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First Interim Report on Salmon Fishery Modelling

Dr. Frederick C. Johnson

Applied Mathematics Division
Institute for Basic Standards
National Bureau of Standards
Washington, D. C. 20234

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First Interim Report on
Salmon Fishery Modelling

by

Frederick C. Johnson
Applied Mathematics Division

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Preface

The salmon fishery modelling project is a joint State-Federal program for the development of improved techniques for analyzing the economic and biological effects of changes in the Pacific Coast salmon fishery regulatory parameters. This interim report covers the initial program design phase of the project. This portion of the project was sponsored by the Washington State Department of Fisheries under Service Contract No. 549.

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I. Introduction

The Pacific Coast salmon fisheries are a highly interconnected system composed of several types of fishing gear active over large geographical areas. The fisheries harvest many different stocks of salmon, and the biological characteristics of these stocks can vary substantially even within a single species. The large number of salmon stocks, their complex life cycles and the dynamic nature of the fishery combine to present a formidable challenge to successful salmon fisheries management. Because of the overall complexity and importance of the fishery management problem there has been an ongoing effort to develop improved techniques for assessing the effects of fishery regulatory action on the economic and biological aspects of the salmon fisheries. In a previous study [1] the development of a management model of these fisheries was recommended in order to provide regulatory agencies with a tool for systematically analyzing the large amounts of data that are being obtained on fisheries performance. This report covers the initial design and implementation phases of such a model.

The purpose of the salmon fisheries management model is to quantitatively analyze the effects of fishery regulatory changes on the economic performance of the fisheries and on the abundance and long term stability of the component stocks of the salmon resource. In this manner, the model can be used as a test bed for the evaluation of alternative regulatory policies for the salmon fisheries. Section II of this report outlines the components of the model, and the current status of the fishery modelling project is given in Section III.

II. The Fishery Model

The fishery model is a time oriented simulation model which emulates the characteristic processes of the major components of the salmon fishery system. The simulation begins with the initial recruitment to the fisheries, continues through the entire ocean life cycle of the salmon stocks and ends with the final escapement by the oldest members of each stock. From initial recruitment to final escapement the model simulates the major biological processes (growth, natural mortality, migration, maturation) of each stock and the stock-fishery interactions. The effects of fishing are determined by the population and location of the stocks, their length characteristics, the regulatory parameters of the different fisheries and the historical performance of the fisheries as reflected in catch statistics. The total catch, catch value and escapement is obtained for each stock, and this information forms the basis of comparison between alternative fishery regulatory policies.

The fishery model is termed a time oriented model because the sequence of events in the model approximates as closely as possible the actual event sequence. A variable time period is used in the model as the basis of the sequential process. The calendar year is divided into 32 time periods which vary from a minimum length of one week to a maximum length of one month. The time periods used in the model are identical to the reporting periods established by the Department of Fisheries and Forestry of Canada for documenting British Columbia catch statistics. This system uses shorter reporting periods during the major fishing seasons and longer periods throughout the rest of the year. For the fishery model this has the advantage of providing a time period length that is inversely proportional to fishery activity.

The prototype version of the fishery model is a steady state deterministic model. It is a steady state model in the sense that the fishery regulations and annual fishing effort are held constant throughout the life of a stock. This emphasizes the major long term effects of a stable fishery and eliminates transitory effects caused by fluctuations in effort and regulatory changes. The model is a deterministic model because the effects of random variations in fishing and in the biological processes of the stocks are not considered. The emphasis of the initial, prototype version of the model is to begin the analysis of the major stock-fishery interactions in the simplest meaningful fashion. Subsequent versions of the model can be expanded to consider transitory and random factors. In many cases, however, a parametric analysis of various combinations of fishing effort and stock characteristics may well be more useful for regulatory analysis for such purposes as the establishment of confidence bounds.

Spawner-recruit relationships are not included in the model because of the great variability which exists in these relationships. Instead, the model computes the total annual escapement for each stock that results from a particular regulatory policy, and it is left to the management agency to determine whether the escapement is adequate. This approach is in keeping with the management practice of establishing minimum escapement quotas and adjusting the terminal fishery effort to achieve these goals.

Figure II.1 gives a summary of the components of the fishery model which consists of three principal tasks: input, calibration and analysis, an outline of each of these tasks is given below.

II.1 Input Requirements

The complexity of the salmon fishery system greatly impacts the input requirements of the model in that large amounts of data may be required in order to adequately describe the essential characteristics of the system. Consequently, the input parameters for the model have been selected with a great deal of care in order to minimize the costs of data preparation. A prime consideration for the selection of the input parameters was that the existing fishery performance data should not require major reprocessing for use by the model. The input to the fishery model consists of three major categories:

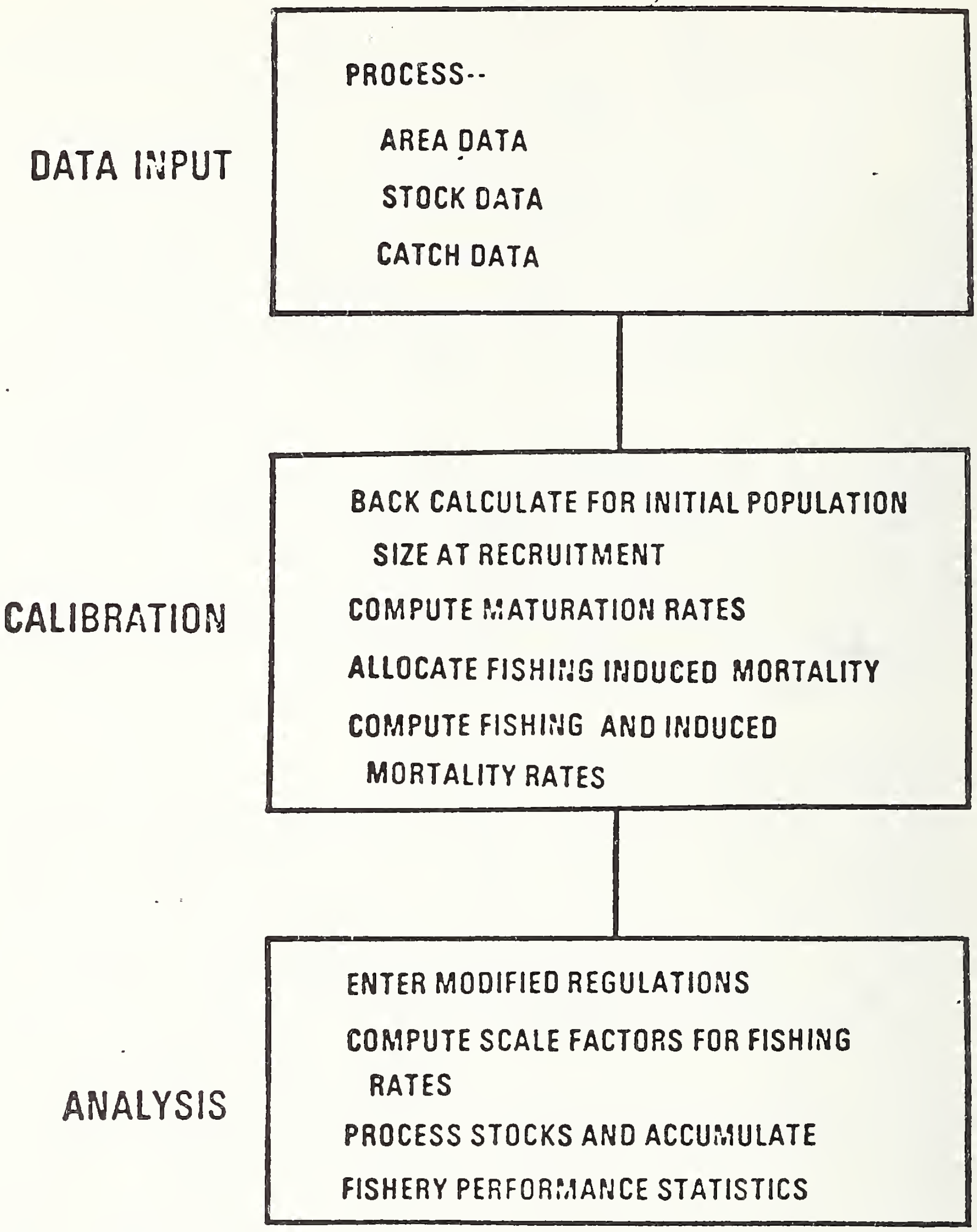

Figure II.1. Fishery Model Task Sequence

- o area data,
- o stock data,
- o catch data.

Fishery regulatory data are included in the area data category.

The basic geographical unit of the model is the area which is used to specify the location of the various fisheries and the migration patterns of the stocks. An area may refer either to a section of the ocean or to a freshwater location. The areas that are defined in the input data serve to partition the fresh and salt water environment into management zones, each of which may contain fisheries that are subject to different regulatory parameters.

The area data contain a description of the fisheries that operate in each area. A fishery description consists of the following items:

- o fishery name,
- o species fished,
- o gear type,
- o open season(s),
- o minimum length(s),
- o catch values,
- o induced mortalities.

A fishery season is defined by specifying the initial and final time periods for the season and the minimum legal length of the catch during the season. A fishery is not restricted to a single season by the model, and, therefore, the minimum length regulation is not required to remain constant. Commercial catch values are specified by giving dollar/pound values to weight ranges of the catch. Thus, a fish between eight and twelve pounds may be valued at $1.00 per pound while a fish larger than twelve pounds may be valued at $1.25 per pound. For sport fisheries the catch values are in terms of dollar/fish rather than dollar/pound, and the weight range feature also applies.

Induced mortality refers to hooking mortality and other types of mortality that is caused by the act of fishing but which does not generate any catch value. The initial version of the fishery model considers the effects of "shaker" mortality caused by the catch and release of sublegal fish. Subsequent versions of the model will be expanded to include other types of induced mortality such as cross-species mortality caused by incidental catch. Shaker mortality is specified as a fraction of the legal catch and applies only to sublegal fish.

The primary unit for categorizing salmon in the model is the stock. A salmon stock is any group of fish that is distinguished for fishery management purposes. For hatchery produced fish a stock would typically be identifed by a single tag code or by a group of codes. While a stock is considered to have uniform biological characteristics, it may be divided into substocks which are similar in all respects except for migration patterns. This enables the model to consider the situation in which portions of the stock are subjected to entirely different fishing pressures because of differences in migration.

The stock data input describe the biological characteristics of the fish. For each stock, this data consists of:

- growth rates,
- natural mortality rates,
- length frequency parameters,
- substock categories,
- migration patterns.

The growth of the stock is given by the initial mean length at recruitment, the maximum mean length, and monthly growth rates. These rates are both age and maturity specific. Thus, the model allows fish growth to vary by time of year, by age and by maturity. It is assumed that each stock has a normally distributed length frequency function at initial recruitment, and that, in the absence of fishing, the population will remain normally distributed. The standard deviations of the initial and final distributions are specified by the length frequency parameters, and the standard deviation follows the same growth law as length. Thus, again in the absence of fishing, the mean length of the stock and the length frequency distribution can be obtained at any point in time.

The natural mortality rates are percentage rates rather than exponential rates. As with growth rates, the mortality rates are distinguished by age and maturity, but annual mortality rates rather than monthly rates are specified. The annual rates are used to compute equal monthly mortality rates.

The substock categories identify the substocks and specify the fraction of the total initial recruitment population of the stock that each substock comprises. The migration patterns are specified for each substock by giving the areas in which the substock resides by age and maturity type (mature or immature).

The catch data forms the major portion of the model input. For each stock the number of fish caught is given by age of fish, time period of the catch, maturity, area, gear type and fishery. In addition the average fish length and weight are given. This data is obtained from historical catch statistics and provides the basis for calibrating all parameters of the model.

II.2 Calibration Process

The calibration section of the fishery model calculates all the fishing rates, maturation rates and induced mortality rates required for a fishery simulation. These rates are based on the catch data and on the number of fish of a given age that are of legal or sublegal size. The first step of the calibration process is the computation of the number of fish of each stock that are initially recruited to the fisheries. A partial estimate of the initial recruitment number is obtained by back calculation using the escapement data, catch data and natural mortality rate data. At the same time that these partial estimates are obtained, the induced fishing mortality data is used to compute the total hooking mortality for each species. Since hooking mortality is calculated by species and not by stock, the next step is to allocate the hooking mortality to the stocks of each species. This computation is based on the relative number of sublegal fish of each stock that is in the area where the hooking mortality occurred. The distribution of the stocks among the various areas is governed by the migration data, and the number of sublegal fish is determined by the growth rates and length frequency curves.

After hooking mortality has been allocated to each stock, it is also back calculated, and the final estimate of the total initial recruitment is obtained. Thus, this estimate takes into account escapement, catch, natural mortality and fishing induced mortality.

At the same time that the back calculations are performed it is convenient to store the number of immature and maturing fish that are alive at the beginning of each year. The ratio of the number of maturing fish to the total number of fish gives the maturation rate for each age, and this rate is computed separately for males and females.

The next step of the calibration process is the computation of fishing rates and induced mortality rates. These rates are obtained by sweeping forward in time and computing the ratio of catch to legal fish population and the ratio of induced mortality to the sublegal fish population for each area and for each time period. This set of computations is performed separately for each substock. The initial number of recruits for each stock is decomposed into substocks using the estimated population percentage of each substock. Since both the catch data and the induced mortality data are categorized by stock rather than by substock, catches and induced mortality must be allocated to each substock. This process is identical to the allocation of hooking mortality to the stocks of each species and uses both the migration data and growth data.

The rates obtained from the calibration process are dependent upon the age of the fish and the area and time period of the catch. Thus, if 1000 fish of age 3 enter a fishing area in the first week of June, the fishing and induced mortality rates determine how many fish are caught, and how many are killed by fishing induced mortality. The entire calibration process is based on a modified version of the standard catch equation which takes into account migration effects and induced mortality effects.

By far the greatest amount of computation in the fishery model occurs in the calibration process, and it would be wasteful to repeat the calibration for each analysis. Therefore, the calibrated fishing rates, induced mortality rates, stock characteristics and supporting data can be saved on magnetic tape and used for subsequent analyses. This substantially reduces the cost of a regulatory analysis, and simplifies the data processing requirements of the program.

II.3 Regulation Analysis

The calibration process calculates fishing rates which are based upon stock characteristics and catch data, and the catch data,in turn, reflect a particular set of fishery regulations in force when the data were obtained. Thus, an analysis of a regulatory change requires the determination of the impact of the new regulation on the fishing and induced mortality rates. Generally, a regulatory change either increases or decreases the catch rate as, for example, when a fishing season is lengthened or shortened or when fishing effort is controlled. However, a change in the minimum length regulation of a fishery does not change the fishing and induced mortality rates but alters the split between legal and sublegal populations instead.

The regulation analysis section of the fishing model first accepts the new regulatory data as specified by the user. This data may change the season length, the fishing effort, the minimum length requirement or impose a catch quota. Based upon the new regulations, scale factors are computed for the fishing and induced mortality rates. The scale factors alter these rates to correspond to the fishing effort under the new regulations. The next step of the regulatory analysis process is a forward time sweep which begins with the initial recruitment of each stock to the fisheries. The modified fishing and induced mortality rates are used to compute new catch estimates and hooking mortality estimates. The split between catch and hooking mortality reflects any changes in minimum length regulations since the model uses minimum length to divide the stock population into legal and sublegal components.

The forward sweep continues through the first year of each stock until the escapement (if any) is computed. The fish remaining at the end of the year are split into immature and maturing groups for the next year, and the process is repeated for these older fish. This sequence continues until all maturation has occurred and the processing of the stock catch and escapement estimates is completed. Processing concludes with the preparation of catch, catch value, escapement and induced mortality summaries. A new set of regulations may be then entered and the entire cycle repeated as often as required for an analysis of various regulatory alternatives.

III. Project Status

A mathematical description of the major components of the biological, economic, fishery and regulatory sectors of the fishery model has been completed. The input requirements for the model have been specified, and these requirements have been approved by the Washington State Department of Fisheries.

A simplified prototype fisheries model is being implemented. This model is designed to test the basic structure of the modelling approach and will serve as the basis for the full fishery model. Because of the complexity of the full fishery model, it is more efficient to begin with a relatively small submodel which can gradually evolve into the full operating model. This approach simplifies both the construction and validation of the model. In particular, the prototype model can be used to pin-point trouble areas very early when corrections can be easily made. This is most important since it is most likely that the validation process will indicate a need for modifications and adjustments. The prototype model has been specifically designed to accommodate this possibility.

A complete set of test data for the prototype model has been prepared for a Willipa Bay Coho stock. This data set consists of approximately 750 cards which contain about 4500 data items. The stock is divided into two substocks, a north migrating substock and a south migrating substock. The area data consists of ten ocean areas and one freshwater area, and the ocean areas range from central British Columbia to the California coast. Fishery regulatory data and catch performance data is given for the American and Canadian troll fisheries, the Willipa Bay gill net fishery, the Juan de Fuca Strait gill net fishery, and ocean and river sport fisheries. This data set will provide the principal initial test data for the prototype model. Additional data sets are in preparation which cover both Coho and Chinook salmon stocks.

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1. Johnson, F.C., "Fishery Modelling and Analysis". Report No. D180-17515-1, The Boeing Company, June 1973.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The salmon fishery modelling project is a joint State-Federal program for the development of improved techniques for analyzing the economic and biological effects of changes in the Pacific Coast salmon fishery regulatory parameters. This interim report covers the initial program design phase of the project.

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