Managing the Skeena River Sockeye Salmon (*Oncorhynchus nerka*) Fishery — the Process and the Problems

P. E. Sprout[1] and R. K. Kadowaki

Department of Fisheries and Oceans, Fisheries Research Branch, Pacific Biological Station, Nanaimo, B.C. V9R 5K6

Abstract

SPROUT P. E., AND R. K. KADOWAKI. 1987. Managing the Skeena River sockeye salmon (*Oncorhynchus nerka*) fishery — the process and the problems, p. 385–395. *In* H. D. Smith, L. Margolis, and C. C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Managing the Skeena River sockeye fishery in north coastal British Columbia is an intricate task complicated by biological uncertainties and multiple objectives. This paper traces the development of management of the Skeena fishery from its modest start at the beginning of this century to the present complicated hierarchical decision-making structure. The major components of the present management process are: (1) developing concurrent biological, economic, social, and legal objectives, (2) forecasting run size and formulating fishing plans, (3) consulting with user groups, (4) finalizing fishing plans, (5) executing fishing plans, and (6) evaluating management impact on the resource. The Skeena sockeye run is composed of over 50 stocks, with two enhanced stocks producing most of the run. Timing overlaps in the harvest area between enhanced and unenhanced sockeye and runs of pink, chum, coho, chinook, and steelhead trout have created problems in optimally managing each species. Explicit statement of objectives and specifying decision making procedures may improve management.

Résumé

SPROUT, P. E., AND R. K. KADOWAKI. 1987. Managing the Skeena River sockeye salmon (*Oncorhynchus nerka*) fishery — the process and the problems, p. 385–395. *In* H. D. Smith, L. Margolis, and C. C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

La gestion de la pêche du saumon nerka dans la rivière Skeena sur la côte nord de la Colombie-Britannique est une tâche complexe qui est compliquée par des incertitudes biologiques et des objectifs multiples. Le présent article retrace le développement de la gestion de la pêche dans la rivière Skeena depuis son début modeste au début du siècle jusqu'à la structure actuelle hiérarchique compliquée de prise de décision. Les éléments importants du processus actuel de gestion sont : 1) l'établissement d'objectifs concordants sur les plans biologique, économique, social et juridique, 2) la prévision de l'importance de la remonte et l'élaboration de plans de pêche, 3) la consultation de groupes d'utilisateurs, 4) l'établissement définitif des plans de pêche, 5) la réalisation des plans de pêche, et 6) l'évaluation des répercussions de la gestion sur la ressource. La remonte de saumon nerka dans la Skeena est constituée de plus de 50 stocks, deux stocks mis en valeur étant responsables de la plus grande partie de la remonte. Les chevauchements des moments de remonte dans le secteur d'exploitation des saumons nerkas mis en valeur et de ceux qui ne l'ont pas été de même que les remontes de saumon rose, kéta, coho, quinnat et de la truite arc-en-ciel ont créé des problèmes pour la gestion optimale de chaque espèce. On peut améliorer la gestion en faisant un énoncé explicite des objectifs et en précisant les mécanismes de prise de décisions.

[1] Department of Fisheries and Oceans, Fisheries Branch, 417 2nd Avenue West, Prince Rupert, B.C. V8J 1G8

Introduction

The management of modern salmon fisheries is complicated by high user demand, mixed stocks of different productivities, and conflicting biological, social, and economic policies. Management objectives may not be explicit and are seldom priorized, yet it is the responsibility of the fisheries manager to make biologically sound and socio-economically responsible harvesting decisions. Hilborn and Walters (1977), Keeney (1977), and Healey (1984) have proposed quantitative techniques for developing management objectives but so far there is little evidence that their techniques are being applied in the British Columbia salmon fisheries. In an environment of high uncertainty, competitive economic and social interests, and delicate biological balances, resource management objectives must be explicit and understood clearly by both the management agency and the user groups and they must permit measurement of management performance (ACMRR 1980; Wilimovsky 1985).

The Skeena River drains into the Pacific Ocean just south of the B.C.-Alaska border (Fig. 1). It is second only to the Fraser in British Columbia in terms of the number of salmon it produces.

The Skeena River sockeye fishery is a classic example of a complex resource management system. Seine, gillnet, and troll fishermen, Indian food fishermen, and sport fishermen share the Skeena salmon harvest. Each group has its own economic and social objectives and all come under varying degrees of control by the fisheries management agency, the federal Department of Fisheries and Oceans (DFO). These fisheries will be described later in this paper.

Overlaps in run timing prevent harvesting of single stocks while diverse stock productivities preclude applying a single harvest rate to provide the maximum sustained yield for all stocks (Larkin and McDonald 1968; Takagi and Smith 1973; DFO 1985).

In the face of these complexities in managing Skeena River sockeye, a hierarchical decision-making structure has evolved that attempts to synthesize the variety of biological, economic, and social inputs in order to make the best decision under the circumstances.

The purposes of this report are: (1) to review the development of the management of Skeena sockeye, (2) to describe the current process of managing the Skeena sockeye fishery with emphasis on objective setting and in-season decision making, and (3) to recommend improvements to the management system.

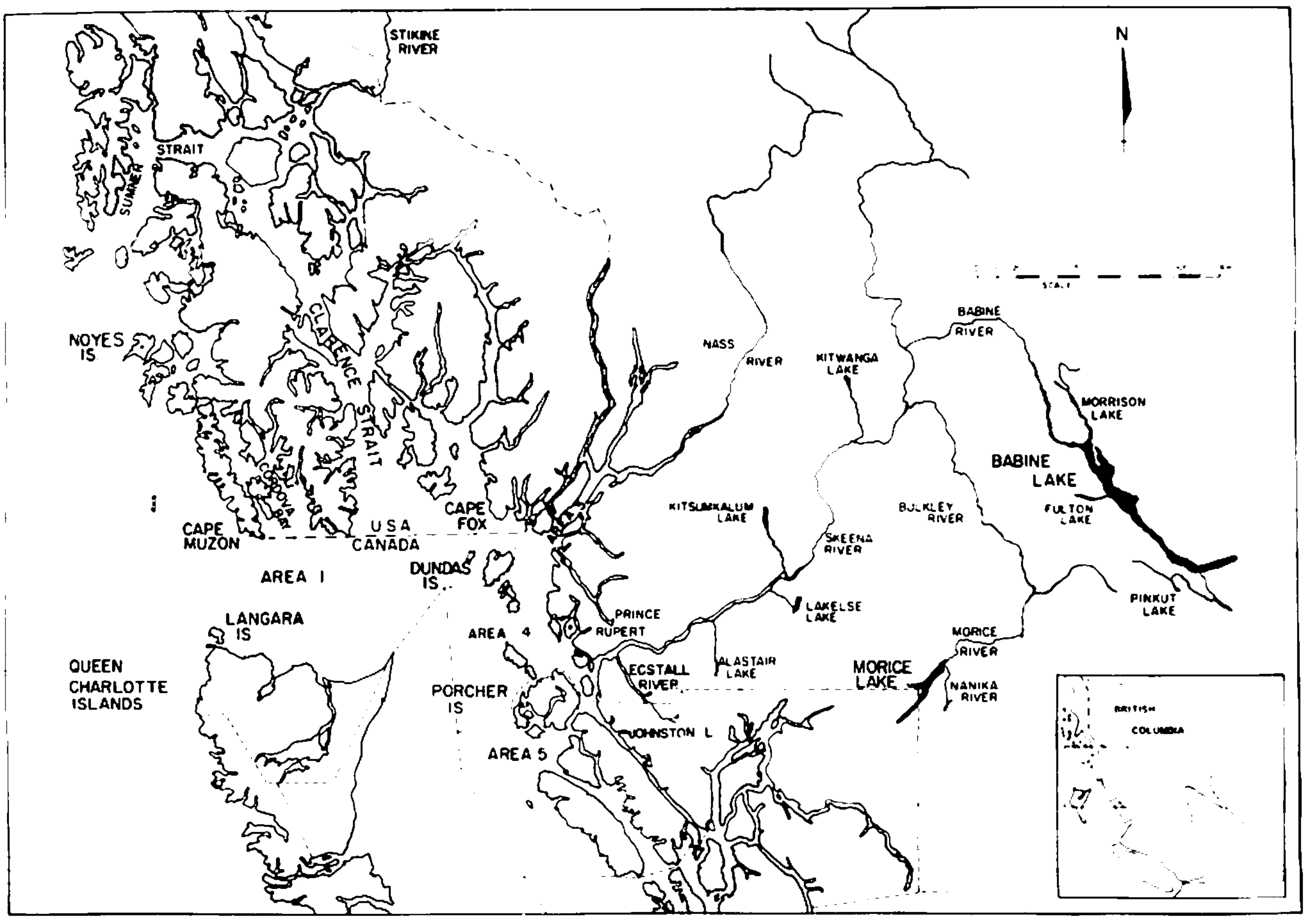

FIG. 1. North coastal British Columbia and southeast Alaska showing the Skeena River and major fishing areas for Skeena sockeye (see text for names of fishing locations).

Evolution of the Management Process

The evolution of the management process can conveniently be divided into three major periods which are characterized by different approaches to the science and politics of fisheries resources management. We will refer to these as the pre-research, research, and current periods. In the pre-research period (1876–1942) the motivation and ability to harvest Skeena sockeye far exceeded the biological understanding. Although slow progress was made in biological investigation during this period, it was not until the research period (1943–71) that a coordinated scientific program was implemented. In the current period (1972-present) the socio-economic and political aspects of resource management have gained in prominence and are the subject of much work by fisheries managers and biologists. Each period is discussed in some detail in the following sections.

Pre-Research Period (1876 to 1942)

The first Skeena River salmon cannery began operation in 1876. It was not until 1889, however, that general fishery regulations were approved for the Province of B.C. Until then the canneries, which had increased to five, controlled the opening and closing of fishing and specified the type of gear needed to meet their production requirements. Commissions were appointed in 1890 and 1891 by the federal government to investigate the B.C. salmon fisheries and make recommendations for a more comprehensive set of regulations. New regulations were issued in 1894, and seasonal restrictions for all salmon species and a weekly closed period were established (Carrothers 1941). Gear restrictions, licensing procedures, Indian food fishery, and industry canning guidelines were also covered. Apart from the enforcement of these regulations, early involvement by the federal government amounted to facilitating the commercial exploitation of the resource; for example, the removal of sunken logs which could damage gillnets was one of the high priority tasks recommended by early fishery managers and for this purpose a specially equipped barge was brought to the Skeena in 1907 (Department of Marine and Fisheries 1907).

By the turn of the century it became apparent that without an annual appraisal of sockeye escapement on the spawning grounds, it would be impossible to determine if the commercial fishery was over- or underexploiting the run. The first exploratory trip to Babine Lake, the major sockeye producer in the Skeena drainage, was made by fishery "overseers" in 1904 (Department of Marine and Fisheries 1905) and over the next few years much of the rest of the watershed was extensively explored. These pioneers focused on the qualitative estimation of escapement and removal of natural and man-made obstructions to spawning.

In 1910, an attempt was made to limit gillnet effort in the northern part of the province by allocating "boat ratings" to specific areas. These boat ratings were based on historic gear levels and average landings. They were altered in later years to encourage more white settlers in the north and to reduce involvement of people of Japanese background in the fishery (Carrothers 1941). Although sockeye salmon were the principal target during the early development of the Skeena fishery, all species of salmon were fished commercially by 1920.

Conservation requirements and overexploitation by the commercial fishery were first expressed as concerns by federal fisheries inspectors in 1916 when the Babine Lake Indians were unable to obtain sufficient sockeye for their winter food supply (Department of the Naval Servie 1917). Over the next 25 years, both the up-river and outer commercial boundaries were gradually moved seaward (Milne 1955). In-season decisions on fishing time and area were not made during this period for a number of reasons:

1) in-season data collection capabilities were limited,
2) weather greatly affected fishing efficiency and hence catch per unit of effort data were suspect,
3) canneries sought a steady supply of fresh raw materials rather than a pulsed supply,
4) announcements of openings and closures could not be communicated to the fleet on short notice.

Throughout this pre-research period, only minor changes were made in the weekly closed time (from 36 to 48 h) and in gillnet mesh sizes. Quantitative information on Skeena sockeye was limited to catch, expressed in cases of canned salmon, with only qualitative estimates of escapement (e.g., poor, average, excellent). The next period in Skeena salmon management corrected most of these data limitations and paved the way for a more scientific approach to salmon management.

Research Period (1943 to 1971)

The work of the Fisheries Research Board of Canada was a dominant force in the management of Skeena sockeye salmon during this period. Beginning in 1943, an intensive exploration of all Skeena sockeye producing systems was conducted by the Fisheries Research Board of Canada (Pritchard 1949). The actual numbers of spawners in all spawning areas were estimated for the first time and in 1946 a permanent counting fence was completed on the Babine River (Aro 1961). In the summer of 1951, a disastrous slide on the Babine River resulted in severe reductions of escapements for two successive years. In response to this calamity, the Minister of Fisheries created the Skeena River Salmon Management Committee in 1955. The mandate of this Committee was to restore and, if possible, increase the production of sockeye salmon from the Skeena. The Committee, which consisted of the Chief Supervisor of Fisheries for the Pacific Area and the Director of the Fisheries Research Board was supported by an Advisory Board composed of industry representatives. One of the Committee's first initiatives was to establish a gillnet test fishery immediately upstream from the commercial fishery (Skeena River Salmon Management Committee Annual Report, 1955). Calibrated against the Babine River fence count of sockeye spawners, this test fishery provided a daily estimate of sockeye escapement and formed the basis for a rational in-season management system. Weekly closed times were varied according to fish abundance and weekly escapement target. Extensive limnological work on Babine Lake in the late 1950's and early 1960's (Johnson 1956, 1958, 1961) identified an untapped plankton food supply that could support many more sockeye fry than were being naturally produced. Spawning channels with partial control of water flow and temperature were constructed at Pinkut Creek and Fulton River beginning in the mid-sixties to bolster the fry output to the lake and take advantage of the food reserve. Smolt output has increased substantially since that time (West 1978) and stocks of the Pinkut and Fulton system have shown a steady increase since the late 1970's. Major accomplishments during this research phase can be summarized as follows:

1) development of a maximum sustained yield escapement target for Skeena sockeye,
2) the establishment of adult and smolt enumeration programs at the outlet of Babine Lake,
3) the development of a gillnet test fishery above the commercial fishery to provide in-season estimates of escapement,
4) the discovery that Babine Lake was being underutilized by sockeye fry and the construction of spawning channels to bolster fry production.

Current Period (1972-present)

The transition from the "Research Period" to the current period began in the late 1960's and was characterized by the transfer of most Skeena stock management responsibilities from the Fisheries Research Board to the stock management sector of the Department of Fisheries. By 1972, fishery managers were responsible for all aspects of Skeena salmon management including the spawning channels, the Babine River adult and smolt counts, and the regulation of the commercial fisheries on the approaches to the Skeena River. Run size still fluctuates widely but has been above earlier averages. Spawning escapement levels indicate that much of the increased production has originated from the spawning channels while stocks have generally declined.

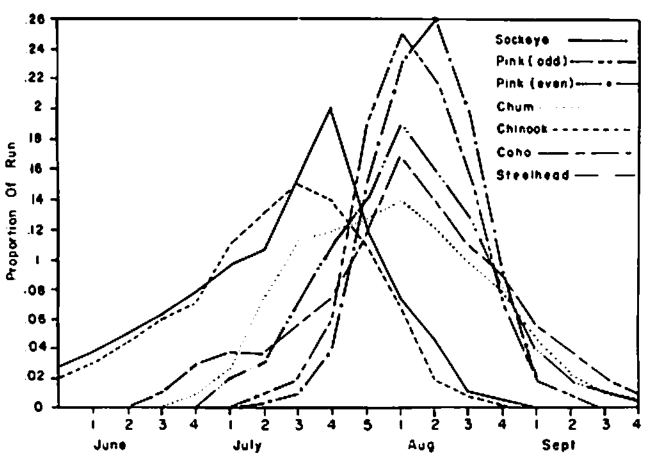

FIG. 2. Proportional run timing of anadromous salmonids through the Skeena River commercial fishery (from unpublished stock timing model, British Columbia Ministry of the Environment, Fish and Wildlife Branch, Vancouver, B.C.)

Probably the outstanding feature of the current management period has been the attention directed toward the mixed stock fisheries problem. The Skeena River chinook salmon and steelhead trout stocks, having migration timing that overlaps with that of sockeye (Fig. 2) (DFO 1985), have experienced very high exploitation rates during sockeye fisheries. In some years Skeena escapements of these species are believed by fishery managers to be well below levels that would maximize production. Although many stocks have been simultaneously harvested in the Skeena sockeye fishery since the start of the commercial fishery, only in the last decade or so have declines in the escapement of incidentally caught stocks been of serious concern to fishery managers. This concern has been echoed, and in some cases initiated, by freshwater sportfishermen and the British Columbia Fish and Wildlife Branch, the agency responsible for steelhead trout management. Management measures taken to alleviate this problem include delaying the start of all net fisheries aimed primarily at harvesting chinook salmon, restricting gillnet mesh size, and closing subareas where the chinook and steelhead catches are high.

Concurrent with the mixed stock problem has been the increasing demands of fishing groups having highly divergent views and preferences on where, how, and by whom Skeena salmon should be caught. This has created considerable pressure on the fishery managers when formulating fishing plans.

Consultation with fishing groups has been recognized as an important step in the preparation of management strategies and fishing plans. However, for an effective fishing plan to emerge, all user groups must understand Skeena stock management objectives and work toward agreement on harvest strategy. Once the fishery begins, managers must make harvesting decisions that are consistent with the guidelines established in the pre-season consultations. This process has been pursued in the Skeena sockeye fishery since the mid-fifties but with mixed results.

Skeena River Salmonid Stocks

Five Pacific salmon (*Oncorhynchus* spp.) and one species of anadromous trout (steelhead, *Salmo gairdneri*) spawn in the Skeena River. Pink (*O. gorbuscha*) and sockeye (*O. nerka*) salmon are the most numerous, followed in order of abundance by coho (*O. kisutch*), chinook (*O. tschawytscha*), and chum (*O. keta*) (DFO 1985). Annual returns of sockeye (1951-1984) range from 1 to 3 million, of which 0.2 to 2 million are harvested. Sockeye spawn in more than 50 lakes, rivers, and streams (Hancock et al. 1983a, 1983b) throughtout the Skeena River watershed. The Babine Lake system is the most important sockeye producer with 90% or more of the spawners (Hancock et al. 1983a, 1983b).

Two management agencies in British Columbia and indirectly one agency in Alaska are involved in the fisheries. The Federal Department of Fisheries and Oceans has responsibility for managing all salmon fisheries in British Columbia. However, responsibility for steelhead rests with the Fisheries Branch of the Province of B.C. (British North America Act 1964). Since the majority of returning Skeena steelhead are caught in the sockeye fishery, federal and provincial agencies must cooperate in managing both steelhead and sockeye stocks. Skeena sockeye are also intercepted in southeast Alaskan fisheries managed by the Alaska Department of Fish and Game. Thus, the U.S. agency's management actions also affect catch, and thus achievement of the objectives of the domestic management agencies in B.C.

The escapement timing of the several species overlaps to varying degrees (see Fig. 2). However, Fig. 2 oversimplifies the situation. In reality, each species curve is comprised of a number of stocks, which may have different life-history characteristics such as migration route and timing and age at maturity. With the exception of the earliest and latest stocks, and given the constraints on fishing techniques and locations, fishery managers have little flexibility in manipulating the timing of fisheries to avoid harvesting non-target stocks.

For management purposes, three sockeye stock aggregates are recognized based on run timing (DFO 1985). The early stocks are primarily destined for the Lakelse and Alastair lake systems, the Nanika River, and small tributaries to Babine Lake. These stocks peak in abundance in the commercial fishing area in late June prior to the start of the commerical fishery in most years. The early run stocks currently constitute about 10% of the Skeena escapement.

The middle timed stock aggregate includes Pinkut, Fulton, and Morrison stocks on Babine Lake. Their peak abundance occurs in mid-July but they dominate the fishery until the end of July. Both Pinkut and Fulton stocks are enhanced by controlled flow spawning channels which were phased into production over the period from the mid 1960's to the early 1970's (McDonald and Hume 1984). The current capacity of the two channels is 200 000 spawners.

The late timed aggregate includes the Babine River and Babine lake spawning stocks which peak in late July or early August.

Fisheries

Three principal fishing groups harvest Skeena River salmon: commercial (gillnet, seine, and troll), sport, and Indian fishermen. Commercial catches occur in eight fishing areas in northern B.C. and southeast Alaska (Fig. 1). The major fishery is conducted in B.C. Statistical Area 4 with smaller fisheries occurring in Areas 3, 5, and 1. In southeast Alaska, Skeena sockeye are primarily intercepted in the Cape Fox and Sumner Strait gillnet fisheries, and the Clarence Strait and Noyes Island seine fisheries (Gazey, unpubl. MS 1983). Very few sockeye are caught in the Skeena troll and sport fisheries.

Retention of sockeye caught by sport fishermen in non-tidal waters is not permitted under present regulations, while in the tidal area, sockeye comprise a small bycatch in a fishery directed primarily at chinook and coho.

In contrast to the sport fishery, the native Indian food fishery targets on sockeye all the way from the coastal approaches to the Skeena, upstream to some of the spawning grounds. Catches average 100 000 fish but have reached 200 000 in some recent years (Kadowaki et al. 1984).

The Management Process

The step-by-step process of managing salmon fisheries must be capable of defining objectives, implementing strategies for their achievement, and evaluating results. The following two sections outline the annual cycle of Skeena salmon management activities, and in-season procedures for executing fishing plans.

The Annual Process

Six major components comprise the annual cycle of activities in the management of the Skeena sockeye fishery (Fig. 3).

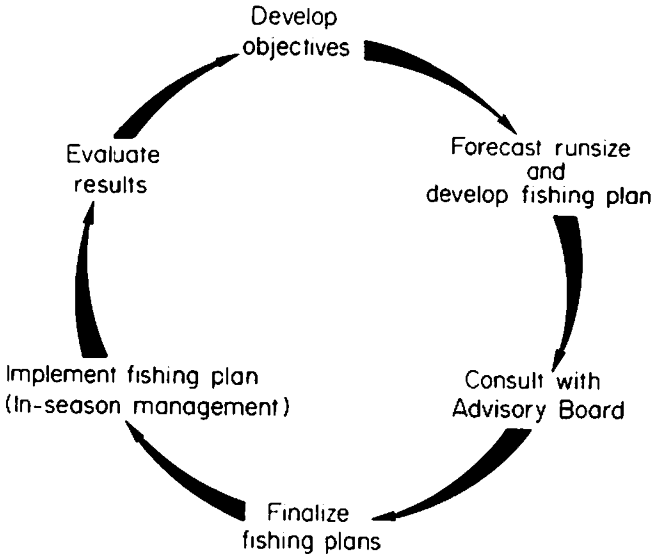

Fig. 3. The annual process for managing the Skeena River sockeye fishery.

Developing objectives

We consider clear management objectives to be essential guidance for those formulating fishing plans. General objectives should give policy direction, while more specific objectives serve as their measurable and practical extensions. For example, the management of fisheries to maximize long-term economic yield is a policy objective, while a target of 900 000 spawners is deemed a measurable specific objective.

The procedure for developing objectives differs from the other components of the fishery management process which are carried out in specified ways and times and linked to the production cycle. Many regional fisheries objectives are developed far from the fishing area, and appear to change very little year to year. This perception can be misleading, however. The priorities assigned to these objectives may change in subtle ways and it is only by examining regulatory actions and through discussions with managers that they are understood.

Within DFO, objectives are developed at the international (Pacific Salmon Treaty 1985), national (Department of Environment 1976, DFO 1982), or regional levels (DFO 1985). In all cases, the primary guiding objectives are the conservation of the resource and the management of stocks to maximize economic and social benefits. However, implementation can vary from arresting the decline in stock diversity (DFO 1982) to ensuring the optimum escapement of all stocks (DFO 1985). Subject to these primary objectives, Indian food fish are the first priority in allocating surpluses. Other objectives are seldom priorized, and some may conflict. Commercial and recreational fisheries are given equal priority after Indian food fisheries and in cases where they compete for the same resource it is not clear how it should be allocated. In another example, the regional 1985 DFO publication of the "Pacific Region Stock Rebuilding Plan" has an overall objective to rebuild salmon stocks (DFO 1985). The lowering of harvest rates in several fisheries is recommended. In the short term, at least, this means less catch, yet it conflicts with another objective from the same report which is to maintain and increase catch in the commerical fishery.

Some of the current objectives driving the Skeena management process can be traced to the early days of the Skeena River Salmon Management Committee. At that time two major objectives guided management actions: (1) rebuild Babine sockeye and (2) maximize the catch. These two objectives eventually culminated in the current escapement target of 0.8 to 0.9 million spawners to the Skeena system. The target was derived from a stock-recruit relationship which suggested the maximum sustainable yield (Shepard and Withler 1958). This escapement target remains one of the few objectives explicitly specified for the Skeena today.

Developing run forecast and fishing plans

There are three methods for forecasting adult returns to the Skeena River: average rate return per spawner, smolt-to-adult survival, and the age 3 to age 4, or age 4 to age 5 ratios. Data from the Babine system are used almost exclusively in forecasting returns. This data set is the most comprehensive of any Skeena sockeye stock and is considered functionally representative of all Skeena stocks since over 90% of the Skeena escapement spawns in the Babine system.

The average rate of return forecast is simply the average number of recruits per spawner for all complete brood years from 1940 to the present. The total spawners for a given brood year are multiplied by this average rate of return to forecast total return. This forecast is then partitioned to the years in which they will return by applying historic age composition data.

Smolt outputs from the Babine system have been estimated by a mark-recapture method since 1961 (Macdonald and Smith 1980). Each year average smolt to adult survival rates are calculated for three periods: all years, most recent 10 years, and most recent 5 years. These values are multiplied by the brood year smolt output to generate a series of run forecasts which are then assigned to the appropriate return year as described above.

The age 3 to age 4 relationship or "sibling" method uses a linear regression to predict age 4 return from age 3 siblings in the previous year. The age 4 to age 5 relationship, conceptually similar to the above, predicts the age 5 return from its age 4 siblings in the previous year. However, instead of using a linear regression relationship, the ratio of the number of age 5 to its age 4 siblings is calculated for all years from 1940 to the present. The average age 5 to age 4 ratio is multiplied by the number of age 4 fish in the previous year to forecast age 5 fish in the current year.

Using the above methods, estimates for each year's return at age 4 and 5 are generated, frequently with wide variability between estimates. A best estimate is chosen by comparing the predicitions using the various forecasting methods with actual returns in past years. This is a subjective process which should be refined analytically.

Given the pre-season run forecast and specific objectives, formulation of the fishing plan is fairly simple. The number of days fishing each week is calculated using historical data to estimate the relationship between run size, effort, e.g., fleet size, and exploitation rate. Since there is no effective means at present of predicting variations in run timing, average timing is assumed. The managers prepare a preliminary report outlining the pre-season forecast and tentative fishing plans. This is distributed to representatives of various interest groups for comments prior to finalizing fishing plans.

Consulting with user groups

The Skeena River Salmon Management Committee remains as the major forum user group input into the management of the Skeena River Fisheries. The Committee, chaired by DFO, is comprised of members from the commercial, sport, and Indian food fisheries. Members are selected by their respective organizations, usually on the basis of knowledge, experience, and gear type affiliation.

The terms of reference of the present Committee are not defined. In practice the Committee advises on the management and enhancement of salmon stocks within the Skeena and adjacent fishing areas. Final authority for management decisions rests with DFO. The committee usually meets two or three times annually: post fishing season (November to December) to review results and give first consideration to plans for the next year's fishery; pre-fishing season (February) to complete fishing plans, and finally; in the fishing season (e.g., second to third week of July) to confirm the expected fishing plan based on an initial assessment of the run size.

Finalizing fishing plans

Following advice from the Committee, fishery managers may modify proposed fishing plans. However, it is often quite difficult to synthesize and apply the advice. Consensus among interest groups on major allocative and other issues is rare, and no formal method has yet been devised to assign weights or values to varied or conflicting advice. Additional factors, such as the catch of Skeena stocks in fisheries which are outside the control of the Committee, such as in southeast Alaska, further confound the development of fishing plans. In any event, managers evaluate the advice as fully as possible before settling on a final fishing plan.

Implementing decisions (in-season management)

In-season management is the process by which actions are implemented during the fishing season to meet the pre-season objectives. It is an iterative decision making process which includes monitoring catch and escapement and achieving weekly harvest rates by manipulating effort i.e., openings, fishing areas, and gear type. Details of in-season management are reviewed in the next section.

Evaluating results

The primary evaluation performed by fishery managers is to determine the effectiveness of management decisions in achieving desired spawning escapements. All fish entering the Babine Lake system are counted through a fence. A large Babine River population spawns between the counting fence and Babine Lake and is estimated by a mark-recapture program. Of the fish that enter the lake, the majority will spawn in the two enhancement facilities where counting fences permit accurate counts to each. Smaller stocks in tributary streams are enumerated by foot and from the air. Lake spawners, which have comprised up to 30% of the run, are calculated by deducting the total number of fish that enter the lake from the combined numbers estimated in the tributaries, Babine River, and the enhancement facilities. The remaining non-Babine systems are surveyed by foot or air to obtain escapement estimates; the accuracy of these counts is unknown.

Annual escapement data are reviewed with the Skeena Management Committee in a post-season meeting. Deviations from pre-season goals and expectations are analyzed to see what prevented attainment of goals, which assumptions proved untenable, and what corrective actions might be appropriate in the future.

THE IN-SEASON PROCESS

In-season management has four major components; (1) data collection, (2) run assessment, (3) decision-making, and (4) implementation. These are discussed below.

Data collection

This includes the following data and observations to assess run strength, composition, and timing.

i) Test fishery

The gillnet test fishery provides a daily in-season estimate of sockeye and pink salmon escaping the fishery into the Skeena River. Fish usually require only a single day to travel from the fishery to the commercial fishing boundary, thus making the test fishery a very effective management tool. Catch per hour indices are regressed against counts at the Babine fence. This has been done over many years to produce the predictive relationship. This relationship is particularly reliable for sockeye because of their predominantly Babine River origin. Despite this high quality calibration, the error in the in-season escapement estimate in recent years has averaged 15% in the period from 1979 to 1984 (Fig. 4). A correction factor accounting for variability in annual mean fish length was incorporated into the relationship prior to the 1985 fishing season (Kadowaki 1985, unpubl. MS). This significantly improved the 1985 estimate (L. Jantz, DFO Prince Rupert, pers. comm.).

ii) Commercial catch

Commercial catches are a second important source of data on run strength and timing. Estimates are made by fishery officers using catch per unit effort (CPUE) and effort (i.e., boat day or set) from the fishing grounds. Catch and CPUE from Area 4, the commerical fishing area closest to the Skeena River, provides the most useful information, while catches from more distant fisheries require more careful interpretation due to uncertainty over constituent stock timing and composition and Skeena sockeye migration routes. For example, although the seine fishery at Noyes Island in southeast Alaska catches significant numbers of Skeena sockeye (Gazey 1983) their proportion in the fishery is likely quite variable. CPUE data in distant fisheries is therefore of little value to the in-season process.

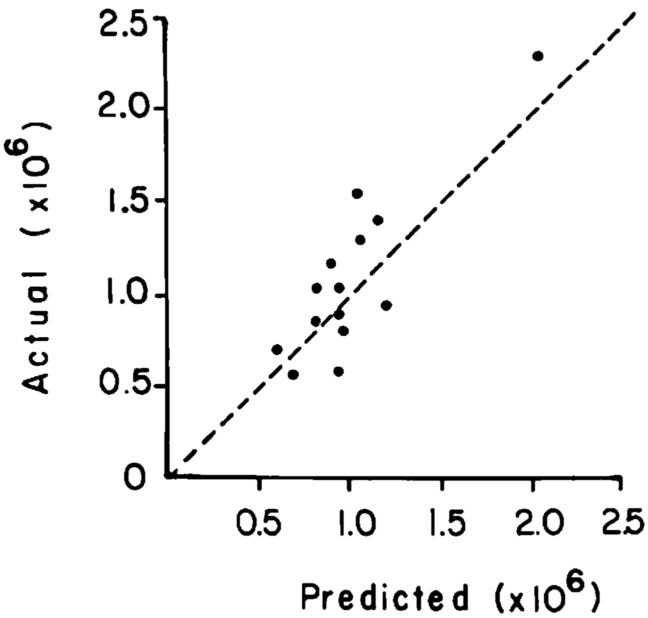

FIG. 4. Actual versus predicted escapements by the Skeena River test fishery 1970–85 (from unpublished data files of the Department of Fisheries and Oceans, Prince Rupert, B.C.).

iii) Indian food fishery

The coastal waters Indian food fishery occurs during commecial fishery closures. It can be a useful information source but requires careful interpretation. The fleet of 10 to 40 Indian vessels can attain very high CPUE's on medium-sized runs since they have unhindered access to preferred fishing areas. They also usually fish on preferred tides causing further inflation of CPUE estimates.

iv) Biological sampling

The test fishery and commercial catches are sampled for age, size, and sex composition. These attributes are most important in post-season assessment and pre-season forecasting, but they also provide in-season clues to the strenght and timing of the run to come. For example, age 5 sockeye almost always have have an earlier mean date of return than age 4's and males tend to have an earlier mean date of return than females (Withler 1945). Further analysis is required before the reliability of these tendencies can be quantified.

v) Environmental variables

All catch data must be interpreted in terms of environmental factors. Tide height and stage, wind speed and direction, sunlight, and rainfall can all affect catchability. General trends in climatic and oceanographic conditons probably constitute significant influences but have not yet been factored into our analyses.

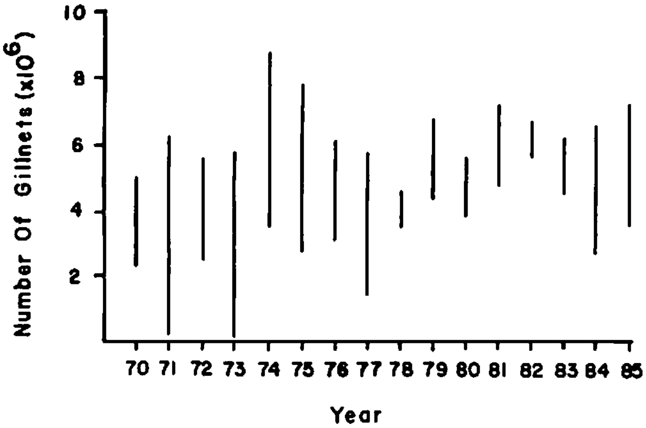

FIG. 5. Range of daily gillnet fleet size for July, 1970–85 (from unpublished data files of the Department of Fisheries and Oceans, Prince Rupert, B.C.).

vi) Fleet size and distribution

Fleet size can vary greatly (Fig. 5). Good fishing in other areas can draw boats away while poor fishing or closures elsewhere could divert them to the Skeena. Increases in gear generally lead to higher exploitation rates and must be taken into account when setting fishing times. The impacts of fleet distribution are evaluated subjectively based upon the experience of fishery managers and their knowledge of historical response patterns.

Fishery managers weight the data from all these sources to assist them in making in-season management decisions (Table 1).

TABLE 1. Information inputs and their priority and uncertainty for in-season management as determined by fishery managers.

Input	Priority	Uncertainty
Test fishery	high	low
Commercial catch	high	low
Indian food catch	low	high
Biological sampling	low	high
Environmental variables	moderate	moderate
Fleet distribution	moderate	moderate

Run assessment

Fisheries managers carefully monitor the runs as they progress and when needed they modify expectations and fishing plans accordingly. A fishery management model (Fig. 6) similar to the one proposed by Walters and Buckingham (1975) represents the in-season control system for predicting run size and evaluating the impacts of alternate harvest strategies on catch and escapement. The model utilizes an iterative process which uses catch and escapement from the current week to forecast fishing effort and run size for the next week and the total run to come. The variances of the pre-season and in-season run estimates are weighted to minimize the variance of the total run estimate. The accuracy of the pre-season forecast is highly variable (Fig. 7) and once in-season information is available the pre-season estimate becomes progressively less important (Fig. 8).

The weekly escapement target proposed in the pre-season fishing plan is also modified at intervals after the season

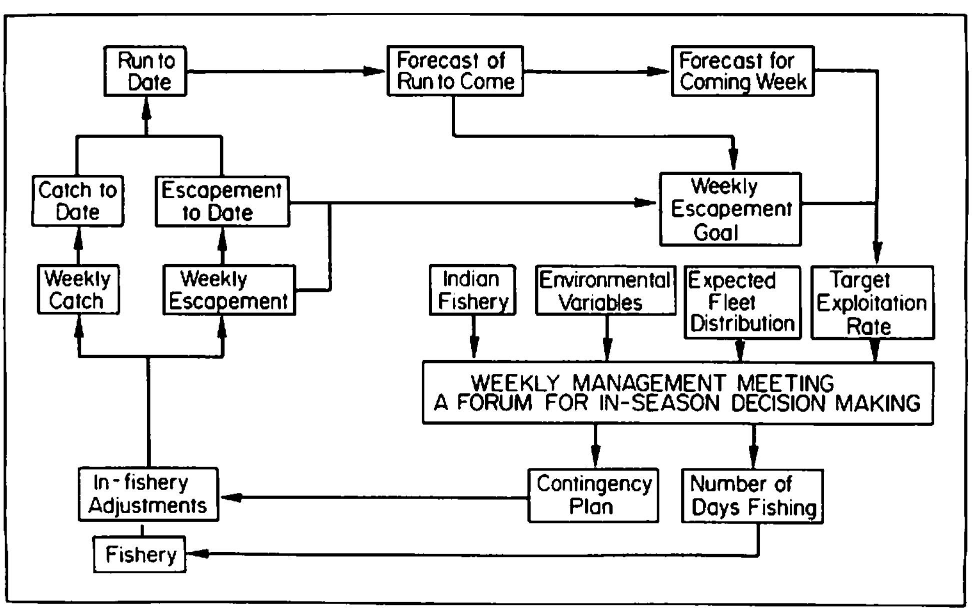

FIG. 6. The in-season management process for the Skeena River sockeye fishery.

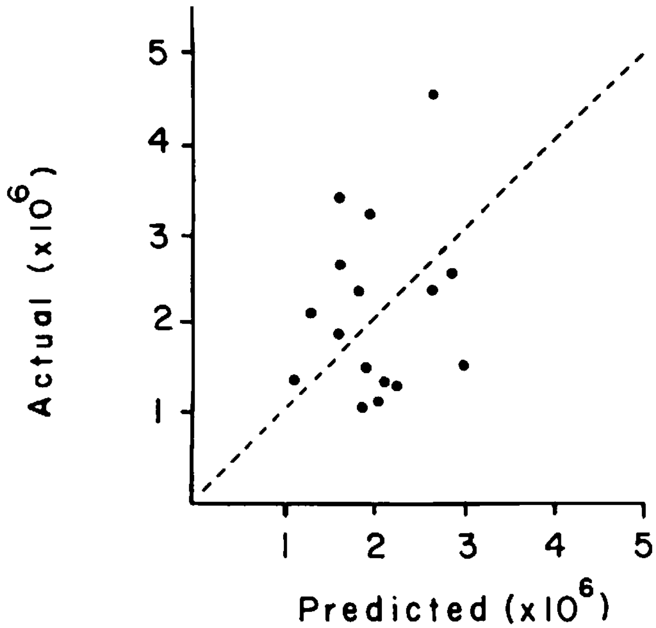

FIG. 7. Actual versus forecasted (pre-season) run sizes of Skeena sockeye 1970–85 (from unpublished data files of the Department of Fisheries and Oceans, Prince Rupert, B.C.).

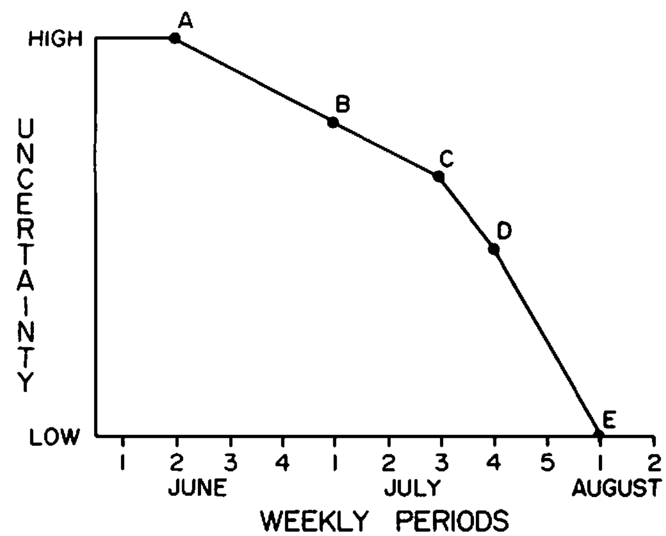

FIG. 8. Run size uncertainty in the in-season management of Skeena River sockeye: A — test fishery begins, B — commercial fishery begins, c — peak of run observed, D — peak confirmed, E — most of run accounted for.

begins according to the escapement to date and the run still expected. In years of large returns (>2.0 million), and assuming a 4 day per week fishery, this modification is designed to maintain weekly harvest rates at no more than 60%. This ensures that some of the less productive stocks are maintained although not necessarily at maximum sustained yield levels.

The in-season decision making process is driven by the rate of fishery exploitation required to produce the desired spawning escapement. Measurement error and uncertainties in the relationships between indices and actual abundance fuel discussion in the decision making step.

Decision-making

Deciding when and how long to allow fishing is very difficult, and managers are typically faced with a variety of uncertain biological and non-biological data on which to base their decision. On the Skeena, a group decision-making process attempts to reconcile uncertainties and evaluate the various inputs to arrive at the best decision.

Management meetings are held almost daily and are attended by key DFO personnel (Table 2) to: (1) decide on the fishing pattern for the following week and (2) determine if in-fishery adjustments to seasonal plans are warranted.

TABLE 2. Participants and their roles in the in-season decision-making process.

Participant	Role
1) District supervisor	— the senior fishery officer in the District, acts as chairman.
2) Sub-district officer	— fishery officer in charge of the fishing area, has the legal authority to regulate fisheries and is usually most familiar with the actual prosecution of the fishery. He provides data on current and historical catch and effort patterns.
3) Management biologist	— an advisor to the fishery officer, responsible for stock and fishery assessment. This involves the analysis of catch and escapement data and projections of the run to come.
4) Senior management biologist	— ensure consistency in stock and fishery assessment between fishing areas. Not always present at routine management meetings but is usually present for critical and very difficult decisions to lend his experience and expertise.
5) Area manager	— has final authority at the field level for all fishing plans. Attends crucial meetings but reviews all decisions before they are implemented to ensure consistency with objectives.

Prior to the meeting each participant decides how much weight should be assigned to specific factors. The fishery officer and management biologist outline their initial position as to the appropriate management decision and explain their rationale for the relative weights they have assigned to the available information. Colleagues discuss these positions and may offer views of their own. More discussion occurs if the positions and the emphases differ. Differences are likely to occur because: (1) regional objectives are open to differing interpretations, (2) there are contrasting perspectives on acceptable risk, (3) there are differing gear expections, and so on. This discussion usually produces a decision supported by all participants. It is very much like a negotiation but rather than being adversative, it usually brings cooperating individuals to a shared decision.

Implementation (regulatory action)

Fishery officers promulgate regulations for the commercial, sport, and Indian fisheries and are responsible for directing and enforcing in-season management decisions. Their major regulatory tools are fishing time, area, and gear. The commercial fishing areas are subdivided into management units and, under the authority of the fishery officers, they are opened and closed to regulate the fisheries. Typically, fishing areas are open for a specified gear type and time. For instance, net and troll gear openings generally vary from 24 to 96 h weekly, over an 8-wk period. However, in offshore fishing areas trolling may continue 7 days per week until a season ending date or a catch ceiling is reached. Sport fish regulations are usually developed a year in advance and seldom adjusted. The Indian food fishery is regulated by permits which prescribe gear, area, and time. In the coastal area they are issued for specified days throughout the fishing season upon request.

Discussion

Effective in-season Skeena fishery management requires well defined objectives specified in advance, and rapid digestion and sythesis of a broad spectrum of emerging information. If this process operates well, good decisions on fishing gear, times, and areas can, and usually do result. Conversely, if objectives are vague and data are incomplete or uncertain, it becomes difficult or impossible to create an effective regulatory regime. For instance, in recent years unclear harvesting priorities and uncertain test fishery interpretations have resulted in underexploitation of sockeye produced in the Babine enhancement facilities. Thus, significant harvests were foregone. We also believe that rigid adherence to traditional fishing methods have at times contributed to overexploitation of several less resilient stocks (Kadowaki et al. 1984).

Defining Objectives

The Advisory Committee on Marine Research and Resources (ACMRR 1980) stressed the importance of considering fisheries management as a coordinated system which progresses logically from defining objectives to evaluating results. A prominent feature of Skeena River sockeye management (and Pacific salmon fisheries management, in general) is a hierarchical structure for decision-making (Peterman et al. 1978). Consequently, it should be possible to trace historic in-season management decisions back through the decision-making process to the pre-season objectives which generated them and learn more of past decision-making. Unfortunately, the linkages are often found to be tenuous or unclear, suggesting that no specific objectives existed. In the absence of this historic information, and the vagueness of some contemporary objectives, it has been enormously difficult to settle on the most appropriate management actions, and the chances of making poor decisions and putting the stocks at risk are greatly increased.

Objectives which have been documented have not always been explicit or priorized so most suitable management responses can only be generally inferred from past records and experiences. This frustrates managers and exacerbates difficulties in reconciling multiple objectives, many of which conflict (Peterman et al. 1978).

Multi-attribute utility theory (MAUT) has been suggested as an objective and quantitative technique to resolve multiple objective problems such as those on the Skeena. Walters and Hilborn (1977) and Keeney (1977) applied this technique to evaluate multiple objectives of the Skeena River salmon fishery. The results, as noted by Healey (1984), did not attract much attention from fishery managers. This could be partly due to the preliminary nature of the findings, but a more serious problem may be uncertainty of some user groups as to the rationale and wisdom of particular management objectives. In any event, when the objectives are clearly outlined and carefully priorized, the fishery managers decision making should be relatively straight forward.

Ideally, explicit and priorized biological and social management policy objectives would be reached through cooperative DFO user group dialogue. Once in place, local management, with input from local users, could move directly to the required specific objectives.

Coping With Uncertainties

Biological uncertainty is a most pervasive factor in fisheries management, and effectiveness in dealing with this uncertainty and making suitable harvesting decisions is one measure of management's success. Sissenwine (1981) has suggested various methods of minimizing uncertainty, and such actions as improving stock abundance models and designing efficient fishing regimes should be done where possible.

Uncertainty which arises because of unknown fleet size, test fishery performance, or dubious pre-season forecasting obviously compounds management difficulty and heightens risk to the stocks. In our experience, the weekly management meeting provides the best forum for discussing the uncertainties and assessing the risk associated with various courses of action.

The management meetings necessarily involve a good deal of subjective rather than analytical decision making. For example, in recent years the test fishery has consistently underestimated the sockeye escapement. Prior to 1985, this was thought to result because fish were becoming smaller and fewer were being caught in the test net. This subjective reasoning caused managers to lose faith in the test fishing estimates in favor of such measures as total catch and CPUE. In 1985, the suspected relationship between fish size and test net catches was proven and quantified and the test fishery immediately regained its earlier favor as a prime management tool.

Since participants in the management meeting are likely to assign different levels of uncertainty and accept different levels of risk in situations, we believe that our "negotiation process" is an important factor in reaching satisfactory conclusions. In particular, it seemed effective in achieving both social or allocative, and escapement goals. It could, however, be strengthened further and made more understandable to user groups and interested managers elsewhere. Required is an explicit statement of the criteria used in making management decisions, and rigorous documentation of both analytical and subjective judgements (Wilimovsky 1985). Predicted and actual outcomes can then be compared and the performance of the decision-making process evaluated and fine tuned. This would be similar to the "clock work" management approach currently used in the Johnstone Strait chum fishery (Johnstone Strait-Fraser River Chum Advisors 1985, Nanaimo, B.C. unpublished). This plan sets rules on a weekly basis which are agreed to prior to the season and which drive the decision making process.

Conclusion

Management of the Skeena River sockeye fishery has evolved into an intricate hierarchical decision-making structure. A group decision-making process usually copes effectively with uncertainties when making in-season decisions. Defining the set of decision criteria and documenting value judgements would improve the process. The lack of explicit objectives and goals, however, inhibits the analysis of management alternatives and impedes the evaluation of management performance. A detailed "clock-work" management plan could be used to document decision criteria and make the process more understandable to fishing groups.

References

ADVISORY COMMITTEE ON MARINE RESEARCH AND RESOURCES (ACMRR(FAO)). 1980. Report of the ACMRR working party on the scientific basis of determining management measures. Hong Kong, 10-15 December, 1979. FAO Fish. Rep. (236): 149 p.

ARO, K. V. 1961. Summary of salmon enumeration and sample data, Babine River counting weir, 1946-1960. Fish. Res. Board Can. MS Rep. 708: 63 p.

CARROTHERS, W. A. 1941. The British Columbia fisheries. University of Toronto Press, Toronto, Ont.

DEPARTMENT OF ENVIRONMENT, FISHERIES AND MARINE SERVICE. 1976. Policy for Canada's commerical fisheries. Department of Environment. Ottawa. Ont. 70 p.

DEPARTMENT OF FISHERIES AND OCEANS. 1982. Pacific and Feshwater fisheries planning overview document 1982-1986. Department of Fisheries and Oceans, Ottawa, Ont. 92 p.

1985. Pacific region salmon resource management plan. Discussion draft: Volume II. Appendices. Department of Fisheries and Oceans, Vancouver, B.C.

DEPARTMENT OF MARINE AND FISHERIES. 1905. Thirty-eighth annual report. Department of Marine and Fisheries, Ottawa, Canada. 370 p.

1907. Fortieth annual report. Department of Marine and Fisheries, Ottawa, Canada. 390 p.

DEPARTMENT OF THE NAVAL SERVICE. 1917. Fiftieth annual report. Department of the Naval Service, Ottawa, Canada. 434 p.

GAZEY, W. J. 1983. Appendix 1. Interception estimates. *In* W. J. Gazey and D. A. Birdsall [ed.] Design and execution of a stock interception study. Unpubl. Rep. by LGL and ESSA Environmental and Social Systems Analyst Ltd., for Fisheries and Oceans, Canada.

HANCOCK, M. J., A. J. LEANEY-EAST, AND D. E. MARSHALL. 1983a. Catalogue of salmon streams and spawning escapements of Statistical Area 4.

1983b. Catalogue of salmon streams and spawning escapements of Statistical Area 4 (Upper Skeena River). Can. Data Rep. Fish. Aquat. Sci. 394: 324 p.

HEALEY, M. C. 1984. Multiattribute analysis and the concept of optimum yield. Can. J. Fish. Aquat. Sci. 41: 1393-1406.

HILBORN, R., AND R. M. PETERMAN. 1977. Changing management objectives. *In* D. V. Ellis [ed.] Pacific salmon management for people. Western Geographical Series, Vol. 13. University of Victoria, Victoria, B.C.

HILBORN, R., AND C. J. WALTERS. 1977. Differing goals of salmon management on the Skeena River. J. Fish. Res. Board Can. 34: 64-72.

JOHNSON, W. E. 1956. On the distribution of young sockeye salmon (*Oncorhynchus nerka*) in Babine and Nilkitkwa lakes, B.C. J. Fish. Res. Board Can. 13: 695-708.

1958. Density and distribution of young sockeye salmon (*Oncorhynchus nerka*) throughout a multi-basin lake system. J. Fish. Res. Board Can. 15: 961-987.

1961. Aspects of the ecology of a pelagic, zooplankton eating fish. Verh. Int. Limnol. 14: 727-731.

KADOWAKI, R., L. JANTZ, AND P. E. SPROUT. 1984. A review of the 1983 commercial salmon net fisheries in Northern B.C. (Areas 3, 4, and 5): catch, escapement, and management strategies. Can. MS Rep. Fish. Aquat. Sci. 1765: 47 p.

KEENEY, R. L. 1977. A utility function for examining a policy affecting salmon on the Skeena River. J. Fish. Res. Board Can. 34: 49-63.

LARKIN, P. A., AND J. MCDONALD. 1968. Factors in the population biology of the sockeye salmon of the Skeena River. J. Anim. Ecol. 37: 229-258.

MCDONALD, J., AND J. M. HUME. 1984. Babine Lake sockeye salmon (*Oncorhynchus nerka*) enhancement program: testing some major assumptions. Can. J. Fish. Aquat. Sci. 41: 70-92.

MACDONALD, P. D. M., AND H. D. SMITH. 1980. Mark-recapture estimation of salmon smolt runs. Biometrics 36: 401-418.

MILNE, D. J. 1955. The Skeena River salmon fishery, with special reference to sockeye salmon. J. Fish. Res. Board Can. 12: 451-485.

PETERMAN, R. M., C. J. WALTERS, AND R. HILBORN. 1978. Pacific salmon management, p. 183-214. *In* C. S. Holling [ed.] Adaptive environmental assessment and management. John Wiley and Sons, Chichester, England and New York, NY.

PRITCHARD, A. L. 1949. The Skeena River salmon investigation. Can. Geogr. J. 39(2): 60-67.

SHEPARD, M. P., AND F. C. WITHLER. 1958. Spawning stock size and resultant production for Skeena River sockeye. J. Fish. Res. Board Can. 15: 1007-1025.

SISSENWINE, M. P. 1984. The uncertain environment of fishery scientists and managers. Mar. Resour. Econ. 1(1): 1-30.

SKEENA RIVER SALMON MANAGEMENT COMMITTEE. 1956. Annual report for 1955. 26 p.

TAKAGI, K., AND H. D. SMITH. 1973. Timing and rate of migration of Babine sockeye stocks through the Skeena and Babine rivers. Fish. Res. Board Can. Tech. Rep. 419: 61 p.

WALTERS, C. J., AND S. L. BUCKINGHAM. 1975. A control system for intraseason salmon management. International Institute for Applied System Analysis conference series CP-75-2.

WEST, C. J. 1978. A review of the Babine Lake development project, 1967-1977. Fish. Mar. Serv. Can. Tech. Rep. 812: 105 p.

WILIMOVSKY, N. J. 1985. The need for formalization of decision algorithms and risk levels in fishery research and management. Can. J. Fish. Aquat. Sci. 42 (Suppl. 1): 258-262.

WITHLER, F. C. 1945. An investigation of the distribution of age groups and sexes of sockeye salmon throughout the fishing season at the Skeena River. M.S. in the Department of Zoology Library, University of British Columbia, Vancouver, B.C.