investigated by Grabacki (1981) in the Chena River. Additionally, computer models have been used to describe stream fisheries for a variety of species in the lower forty-eight (Clark et al. 1980; Clark 1981, 1983). The model developed by Clark is similar to the one used by us in these studies with minor exceptions. We did not use the length structure of an age cohort as a component in the model. Simulation of sizes of fish was approximated by applying harvest rates to specific age classes. The slow growth and reasonable predictability of the age class of a fish by its length allowed harvests to be evaluated using age classes directly with interpretation of the results by examination of the age length data relationships. We also used age class specific fishing mortality rates. Our data from hook and line collection suggests a differential probability of capture of the different sizes of fish which is significant enough to affect the results. We have obtained copies of the FORTRAN models used by Clark (1983) and hope to compare results in the final draft of this report.

Grabacki (1981) did not model the harvests but did provide comparative data on the structure of the population of heavy and lightly fished portions of the Chena River. This information is primarily of use in comparing the outcomes of our model with actual results of exploitation.

portion of Kosina Creek may be subjected to significantly more fishing pressure than Deadman Creek because of the publicity this lake received during the presidential tour of Jimmy Carter. The department has reduced the bag limit to two fish per day on this lake. Increased fishing mortality on the system could not be separated from natural mortality with the data base we have available.

The second hypotheses, and one that may have implications for removal of the fish passage barrier, suggests that the current population structure is created by high density dependent mortality of the younger age class fish. This may occur because the falls prevents the immigration of fish from the large mainstem reserve into the creek. Young of the year and other small fish occur in habitats associated with the mainstem Susitna in both the upper and lower portions of the Susitna River. Without such an area to act as a reserve, mortality rates of the younger age classes may be considerably higher. Less competition for territories by the smaller number of the younger cohort of the Deadman Creek population with the older fish may result in an improved growth rate. This suggests a density dependent mortality effect. By inadvertently adding fish to the system by removal of the barrier falls, the population structure could change if the current population structure of older fish is driven by density dependent mortality.

Regardless of which hypothesis is correct, the inherent productivity of the stream should not be affected, and consequently the sustained yield of fish should not change, assuming reduced populations caused by fishing mortality could emulate any density dependent mortality effects on population survival and growth rates. Careful monitoring of the system after inundation of the falls, coupled with a highly regulated sport fishery, may provide some insights onto how to manage and maintain a trophy sport fishery.

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5.0 CONTRIBUTORS

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APPENDIX 1

Equations Used to Model Population Changes

The following equations were used to project population changes:

(1) $N_{t+1} = N_t \times S_{tn}$ where: N_{t+1} = Population number of age class t plus one year.

N_t = Population number of age class t fish

S_{tn} = Natural survival rate of age t fish

N_t and N_{t+1} are known for each age class and give estimates for S_{tn} for each age class.

In an exploited fishery then,

(2) $N_{t+1} = N_t \times S_{tn+F}$ where: S_{tn+F} = Survival rate of age t fish after combined natural and fishing mortalities.

The annual total mortality rate, A, is related to S, as:

(3) $A_{tn+F} = 1 - S_{tn+F}$ and,

(4) $S_{tn+F} = e^{-Z_t}$ and, where: Z_t = Instantaneous rate of total mortalities of age t fish.

(5) $Z_t = F_t + M_t$ and, where: F_t = Instantaneous rate of fishing mortality of age class t fisn.

(6) $M_t = -\ln S_{tn}$ where: M_t = Instantaneous rate of natural mortalities of age class t fish.

Since M_t is available from N_t and N_{t+1} data, it is possible to substitute (model) values of F_t for a hypothetical fishery and predict the resulting age structure of the population with time. To do this, the following assumptions are made. (1) The rate of catch for each age class of fish per unit of fishing effort experienced by ADF&C will hold true for the general public. (2) Only grayling of age III and older are subject to increased mortality by (hook and line) fishing. (3) Recruitment of age II class fish is constant.

In an exploited system then, F_t is viewed as:

(7) $F_t = q_t \times f$ where: q_t = catchability of age class t; proportioned fish per unit time fished.

f = fishing effort, (98.25 hrs or 6.05 hrs/mile stream).

and q_t is estimated from:

(8) $q_t = -\ln (1-u_t)$ using,

$$(9)\ u_t = \frac{R_t}{M'_t}$$

where: R_t = number of grayling marked in July 1982 that were recaptured in August 1982 by age class t.

M'_t = number of grayling marked in July 1982, by age class t.

The term u_t is called the rate of exploitation and was calculated from the mark-recapture fishing data found in ADF&G (1983).

Calculation of the annual total mortality rate (A_{tn+F}) n equation (3) thus allows calculation of predicted catch at different levels of exploitation.

$$(10)\ A_{tF} = A_{tn+F} - (1-S_{tn})$$

where: A_{tF} = annual fishing mortality

$A_{tn} = 1-S_{tn}$ = annual natural mortality

$$(11)\ C_t = \sum_{t=IV}^{t=XIII+} A_{tF} \times N_t$$

C_t = total catch

The effects of catch and release on total numbers caught were simulated by reduction of the Ft by the percentage of fish released without mortality. The catch then included the value from equation 11 in addition to the numbers of fish released, the difference between Ft assuming 100% mortality and Ft assuming the appropriate level of successful catch and release.