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COLLECTION AND ANALYSIS OF BIOLOGICAL DATA FROM THE WOOD RIVER LAKE SYSTEM, NUSHAGAK DISTRICT, BRISTOL BAY, ALASKA

HOW TO INCREASE CATCHES OF SOCKEYE SALMON IN THE NUSHAGAK DISTRICT

by

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[signature]
Director

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INTRODUCTION

The purpose of this part of the report is to respond to the contract requirement by the Alaska Department of Fish and Game (ADF&G) that:

> "A written and acceptable report will be prepared which further documents the rationale used in Appendix A (of the contract proposal). The documentation will be accomplished by expanded discussion with supportive condensed data analysis and associated literature. Additionally, this report will include recommendations concerning future direction of Wood River system sockeye salmon research."

Appendix A was a brief justification for an investigation of artificial fertilization as a method of increasing the runs of sockeye salmon in the Nushagak District and hence the catches in the commercial fishery. The data analysis and literature were presented in the previous parts of this report and in past reports (Rogers 1974 and 1975). Therefore this report is largely a repetition except for the recommendations for future research.

THE DECLINE IN CATCHES

The history of the Nushagak fishery, after the initial build-up of fishing effort in the late 1800's, can be divided into three periods according to the abundance of annual catches. The average annual catches during the first (1900-1918), second (1919-1945), and third periods (1945-present) were 5.1, 2.8, and 0.9 million respectively. This decline in catch was due partially to a decline in the fishing effort or rate of exploitation. In the recent period, catches are about 30% of those in the middle period, whereas the runs are about 40% of those in the middle period.

The primary cause of the decline in the catch was a decline in the abundance of the runs. This decline was not caused by a decline in the abundance of spawners since the level of escapement has not changed significantly during the history of the fishery. In addition, declines in runs usually followed large escapements rather than small escapements (Rogers 1974).

It is unlikely that the decline in the abundance of annual runs was caused by a change in the distribution of spawners since the distribution of spawners is approximately proportional to the availability of spawning grounds and to the level of primary productivity of the nursery lakes (Burgner 1964). It is also unlikely that the decline was caused by a change in the quality of the spawners. The age-sex composition of the catches has not changed significantly even though the age compositions of the runs to the various lakes and spawning grounds do vary considerably during the recent period (Rogers 1974).

The most probable cause in the decline in the abundance of the annual runs is a decline in the productivity of the spawners (Mathisen 1971). Among the Nushagak stocks, this decline occurred primarily in the Wood River stock, and within this stock, primarily in those races located in the upper lakes of the system which spawn on lake beaches, and secondarily in two races which spawn in major rivers (Rogers 1974).

This decline in survival of the Wood River stock was probably not caused by a change in the oceanic environment because such a change would probably affect all the local stocks and this has not happened. It was probably due instead to a change in the freshwater environment of the Wood River lakes. Physical and chemical factors alone probably did not cause this decline; instead, each may have acted in combination with other factors. Biological factors, however, could have acted either alone or in combination with other factors.

The climate has been colder since the mid-1940's and this may act in combination with above-average abundance of spawners to decrease the survival of eggs only in beach spawning areas (Rogers 1975). No correlation has been found between survival from eggs to fry and winter temperatures when abundance of beach spawners was low and no correlation was evident for fish spawning in rivers and creeks. In addition, the lower temperatures may have an indirect effect by decreasing the growth of the juvenile salmon and thereby also decreasing the survival rates of the juveniles (Rogers 1977*b*).

Arctic char, a major predator on juvenile salmon, probably increased in abundance soon after the predator control program stopped in 1940. Because this fishery was concentrated in the Wood River lakes of the Nushagak District, the end of the program has allowed the char to become very abundant again (Rogers, Gilbertson, and Eggers 1972). Even if an increase in predation did not cause the decline in survival of the Wood River stocks, it probably limits survival during the recent period, and thus partly limits a build-up of the stocks to former levels of abundance.

Juveniles in the Wood River lakes are presently the smallest fish among the major sockeye stocks in Bristol Bay. Smolts migrating from the Wood River lakes in the early 1900's were 25% longer than during the present period (Rogers 1977*b*). Since survival of the juveniles is proportional to growth and size, this decrease in growth has probably been an important cause for the decrease in survival of the Wood River stocks.

At present, the size of juveniles is inversely related to their abundance and the abundance of parent spawners (Rogers 1976 and 1977*a*). The abundance of spawners was large in at least three successive years, 1946-1948, preceding the recent decline.

Apparently a combination of conditions caused the decline in the abundance of sockeye runs to the Nushagak District, such as large escapements, cold winters, poor growth, and increased predation. The factors that caused the decline in abundance are not necessarily the factors which limit production during the recent period; however, predation by char and poorer freshwater growth affected both situations.

Production of adult sockeye in the Wood River lakes is seldom limited by the amount of spawning grounds except for those races spawning in small creeks (predominantly in Lake Aleknagik). Predation is probably limiting when the abundance of juveniles is average to below average but not when abundance is above average. This possibility requires further study. Disease and parasites seem to have little effect on the production of adult sockeye except that the parasite *Triaenophorus crassus* may cause some mortality by causing infected smolts to be more susceptible to predation (Rogers, Gilbertson, and Eggers 1972).

The main cause of the decrease in sockeye production is probably a deterioration of the rearing capacity or growth conditions in the Wood River lakes. The amount of freshwater growth determines the size of fish and age at seaward migration. Small smolts have a lower early marine survival than large smolts, and poor growth during the first summer generally results in a higher-than-average proportion of age II smolts and a lower overall survival (Rogers 1977*b*).

The growth of juvenile sockeye in the Wood River lakes is limited in part by a short growing season (between ice break-up and freeze-up) since the ice-free period in these lakes is shorter than the growing seasons in the other sockeye-producing lakes in Bristol Bay (except the Tikchik lakes). The actual water temperatures probably affect growth only in the spring and early summer (Rogers 1968 and 1973).

The abundance of competitors (primarily threespine sticklebacks) may possibly affect the growth of sockeye juveniles. However, no evidence has been found to indicate that the abundance of competitors affects the annual variation in the growth of juvenile sockeye although the abundance of sockeye definitely affects the growth of other species (Rogers 1973).

The abundance of sockeye in the Wood River lakes probably limits their growth since the growth of the juveniles during July and August is strongly density-dependent and a major portion of their freshwater growth occurs during this period (Rogers 1968 and 1973). This density-dependent growth implies that there is a limited food supply. Because the density of zooplankton is inversely related to the density of sockeye, abundance of food is probably limiting growth (Rogers 1977*b*).

INCREASING CATCHES

The catches of sockeye salmon in the Nushagak District can be increased in three ways:

1) <u>More precise management of the fishery</u>. Management in recent years has tended to be conservative in favor of obtaining escapement goals rather

than maximum allowable catch. When an average or low run was expected, fishing was often greatly restricted until escapement goals were assured, and when the run was then larger than expected, there was under-exploitation and over-escapement. More precise forecasts and a realization that future runs are only slightly dependent on the number of fish in the escapement should provide some increase in the catches.

2) A reduction in the mortality of juveniles in freshwater. Arctic char are the most abundant predator on juvenile sockeye salmon in the Wood River lakes. A significant reduction in their abundance or their predation on sockeye salmon should cause some increase in future runs, provided that those juveniles that are not eaten have an equal probability of surviving other natural causes of mortality. It is also essential that a reduction in abundance of char does not cause an increase in the rate of predation by the remaining population of predators (including predators other than char).

3) An increase in the growth of juveniles. This method of increasing the runs of sockeye salmon to the Wood River lakes is discussed in detail in Part C of this report. Phosphate fertilizers can increase the production of food for sockeye salmon and thus their growth. Increased growth should cause a higher rate of survival to adult returns and thus increased runs and catches.

RECOMMENDED RESEARCH

The methods of increasing catches in the Nushagak District that are given above obviously require further study through implementation. We cannot determine whether fertilization, for example, will indeed increase the runs to the Wood River lakes unless it is done on a relatively large scale and the experiment is thoroughly conducted.

Research is needed on the genetic regulation or control of the abundance of sockeye stocks in the lake system. We need to determine to what extent growth and survival are genetically affected and whether some populations are inherently more productive than others.

There is a need for a basis for management in which runs are the dependent variables rather than returns and the runs to the individual lakes are considered rather than simply the run to the lake system. The return-escapement relationship is a poor basis for management because a calculated optimum escapement for the lake system has little theoretical basis and the runs are exploited, not the returns.

Finally, there is a need for more complete models of the freshwater ecosystems in the Wood River lakes, i.e., ones that combine trophic levels of production. Therefore, some important parameters, e.g., annual abundances of phytoplankton, zooplankton, and fish, should be measured as long as field research is being conducted on methods of increasing the production of salmon in the lake system. The accuracy of a mathematical model of the ecosystem is clearly dependent on the precision of our abundance estimates; thus, improved methodology, e.g., in estimation of smolt abundance, should improve our ability to predict biological phenomenon and our understanding of the causal relationships that involve sockeye salmon production.

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