AN ECONOMIC EVALUATION OF COLUMBIA RIVER ANADROMOUS FISH PROGRAMS

by

Jack Arthur Richards

Working Paper No. 17

February 1969

BUREAU OF COMMERCIAL FISHERIES
DIVISION OF ECONOMIC RESEARCH

WORKING PAPER SERIES

1. An Application of an Investment Model to Channel Catfish Farming by R. Thompson and F. Mange.

2. The Development of Catfish as a Farm Crop and an Estimation of Its Economic Adaptability to Radiation Processing by D. Nash and M. Miller.

3. Design Study: An Optimum Fishing Vessel for Georges Bank Groundfish Fishery by A. Sokoloski (Project Monitor).

4. The Relation between Vessel Subsidy Percentages and the Rate of Return on Investment for Various Technologies and Scale Levels: The Haddock Fishery by D. Nash, A. Sokoloski and F. Bell (Project Monitors).

5. An Economic Justification for Recommended Legislative Changes in the 1964 Fishing Fleet Improvement Act by F. Bell, E. Carlson, D. Nash and A. Sokoloski.

6. The Economic Impact of Current Fisheries Management Policy on the Commercial Fishing Industry of the Upper Great Lakes by D. Cleary.

7. Cost and Earnings in the Boston Large Trawler Fleet by B. Noetzel and V. Norton.

8. Some Elements of An Evaluation of the Effects of Legal Factors on the Utilization of Fishery Resources by A. Sokoloski.

9. A Report on the Economics of Polish Factory Trawlers and Freezer Trawlers, by B. Noetzel.

10. An Inventory of Demand Equations for Fishery Products by D. Nash and F. Bell.

11. Industry Analysis of West Coast Flounder and Sole Products and an Estimation of Its Economic Adaptability to Radiation Processing by D. Nash and M. Miller.

12. Bio-Economic Model of a Fishery (Primarily Demersal) by E. Carlson.

13. The Factors behind the Different Growth Rates of U. S. Fisheries by F. Bell.

(continued on inside back cover)

AN ECONOMIC EVALUATION OF COLUMBIA RIVER ANADROMOUS FISH PROGRAMS

By

Jack Arthur Richards
Division of Economic Research
Bureau of Commercial Fisheries

ABSTRACT

It is important to avoid misallocation of resources for either private or public production. Misallocation in public programs can result from failure to employ resources in high priority uses or to eliminate programs that have become obsolete. This study evaluates the benefits and costs of the continuing public program aimed at maintaining Columbia River anadromous fish runs.

The hydroelectric power potential of the Columbia River exceeds that of all other United States river basins. Irrigation, flood control, navigation and recreation are other important products that are often complementary with dam construction. Anadromous fish, however, compete with products requiring construction of dams that blockade essential fish migration routes. Costly passage facilities at the dams prevent total blockage of the lower

river and supplemental projects such as fish hatcheries at least partially replace lost productivity.

Benefits from the available supply of Columbia River anadromous fish result from commercial, sport and Indian fishing. These benefits cannot be directly measured through market prices, however, and thus must be estimated.

The cost of regulated inefficiency was used to estimate net benefits from commercially-caught fish. Regulated inefficiency results from management policies that equate physical supply capability with market demand through regulated increases in fishing costs.

Transfer costs were used as a proxy for nonexistent market prices to estimate the value of sport-caught fish. Revenue maximization using this estimating method implies that some sport fishermen will be excluded. Thus, an assumed transfer from sport to commercial catch was also taken into account.

Past, present and future program costs and associated benefits indicate that the effort to preserve Columbia River anadromous fish probably could not have been justified by economic criteria in the 1930's when major costs first began. However, the share of this program remaining in 1965 could be justified on economic grounds if traditional capital costs were used and where alternative investment possibilities were not considered.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

LIST OF FIGURES

An Economic Evaluation of Columbia River Anadromous Fish Programs [1]

CHAPTER I

INTRODUCTION

In our society where much of our national production occurs in the public sector, it is just as important to continually improve the allocation of resources within the public sector as it is within the private sector. To do this, it is necessary to evaluate the results of public programs.

Charles Shultz, Director, Bureau of the Budget, has indicated two major questions that need to be posed in evaluating public programs. First, does this program merit continued public support:

> "We spend for some purpose--to provide directly an item or service which meets national objectives, or to augment private or state and local spending in desired directions. But each expenditure program must be judged on its own merits . . . (60, p. 61)

and second, if continued public support is justified, how can objectives be attained at minimum cost to avoid misallocation of public resources:

> ". . . the level of national output and national welfare we achieve, . . . will depend in an important way upon how well we can make individual program decisions about Federal spending. We can misuse our national resources: by failing to employ Federal spending in areas where it can best achieve important national purposes; and on the other side of the coin,

1/ Dissertation completed June 1968

> by using resources in the Federal sector inefficiently or to keep obsolete and low priority programs intact." (60, p. 62)

Funds committed to each public program need to be compared in some way to the benefits associated with these expenditures. Relating benefits to costs provides a common denominator for comparing the merits of particular projects, segments of projects, or alternative projects provided similar techniques are used in evaluation. The existence of extra market values may make this more difficult, but does not reduce the need for this evaluation.

Using economic criteria of consumer welfare as expressed in actual or estimated market prices, and given past decisions, a framework can be established for future policy formulation. This includes determining the level of investment in the program and in component subprograms. Ideally, all programs would be completely planned from the start with economic and social objectives specified. In the past, and perhaps to a lesser extent at present, this often has not been attempted. In any case, where programs stretch over many years, new data and new methods require reappraisal of public expenditure programs.

The purpose of this study is to develop a framework for evaluating continuing natural resource development programs in order to encompass new information and new programming and planning techniques. This requires reexamination of objectives and a detailed appraisal of past results and future plans. Based on this information, these programs can be examined for consistency with national objectives and efficient resource use.

Methodology

An economic evaluation of Columbia River anadromous fish programs is considered as a case study of the effectiveness of a Government expenditure program. The Columbia River anadromous fishery combines the productivity of inland water with the ocean to provide food, recreation, and an important source of income to both the regional and national economy. This study is an attempt to compare the value contributed by these fish resources with the expenditures required to prevent their destruction through river basin development for hydroelectric power and uses complementary with power generation.

The cumulative effect of dams and economic development of the Columbia River Basin has threatened the continued existence of anadromous fish. Dams retard upstream migration, block access to upstream spawning areas, and flood downstream spawning areas. Pools behind the dams affect temperature patterns and create conditions that favor the growth of fish species that prey on young salmon. Probably most important of all is the loss of young downstream migrants during their voyage to the ocean. The Federal

Government has cooperated with state and private agencies to initiate programs to develop the means for coexistence of dams and anadromous fish.

The economic problem is to determine if society places a sufficiently high value on the products of these fish resources to willingly continue to pay the cost of developing the necessary technology for coexistence of anadromous fish and competitive water uses. Our economic system is committed to the principle of resource allocation based primarily on the desires of consumers. Thus, it is desirable to develop a basis for determining the willingness of society to pay the cost of facilities and research necessary for the continued coexistence of these anadromous fish resources and river basin development.

The fundamental goal of the present study is to use economic criteria of maximum consumer welfare as expressed by actual or estimated market prices to evaluate the merits of past programs and to indicate the directions and appropriate level of future public expenditures.

Economic Importance of Columbia River

The economy of the Pacific Northwest is closely related to development of the Columbia River Basin. Agriculture, lumber, and fishing constitute a greater percentage of economic activity in this area than in most other regions of the nation. Columbia River spawned salmon make an important contribution to the sport and commercial catches from Oregon to Alaska, and at least a minor contribution to the California commercial catch. In addition, a major share of the British Columbia, Canada, catch also can be traced to Columbia River origin. Commercial, sport, and Indian fishing occur in the Columbia River and its tributaries, including a valuable sport fishery in Idaho.

The Columbia River Basin has the greatest hydroelectric potential of any area in the United States (53, vol. 2, p. 1-2). This region, with wide interior plateaus east of the Cascades that are often semi-arid or desert, receives most of its precipitation at high elevations during the winter. Although the vast water resources of the region come during the wrong season or in the wrong areas to be used directly for crop production, much of this water falls at high elevations and traverses the distance to the ocean through excellent sites for the production of hydroelectric power. Because of this, many dams have been built. Dams also can provide navigation for commerce, irrigation for agriculture, flood and water control for urban development, and recreational facilities for leisure time.

Dams often result in complementary uses of water resources, particularly when development of an entire river basin is considered. But this is usually not the case for anadromous fish. Dams impede, and in some cases prevent, movement of fish in the river, and result in serious deterioration of fish habitat. These detrimental changes in the environment for anadromous fish have led to serious conflicts between fishing interests and those desiring development of the river for other uses.

The Shrinking River

The area of the Columbia River Basin still available for anadromous fish can be seen in Figure 1. Over 500 miles of the upper Columbia River plus many miles of tributaries were lost as spawning and growing areas for anadromous fish with the construction of the Grand Coulee Dam in 1941. This loss was increased in 1955 with construction of the impassable Chief Joseph. Over 50 percent of the Snake River is no longer inhabited by anadromous fish (49, p. 1-3, 1965). Passage facilities were provided at Brownlee Dam, but failed to function adequately and were abandoned in 1963. Spawners are now being hauled around the Oxbow Dam that is downstream on the Snake River from Brownlee Dam. The success of this venture is questionable.

The result of these and other dams further downstream is a shrinking as well as a changing environment for anadromous fish. With full river development, the mainstream Columbia and many of

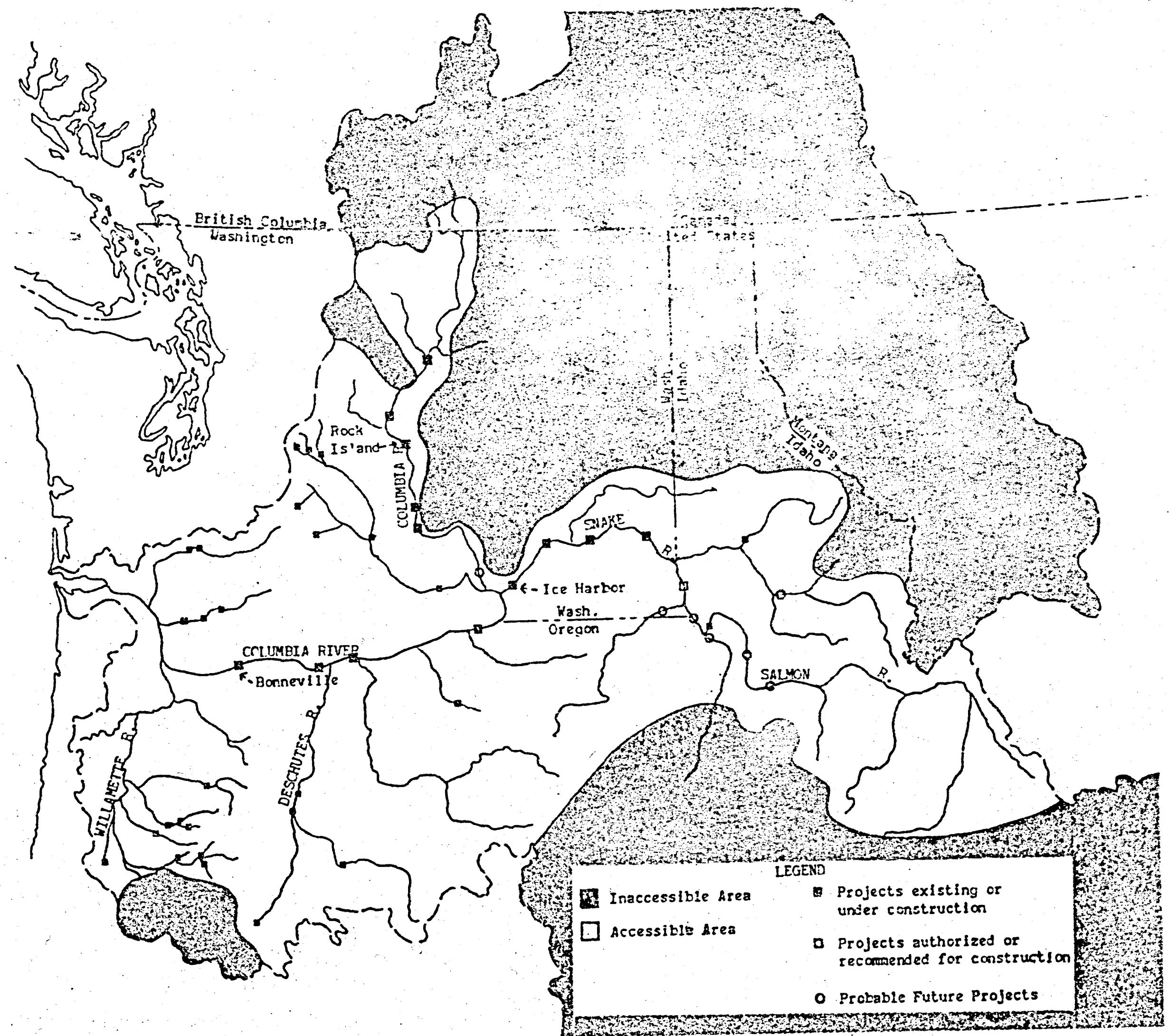


Figure 1. Area of Columbia River Basin accessible to anadromous fish (1967) and existing or proposed dams with fish-passage facilities.

its tributaries will become essentially a series of pools formed behind dams. These pools, with characteristics of neither a lake nor a stream, are detrimental to the environment of anadromous fish in a number of ways. Only 50 miles of the mainstream Columbia River will remain that is not directly affected after dams, now under construction or authorized, are completed and this remaining area is threatened by a potential project.

The Changing Fish Habitat

Anadromous fish are hatched in fresh water, migrate to the ocean for the growing stage of their life cycle, and return to the fresh water of their birth for spawning. Thus, for natural propagation, it is necessary that these fish have freedom to migrate in the river. Construction of dams for power and other uses impedes the migration of anadromous fish and results in detrimental changes in fish environment in the river. 1/

The effect of dams has important consequences for both upstream and downstream migration. Particularly detrimental is the downstream loss at dams and in the reservoirs behind the dams.

1/ For a complete discussion of the effects of dam construction and economic development on upstream and downstream fish migration, see: Salmon Research and Hydroelectric Power Development, Bulletin No. 114, by J. R. Brett, Fisheries Research Board of Canada, Ottawa, 1957, p. 3-4.

Loss of young fish passing through the power generating system, abrasions on spillway surfaces, turbulence at the base of the spill, and destruction by predators in the reservoirs are important examples. Reservoirs provide favorable conditions for the growth of predators that feed on young salmon and steelhead. Stream flow and temperature in these pools retard the natural passage of the young downstream migrant, subjecting them to additional losses and increasing the likelihood of disease.

The cumulative effect of loss in power-generating turbines is especially serious where a number of dams must be navigated. A three-year test at McNary Dam in the late 1950's demonstrated that the most serious loss of young fish occurred through the turbine system. An estimated 9 to 13 percent loss was found for each instance where movement occurred through the turbines, compared to 1 or 2 percent through the relatively harmless spillways (59). If the effect of a single dam is assumed to be 10 percent, the cumulative effect of passage through the turbines of 10 such dams would be a reduction of 65.13 percent of the young fish. The effects of dam construction for anadromous has been summarized as follows:

> "Starting in the 1930's a series of multipurpose dams for flood control, hydroelectric power, and navigation were con-constructed on the mainstream Columbia River, and with completion of the Wells Dam, the Columbia River will be a series of pools from tidewater to the Canadian border except for a 50 mile stretch below Priest Rapids Dam. So instead of a normal-flowing river, there is a series of pools that

> interfere with both upstream and downstream migration of salmon. In addition, the dams which form those pools delay passage of the upstream migrants and kill many of the young. The pools also have changed the temperature patterns of the river, generally raising temperatures, thus decreasing further the suitability of the river for salmon and steelhead production. Dams now under construction or proposed for the mainstream Snake River will change it also into a series of pools, with all of the attendant problems of successful fish passage and survival." (78, p. 6).

Problems facing anadromous fish are not entirely the result of the construction of dams, nor are all influences of dams on anadromous fish necessarily undesirable. Anadromous fish runs have fallen in Alaska where few dams have been constructed. Salmon runs on the Sacramento River in California may have increased due to improved stream and temperature control resulting from the construction of the Shasta Dam. In the Columbia River, however, most of the deterioration in fish habitat can be associated with dam construction and corresponding economic development.

This study considers only the cost of programs to cancel the negative effect of dam construction and maintain or improve natural productivity of these fish resources or supplement this through artificial propagation. Other costs, such as prevention of water pollution, are not included.

General Framework of Study

Figure 2, which shows a production surface relating physical yield in benefits as a function of fishing effort (sport and commercial) and programs to mitigate or enhance fish productivity, sets a general framework of reference for the study.

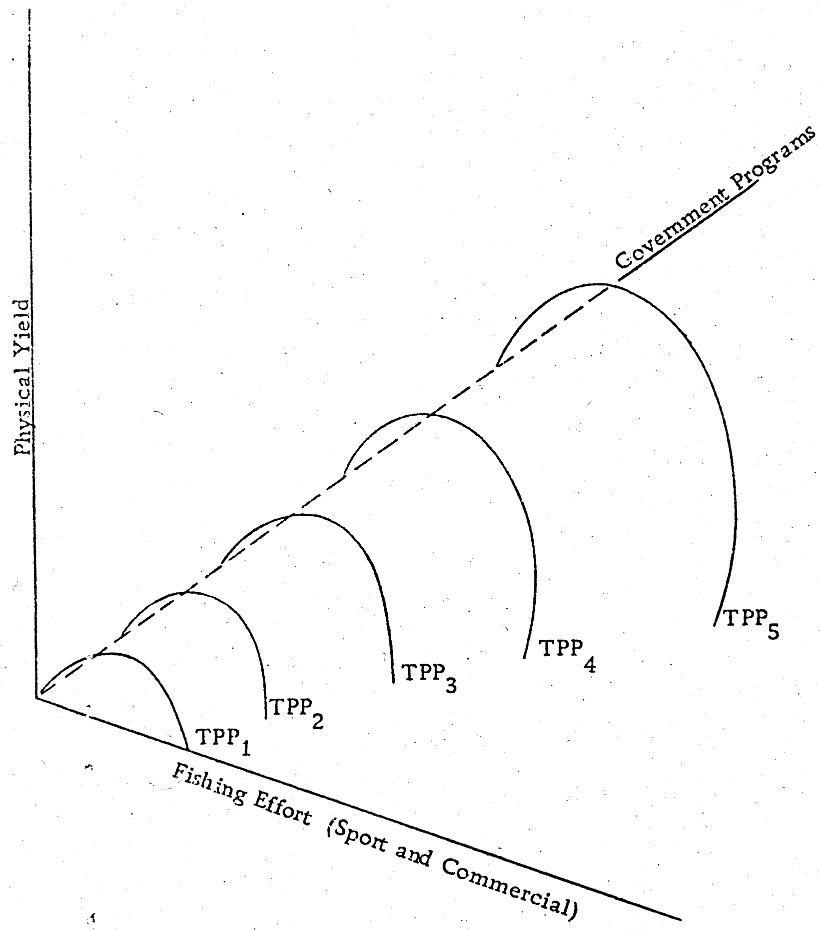


Figure 2. Relationship of yield, fishing effort, and government programs in physical terms.

With any given level and type of expenditures to improve or maintain productivity of the fishery, the resulting yield (benefits) will depend on natural productive capabilities and on sport and commercial fishing effort. The height of the surface above the horizontal plane depends on the size and type of public expenditure programs and the interaction of this expenditure with natural productivity and sport and commercial effort. 2/

Investment in fish passage facilities at the dams, for example, preserves only part of the fish run. This possibility gives the production surface shown in Figure 2 an indeterminant shape depending on natural fish productivity given the type and magnitude of public programs and the extent natural productivity is supplemented through hatcheries and similar facilities. Figure 2 illustrates the case where over-all program results are expected to increase fish productivity.

Investment also takes place in the reproductive stock of the fishery. The level of current use is related to future productive capacity of the resource up to some limit imposed by the fish habitat of the river basin. Investment in supplemental or improved natural productive capacity in one area of the river basin may also

---

2/ Although funds are also provided by private and public utility firms, for simplicity these are combined with public expenditure.

be used to offset lost natural productivity in another area. Investment in natural productivity of the resource (i.e., catch to escapement ratio) is also reflected in the height of the production surface.

Physical production functions are based on expected long-run biological responses. Fishing effort is simply one additional form of predation on fishing stocks--in this case by man. (For more detail on these physical relationships, see 19, p. 12-17, and 55). The Columbia River case is unique primarily because of the importance of investment in supplemental facilities as illustrated in Figure 2.

The type and cost of public programs is the topic covered in Chapter II. In Chapter III, the influence of these programs and fishery management policies on fish productivity is taken up. This is followed by estimation of benefits associated with commercial fishing in Chapter IV. Potential benefits possible from a sport fishery evaluated independently from commercial catch is considered in Chapter V. Chapter VI deals with the special problem of combining potential net benefits from sport and commercial fishing and compares total benefits with costs of public programs for different time periods and relevant decisions pertaining to public expenditure programs. Limitations of the study and conclusions reached are given in Chapter VII.

CHAPTER II

PROGRAMS AND COSTS FOR PRESERVING FISH RUNS

The Federal Government has cooperated with state and private agencies to initiate and fund programs to solve problems associated with the coexistence of anadromous fish and river basin development. Two major programs seek to develop and implement the necessary technology for coexistence of anadromous fish with other water resource products. The fish passage program has two aspects: fish passage facilities provided at major downstream dams and the Fish-Passage Research Program which has the primary goal of increasing the effectiveness of passage facilities. The other major program, the Columbia River Fishery Development Program, seeks to replace lost natural productivity either through supplemental hatchery facilities or by improving remaining natural habitat. Removal of stream blockages, screening irrigation outlets and similar techniques are examples of methods used in the latter program to improve productivity of remaining fish habitat. In addition to these, certain other efforts are being exerted to provide protection to the anadromous fish runs.

Basis for Expenditures

Past investment decisions have been guided by a desire to preserve at least a portion of the anadromous fish run while making other water resource products available. However, investment objectively guided by the desire to improve productivity of the fishery, and free from the goal of preserving historical production patterns, has been the basis for little of the funds committed to the above programs.

It may be useful to distinguish two stages of investment in these water resource projects. The first stage involves investment in a composite product with over-all positive benefit anticipated but a negative return expected for fishery resources. In other words, the fishery would be more productive prior to construction of dams. This initial investment in passage facilities at the dams is needed for production of a composite product and would never be made from the viewpoint of improving output from fish resources.

Investment in fish preservation facilities in this case has typically fallen in the general category of mitigation expenditures. The cost of fish facilities and lost productivity, if any, is included in the cost of producing hydroelectric power, navigation, irrigation and other uses of limited water resources. The costs of these fish protection facilities (plus fish losses not mitigated) are included in the over-all cost of the composite product and thus, in the denominator of the final benefit-cost ratio.

Even though anadromous fish do not benefit from dam construction, this loss may be reduced by providing passage at the dams. This will result when the value of the fish resources preserved exceeds the cost of necessary preservation facilities.

In some cases such as high storage dams, it is technically not feasible to try to preserve historical fish production patterns. Funds may be provided in dam construction costs to mitigate this loss by improving production in other river areas. Further expenditures that can be shown to enhance rather than simply preserve a portion of the fishery are often intended to replace productive capacity lost elsewhere in the river basin. As a result, most present investment in the Columbia River anadromous fishery is mitagory in nature.

Fish Passage Program

Federal and state governments have long expressed an obligation to mitigate detrimental effects of river basin development. To achieve this end, fish passage facilities have been included at downstream dams below the Chief Joseph on the mainstream Columbia and the Oxbow Dam on the Snake River. Fish-passage facilities at the dams have, for the most part, been constructed under the direction of the Corps of Engineers and private utility companies. Other Federal agencies, such as the Bureau of Reclamation and Bureau of Sport Fisheries and Wildlife, have been involved in relatively minor fish preservation projects.

The purpose of fish-passage facilities is to preserve, as far as possible, the natural fish stock, as well as to provide facilities for migration of fish produced through supplemental programs. But fish-passage facilities do not prevent changes in natural fish habitat nor deterioration of environmental conditions favorable to production of anadromous fish. The loss of fish at the dams, the effect of pools created by the dams, and the reduced spawning area resulting from high storage dams are examples where passage facilities are only a partial answer to coexistence of anadromous fish and river basin development.

To improve the effectiveness of fish passage facilities, the Fish-Passage Research Program was started in 1961 with headquarters at Seattle, Washington. The basic goal of this program is to develop necessary technology to reduce the competitive situation that exists between fish and water resource products associated with dam construction. The results of this program have applicability to any area where dam construction affects the normal migration routes of anadromous fish. Alaska is an excellent example of an area likely to benefit in the future from the results of work currently being done through this program in the Columbia River. Nearly a hundred potential dam sites are listed for Alaska (77). The Columbia River provides a "laboratory" for this program, as well as the central goal for solving current problems resulting from competition between fish and dams.

Cost of Fish-Passage Facilities

By far the most costly item of fish preservation, both in the past and in the foreseeable future, is the construction of fish passage facilities at the dams. Federal funds for passage facilities in the Columbia River Basin have originated primarily through the U. S. Army Corps of Engineers, although relatively minor amounts of mitigation expenditures associated with dam construction have also come from the Bureau of Reclamation. In addition, public and private utility firms have expended considerable funds for passage facilities at their dams.

The cost of fish facilities associated with dam construction in the Columbia River Basin are presented in Table 1. A total of $217, 738, 944 has been committed to completed projects or projects under construction. This amount has gone primarily for passage facilities at the dams, although relatively minor amounts are also included for hatcheries, spawning channels, and other forms of mitigation associated with dam construction. An additional $5, 879, 601

Table 1. Construction costs for fish facilities associated with dam construction in the Columbia River Basin

	Total expenditures	Annual amortization or fixed costs
Passage facilities 1/		
U. S. Corps of Engineers, completed projects, (July 1967) 2/	$ 66,587,900	$ 2,107,301 3/
U. S. Corps of Engineers, projects under construction, (July 1967) 2/	68,770,500	2,176,373 3/
Private and public utility projects, (December 31, 1965) 4/	80,106,943	5,773,388 5/
Hatcheries and spawning channels		
Bureau of Reclamation (fiscal year 1967)	3,606,000	140,150 6/
Private and public utility projects (December 31, 1965) 4/	2,273,601 7/	8/
Total	$221,344,944	$10,197,212

1/ Includes funds for hatchery facilities constructed as mitigation for dams. Data not available by type of construction.

2/ Appendix Table 1.

3/ Amortized at 3% for 100 years: Although some dams were built prior to the time this rate of interest was justified, and current interest rates are higher than this amount, this figure is used as an average for construction occurring since 1938.

4/ Data provided by utility firms.

5/ Annual fixed charges include debt service (cost of money, depreciation or amortization), replacements, insurance and taxes.

6/ Amortized for 50 years at 3%.

7/ Includes only those funds reported by purpose for utility firms. Many firms included these costs with passage facilities.

8/ Included with annual fixed charges for passage facilities.

committed specifically to fish rearing facilities in connection with mitigation resulting from dam construction. Other minor amounts should also be listed in this category, rather than in passage facilities as shown in Table 1, but these data were not isolated in all cases by firms and agencies involved. Of fundamental importance, however, is the fact that $221, 344, 944 has been spent in an effort to preserve at least a portion of existing anadromous fish runs.

Cost of Fish-Passage Research

Additional deterioration in fish habitat occurs with the construction of each dam and new problems may result that have not been encountered in previous dam construction. Thus, related to the cost of fish passage facilities made necessary by dam construction, is the cost of the Fish-Passage Research Program which is designed to develop the necessary technology to provide the means for coexistence of fish and dams. Annual expenditures for the Fish-Passage Research Program since its beginning in 1961 are shown in Table 2.

Columbia River Fisheries Development Program[3/]

Unlike passage facilities and the Fish-Passage Research Program that, for the most part, seek to preserve existing runs, the

3/ Originally called the Lower Columbia River Fishery Plan.

Table 2. Annual expenditures through the Fish-Passage Research Program 1/

Fiscal year	Annual expenditure
	Thousand dollars
1961	$ 361.2
1962	1,126.0
1963	1,654.7
1964	1,651.3
1965	1,568.5
1966	1,532.5
1967	1,591.2

1/ Source. Division of Biological Research, Bureau of Commercial Fisheries, Seattle, Washington, August,1967.

Columbia River Fisheries Development Program seeks to increase the output of specific areas of the river. It has long been recognized that many of the effects of river development could not be cancelled by mitigation expenditures on fish passage alone. In 1950, the Report of the President's Water Resource Commission expressed this view of the problem:

> "The construction of large dams across the mainstream of the Columbia River and lower reaches of its tributaries presents a problem for the passage of anadromous fish and in the inundation of spawning grounds. Studies by the United States Fish and Wildlife Service, the Corps of Engineers, and the States have resulted in the formulation of the Lower Columbia River Fishery Plan to improve the lower tributaries of the Columbia River for salmon spawning. This plan proposes to develop the salmon runs in the lower tributaries to the highest possible level of productivity by the removal of obstructions, abatement of pollution, screening of diversions, fishery construction, transplantation of runs, extension of artificial propagation, and establishment of fish refuges. These improvements of the lower

tributaries are intended to maintain, insofar as possible, the level of fish productivity in the basin, in the face of greater losses likely to result from the construction of large dams upstream. (53, vol. 2, p. 45)

Costs of the Columbia River Development Program

Although much of the money spent in this program has gone for construction of facilities to improve productivity and operation and maintenance of these facilities, research also is an important part of this program. Funds obligated for expenditure through this program from its inception in 1949 to June 30, 1966, by purpose and agency, are listed in Appendix Table 2. Annual expenditures by purpose only, for fiscal year 1962 through 1966, are presented in Table 3.

Table 3. Annual expenditures by purpose through the Columbia River Fisheries Development Program, 1962-1966 1/

Fiscal year	Construction	Operation and maintenance 2/	Expenditures
		Thousand dollars	
1962	$1,431.0	$1,910.0	$3,341.0
1963	1,626.0	2,095.0	3,721.0
1964	895.6	2,059.4	2,955.0
1965	1,695.0	2,219.0	3,914.0
1966	1,107.0	2,326.0	3,433.0

1/ Source: Columbia River Fisheries Development Program Office, Portland, Oregon.
2/ Includes research expenditures.

The Columbia River Fishery Development Program is a joint venture between the Federal Government and state fish and game agencies. In addition to Federal funds provided for preservation and improvement of anadromous fish runs, the states also provide amounts for operation and maintenance of these and similar facilities.

Nonreimbursed State Expenditures

State agencies may operate facilities constructed as mitigation for losses resulting from additional dams, with funds originating from either the Federal Government or private and public utility firms. In addition, facilities constructed through the Columbia River Fishery Development Program, as can be seen in Appendix Table 2, are also funded through cooperative programs with state agencies.

In this study, in an effort to avoid duplication of expenditures, and at the same time accurately list all justifiable cost data, each agency or firm was asked to provide data on expenditures of their own funds only. This section lists state funds that were not reimbursed through any other public or private firm or agency.

State funds are used primarily for administration of fishery programs and for related functions, such as research, engineering, fish culture, and law enforcement. In most cases, however, usual state accounting procedures do not isolate expenditures for anadromous fish or for the Columbia River Basin only. Thus, each state agency was asked to provide estimated data based on the best available information. The resulting estimates of operating and maintenance funds, by agency and by purpose, for calendar year 1965 or fiscal year 1966 are listed in Appendix Table 3. Operating and maintenance costs were also obtained, where possible, for the period 1962 to 1966. These are presented in Appendix Table 4. However, due to the difficulty in isolating data pertaining only to anadromous fish and only to the Columbia River Basin, no attempt was made to determine a total of all historical expenditures for this purpose.

State funds have also been used for capital construction. The Washington State Department of Fisheries reported $687,826 (as of October 1966), and the Oregon Fish Commission $681,257.80 (total to end of fiscal year 1967). No other state agencies reported capital construction costs. The amounts noted above are summarized along with other capital expenditures in Table 5.

Other Federal Funds

The Bureau of Reclamation has provided $3,606,000 in mitigation funds to construct fish screens and three fish hatcheries (Table 5). These facilities are operated, however, by the Bureau

Table 4. Operation and maintenance expenditures funded through the Bureau of Sport Fisheries and Wildlife, for projects constructed with mitigation funds originating with the Bureau Reclamation 1/

Project	Fiscal year 1963	1964	1965	1966
Entiat National Fish Hatchery	$ 12,611	$ 6,374	$ 5,824	$ 7,318
Leavenworth National Fish Hatchery	113,472	121,218	120,680	120,614
Winthrop National Fish Hatchery	18,371	19,256	30,845	22,295
Yakima Fish Screens	---	10,191 2/	15,207 2/	16,891 2/
Total	$144,454	$157,039	$172,556	$167,118

1/ Source: Bureau of Sport Fisheries and Wildlife, Portland, Oregon, July 1967.
2/ Maintenance costs only; no production at this project.

of Sport Fisheries and Wildlife. Thus, operating and maintenance costs were funded through the latter agency, even though no capital costs were provided by this agency. These operating and maintenance costs are listed in Table 4.

Indirect Costs - Opportunity Cost of Water at Passage Facilities

In addition to construction costs and annual expenditures for operating and maintaining necessary facilities, a value must also be determined for the indirect cost due to loss of power production from water diverted to fish ladders to transport upstream migrating andromous fish over the dams.

Footnotes for Table 5.

1/ Table 1. July 1967, for Corps of Engineer Projects, and December 31, 1965 for projects funded through utility firms.

2/ Appendix Table 1 (July 1967) Annual operation, maintenance, and replacements.

3/ Data obtained from records of private and public utility firms.

4/ Data for all firms or agencies involved not available.

5/ Construction costs funded through Bureau of Reclamation, and operation and maintenance expenditures funded through Bureau of Sport Fisheries and Wildlife, and State of Washington.

6/ Op. Cit. "An Economic Evaluation of Columbia River Anadromous Fish Programs - Preliminary Report," Table 13, p. 39.

7/ Table 4.

8/ Appendix Table 2, Construction plus management techniques.

9/ Appendix Table 2, Amortization at 3% for 50 years for construction plus management techniques.

10/ Table 3.

11/ Oregon Fish Commission $681,257, and Washington Department of Fisheries $687,826.

12/ Amortized at 3% for 50 years.

13/ Appendix Table 4. Law Enforcement expenditures are included, although this function might continue to be needed for resident fishing, to a large extent.

14/ Table 2.

Table 5. Total construction funds, by purpose and annual amortization, for completed projects or projects under construction, by agency and annual operation, maintenance, and water value from 1962 to 1966 for Columbia River anadromous fish programs

Agency or purpose	Construction	Annual amortization	Annual operation and maintenance expenditures, and indirect costs				
			1962	1963	1964	1965	1966
			Thousand dollars				
Corps of Engineers	135,358.4 1/	4,283.7 1/	2,502.7 2/	2,502.7 2/	2,502.7 2/	2,502.7 2/	2,502.7 2/
Public and private utility firms	82,380.5 1/	5,773.4 1/	509.2 3/	543.7 3/	804.4 3/	914.4 3/	4/
Bureau of Reclamation	3,606.0 1/	140.1 1/	5/	5/	5/	5/	5/
Bureau of Sport Fisheries and Wildlife	5/	5/	168.0 6/	144.5 7/	157.0 7/	172.6 7/	167.1 7/
Columbia River Fisheries Development Program	26,052.0 8/	1,012.5 9/	1,910.0 10/	2,095.0 10/	2,059.4 10/	2,219.0 10/	2,326.0 10/
State fish and game agencies	1,369.0 11/	53.2 12/	1,199.8 13/	1,276.3 13/	1,309.3 13/	1,373.5 13/	4/
Fish-passage research program	None	None	1,126.0 14/	1,654.7 14/	1,651.3 14/	1,568.5 14/	1,532.5 14/
Water value for passage facilities	None	None	662.4	662.4	662.4	662.4	662.4
Total	248,765.9	11,262.9	8,078.1	8,879.3	9,146.5	10,440.1	4/

However, all water used in the fishways at the dams would not have an alternative use in power production. When water is passing over the spillways, no loss can appropriately be charged for that amount diverted to fish ladders. As the number of dams increase, particularly with construction of large storage dams, the amount of water passed over the spillways can be expected to decrease.

The opportunity value of water passed through fish ladders, if used for power production, was estimated by Bonneville Power Administration, Branch of Power Resources, Portland, Oregon, for the larger dams in the Columbia River. Power loss at larger non-federal dams on the Columbia River was also included. The value of energy is based on $18,600 per megawatt at a load factor of 85 percent. All dams included in these estimates, and the power loss at each, is listed in Appendix Table 5.

Based on the above values and assuming no spillage occurs, the value for power loss due to water diverted to fish ladders at the facilities listed in Appendix Table 5 that are either complete or under construction is estimated to be $1,104,000 annually. However, under existing conditions, spillage is expected to occur 40 percent of the time. Thus, only 60 percent of this value, or $662,400, is a justifiable annual charge against fish preservation since water used in fishways has no value when it otherwise would have passed over the spillways. 4/

Total Funds Committed to Anadromous Fish Programs

The total of all construction funds, along with annual amortization costs, are summarized in Table 5. Annual operation and maintenance expenditures, including the estimated value of water diverted from power production, is also presented in Table 5, for the years 1962 to 1966.

Over $248 million have been committed to completed projects or projects under construction, in efforts to preserve anadromous fish as a part of the composite product available from Columbia River water resources. The annual amortization on this amount is over $11 million annually, and an estimated expenditure of over $10 million was required in 1965 for operation and maintenance of these facilities (Table 5).

4/ There would be an actual savings in additional power output of $1,104,000 even though spillage occurs 40% of the time. However, only 60% of this loss occurs because water must be in the fishways; the other 40% of the time it would be spilled anyway. The value of fishway water for maintaining fish runs would vary, depending on the time of year. Spillage during winter months may have little value for fish production. Furthermore, in the future, spillage may be reduced by greater control over stream flow through additional storage facilities. These percentages are intended only as rough estimates of this cost of fish preservation.

Future Expected Costs

The Corps of Engineers, Power Development Section, Portland, Oregon, estimates that approximately 35 percent of the power potential in the remaining area below the impassable dams has been developed with existing projects. Twenty-one percent of the unutilized power potential will be available with projects presently under construction (see Appendix Table 1 for projects in each category). An additional 20 percent of potential power sites are listed as probable future projects. The remaining 24 percent of potential production consists mostly of sites on the smaller tributaries that likely will never be constructed. Thus, only costs associated with preserving anadromous fish runs for developing the 76 percent of potential listed as either constructed, under construction, or probable future projects will be given consideration.

Cost of preserving fish runs for all completed projects and those under construction has been summarized in Table 5, accounting for approximately 56 percent of the estimated hydroelectric potential of the Columbia River Basin below the impassable dams.

Direct Future Costs

Cost data for probable future projects, representing approximately 20 percent of the estimated power production potential are listed in Table 6. Only future expenditures for passage facilities and mitigation are estimated at present. Problems for anadromous fish are likely to be increased, however, with construction of additional dams in the future. Either additional effort or improved results from present levels of supplemental programs will be required if production is to be maintained even at present levels.

Sites for major future projects are shown in Figure 1 and listed by project in Table 6. Many factors cannot be taken into account in estimating costs prior to planning for actual construction. Alternative projects may eventually be selected other than those listed in Table 6. Private versus public development, for example, may influence the selection of one site over another. Construction costs also change over time although a construction cost index could be used to convert cost estimates to a similar time period.5/ However, actual construction, if this occurs, will take place in the future under unknown construction cost conditions as well as costs of funding projects (i. e., appropriate amortization rate). Thus, no attempt has been made to convert estimated construction costs to a common year.

Other factors are likely to alter the estimates in Table 6 far

---

5/ For example, see Irrigation and Hydroelectric Cost Indexes, U. S. Bureau of Reclamation, Denver, Colorado, in monthly issues of Engineering News-Record.

Table 6. Estimated cost of fish facilities at probable future projects influencing anadromous fish in the Columbia River Basin

	Construction costs for fish facilities and mitigation expenditures	Annual amortization costs 1/	Annual operation and maintenance costs
Projects authorized for construction 2/	$14,127,000	$ 447,063	$ 113,200
Projects in planning status 2/	8,688,400	274,953	12,000
China Gardens 3/	6,100,000	193,041	110,000
High Mountain Sheep 3/	5,160,000	163,293	316,000
Pennycliffs 3/	4,248,000	134,432	30,000
Lower Canyon 3/	12,440,000	393,676	320,000
Crevice 3/	13,630,000	431,335	210,000
Wensha 3/	5,650,000	178,800	54,000
Freedom 3/	5,900,000	186,711	55,000
Ben Franklin 4/	10,302,900 5/	326,046	144,700 6/
Total	$86,246,300	$2,729,350	$1,364,900 7/

1/ 100 years at 3%.
2/ Appendix Table 1, July 1967.
3/ Estimates based on June 1958 construction costs.
4/ Estimates based on 1963 construction costs.
5/ Includes $2,500,000 estimated mitigation for spawning channels.
6/ Replacement at passage facilities $21,700; operation and maintenance of passage facilities, $88,000; operation and maintenance of spawning channel, $35,000.
7/ Operation and maintenance costs for Wells (private) project were not available for either Table 5 or Table 6.

more than changes in construction costs. Additional supplemental programs will no doubt be proposed to neutralize any detrimental effects resulting from additional blockage and control over stream flows. The type and amount of supplemental facilities will depend on changes in technology and future fishery management policies as well as changes in future demand and supply alternatives for anadromous fish and other water resource products.

The data presented in Table 6 will likely prove to be only a rough estimate of the cost of future construction; however, this data provides the best estimate at present of the cost of necessary facilities for preserving existing fish runs.

Indirect Future Costs--Opportunity Cost of Water for Fishways

The opportunity cost of water needed for future fish ladders also needs to be considered. However, estimates are available for only three future projects. Estimates for Asotin, China Gardens, and Ben Franklin projects are presented in Appendix Table 5. The opportunity cost of water used in fish ladders at these projects, assuming no spillage occurs, is estimated to be $76,000 per year (12-month closure), using 1967 power values. If spillage occurs 40 percent of the time, the appropriate charge for the opportunity cost of water necessary for fish ladders is $45,600 annually. However, control over stream flows is likely to reduce spillage in the future, but the extent of this is unknown at present. The value of this water in production of electric power also will likely change in the future due to new technology and changes in demand.

Indirect Future Costs--Opportunity Cost of the Nez Perce Site

If a superior dam site is rejected specifically to preserve fish runs, an indirect cost results that must be taken into account. Planned rejection of the Nez Perce site in favor of the combined Lower Canyon and High Mountain Sheep sites (see Table 6) represents a case where the opportunity cost must be considered in estimating future fish preservation costs.

A comparison of the costs and influence of these two alternatives on fish runs indicates the issues involved. (63, p. 258)

> "To preserve the Salmon River run, the Nez Perce project has been figuratively divided into two projects, one a short distance upstream on the Snake River and the other close to the confluence of the Snake and Salmon Rivers.
>
> "Together, the plans for High Mountain Sheep and Lower Canyon projects provide approximately the same power output and storage as considered for the Nez Perce project. But there is a tremendous difference in the costs. The Corps of Engineers estimated that Nez Perce would cost $285 million, compared with $420 million for the two-dam plan." (See Appendix Table 6)

The cost of substituting the two-dam plan "amounts to $131 million, after netting out the cost of passage facilities from the gross difference in costs between the two alternative plans." (63, p. 259)

This foregon opportunity cost cannot be justified at present by economic criteria. This conclusion is similar to that reached in the earlier analysis by Sewell and Marts:

> "It involved a resource change over time based in large measure on social and aesthetic values and suggests a serious understatement of such values in conventional economic analysis." (63, p. 260)

Any special value of the Nez Perce site has not been foregone at present, and may never be. If this opportunity is foregone, its inclusion as an economic factor will depend on the basis for foregoing this opportunity. Although this is a relevant cost, the decision at present can be justified only by non-economic criteria. Since this decision is not justified on an economic basis, the opportunity cost of the Nez Perce site is omitted as a future cost even though present plans include construction of alternative projects at Lower Canyon and High Mountain Sheep (Table 6).

Summary

Investment in the Columbia River anadromous fishery for the most part has resulted from attempts to include anadromous fish in the composite product available from limited water resources.

Investment of this type generally is classified as mitigation expenditures. A total of $221, 344, 944 has been committed to preserving anadromous fish runs as mitigation expenditures associated with dam construction. Although a small part of this amount has gone for rearing facilities as mitigation expenditure, most of it has been used to provide fish passage facilities at the dams. These direct mitigation and passage facility costs represent almost 85 percent of the total construction funds committed to maintaining anadromous fish runs. Total construction funds of $248,765,900 committed to this purpose probably should all be considered as mitigation since improvements in one area often replaces lost productivity in another part of the river basin.

Annual amortization on the above investment amounts to $11,262,900, and an estimated $10,440,100 was needed for operation and maintenance of these facilities in 1965.

Future dams that are likely to be constructed in the Columbia River Basin will require at least $86,246,300 additional investment in fish preservation facilities. The annual amortization on this investment will be $2,729,350 annually, with an estimated $1,364,900 needed for annual replacement, operation, and maintenance.

CHAPTER III

BASIS FOR ESTIMATING COMMERCIAL BENEFITS

Costs comprise one side of a public program--what we get for these expenditures is the other. Benefits from preserving the Columbia River anadromous fishery result from both sport and commercial fishing. The estimated value of commercially-harvested fish will be considered first.[6/]

Before benefits associated with commercial fishing can be estimated, however, it is necessary to establish a theoretical background for the estimating technique.

Enforced inefficiency in the utilization of commercially-harvested fish resources precludes the use of market prices to directly determine potential benefits. This point must be clearly in focus to demonstrate the problems involved in estimating possible benefits to society of preserving or enhancing productivity of the Columbia River anadromous fishery. The digression in this chapter is necessary in order to clarify the effects of current management policies on the allocation of benefits associated with commercial fishing. This value, which is wasted under existing

---

6/ Reference is made to commercially-harvested or sport-harvested fish resources to indicate interest is not in gross market values but rather in estimating the net value of the resource.

management policies, must be estimated indirectly to determine benefits.

Fishery Management

Fishing is one of the oldest industries known to man. Agriculture and fishing provide our basic food supplies. A large body of agricultural economic theory has been developed in the United States to explain and guide resource allocation in agriculture and many economists specialize in this field. Fishing, by comparison, until very recently has been practically devoid of economic principles to explain and guide resource allocation.

Much of the difficulty in formulating fishery management policies firmly based on economic principles can be traced to the lack of ownership as a controlling factor in resource use. This means that the value of future products will be excluded as a decision variable for firms in determining the optimum level of use for fishery resources.

The Columbia River anadromous fishery presents an all too vivid example of exclusion of economic criteria in formulation of management policies and implementation of these into action programs. The purpose of this chapter is to point out the divergence of existing policies from those required by efficient resource use and the cost to society of ignoring economic principles and concepts in management of anadromous fisheries.

Historically, fishery management decisions have been based primarily on biological and other noneconomic criteria. These policies tend to emphasize the idea of maintaining the maximum physical yield capabilities of renewable resources. While no argument is intended against the general principles of resource conservation, it is necessary to include economic criteria that gives adequate weight to relative values in formulation of policies affecting resource use. For example, the Great Plains could have been preserved for the maximum sustainable production of deer, elk, and antelope rather than transferred into production of wheat and beef with a different capacity to satisfy human wants. The relative values of the resulting products must be considered if resources are to be allocated according to the desires of consumers. Likewise, for our water resources, economic data must be included if resource use is to conform to the relative values that consumers place on alternative products.

Many problems relating to this general topic are as important on an international level as to national or regional policies concerning resource use. However, the potential solutions between these two situations are different. Tastes, preferences and competing products differ from one nation to another as well as differences in value placed on productive resources available to be committed to fishing. There is also greater freedom in controlling resource use when the fishery is primarily subject to national control.

The Columbia River anadromous fishery is not entirely under national control since Canadian and U.S. fishermen share in harvesting these resources in the ocean. It would also be possible for other nations to fish these stocks, but treaty arrangements or fishing boundaries prevent this in most cases.

A comprehensive discussion of international aspects of fishery management is not necessary for the present study, however, since agreements and natural salmon migratory routes limit the problem primarily to national scope. Although some aspects of the problem require a more general treatment than this, for the most part, attention will be focused on the effect of the common property nature of resource ownership on management techniques applicable to a fishery essentially under national control.

Economic Organization

This study was not concerned with industrial organization aspects of the fishing industry but some observations can be made without empirical support.

Fishery management policies that lead to inefficiency in utilization of commercially-harvested fish are based on an economic organization at fisherman level that approaches a purely competitive theoretical model.

At the fisherman level there are many sellers (fishermen) with little barrier to entry and an essentially homogenous product. These fishermen usually face a fairly concentrated group of fish processors who are able to differentiate many of their products. Economic profit can accrue to processing firms although barriers to entry are probably inadequate to enable processors to obtain major additional returns. This potential threat of new entrants results from the relatively small firm size required by processing technology and the wide geographic dispersion of fish resources. Although the market for fish may be imperfectly competitive, competition for fish supplies and the seasonal nature of fishing is likely to lead to effective competition reflected in the market prices paid for fish.

Common Property Resources

Although common property resources are considered scarce commodities by society, they are treated as free inputs by the individuals using them. Society is concerned not only with the value or present productivity of the resource, but also with the present value of discounted future products. Probably the most important characteristic engendered by common property ownership is the lack of concern for future productivity of these fishery resources by individual fishermen. Resource ownership is a fundamental requirement if the value of future productivity is to be reflected in market prices, and thus given adequate concern in individual decisions affecting levels of use for fish resources.

When ownership is lacking, rational resource use calls for the individual to consider the value of current productivity only. Since no means exists to protect the future value product of his share of the resource, the individual fishermen will place a zero value on future products in determining current levels of resource use. With no assurance of sharing in future products, rational resource use in the fishing industry calls for continued fishing as long as all fishing costs are covered. Any value which might accrue to the fish resource would appear as temporary profit to fishermen and be eliminated over time by the entry of new firms in the typical manner of long-run adjustments in a purely competitive industry. With ownership lacking, the value of the resource cannot be capitalized and will appear as profit to all who enter the industry until it is eliminated in payment for excess resources committed to fishing using inefficient harvesting methods required by regulation.

One fundamental attribute of resource ownership is the tendency to maximize not only the present value productivity of the resource but also the present value of discounted future productivity. Of course, future values are dependent on predictive ability and lack of knowledge is a serious limitation. But to the extent that the net value of future products can be estimated with an acceptable degree of reliability, resource ownership provides a tendency to give consideration to future values in decisions affecting current levels of resource use. When the value of the resource can be capitalized, excessive investment in harvesting current output is prevented.

For the fishery, if the value of the resource can be established, this would also provide a guide to indicate desirable product division between current and future use (i.e., investment in natural fish stocks) to the extent that future productivity is influenced by reduced present use. Since Columbia River anadromous fish supply can be expanded through supplemental facilities such as fish hatcheries, a guide will also be provided for appropriate levels of investment in supplemental production.

Resource Ownership

Resource ownership does not necessarily mean private ownership. A government agency can function as "owner" and seek efficient use of resources although government agencies do not normally function with the profit motive of private resource owners. Efficient use of resources for either a private or public "owner" needs to consider the value of both current and future value productivity.

The value of future products is considered by private owners due to the desire to obtain maximum profit over time from resource use. Maintenance of capital needed for future productivity is undertaken by private owners with expectation of anticipated future profits. Although public "owners" do not look upon capital as a means to future profits but as the means to increased benefits, this distinction is unimportant.

It is possible for value product to increase over time even if physical production is simply maintained at a constant level or even declines. This is due to shifts in demand over time resulting from such factors as increase in the number of consumers. Public "owners," like private owners, must give appropriate weighting to the relative values of current and anticipated future products of the fishery.

In the absence of data that is attributed a high degree of reliability concerning future needs and supply, there may be a tendency for public "owners" to over-emphasize the value of future products as a "hedge" against uncertainty. Past errors in protecting the productivity of renewable resources through insufficient valuation of future products and uncertainty concerning future needs lend popular support to public management policies that place a high value on future productivity.

Product value, efficiency of fishing methods and international agreements are factors affecting the equilibrium level for a particular fish population. Salmon and steelhead, the principal anadromous species of the Columbia River, have a high value both for food and recreation and can be harvested efficiently unless prevented by regulated inefficiency. When these fish return to fresh water, they are mature, in excellent physical condition, concentrated in shallow water, and close to processing facilities. It is these factors that enable the salmon and steelhead to be exploited so efficiently.

Natural reproductive capacity of the resource is inadequate to meet economically feasible fishing intensity with known technology. Thus, regulations have been enacted to limit efficiency to prevent depletion of the capital stock of the fishery. Public control has been primarily in the role of protector of the physical productivity of the resource rather than providing the functions of resource ownership.

With common property ownership for these anadromous fish, social regulation is needed to limit use. Otherwise, the capital stock of the fishery would be appropriated to pay for fishing costs, and eventually the fish population would decline. As the fish population falls, the point where fishing is economically feasible will also decline resulting in reduced fishing intensity and a lower level of equilibrium in the fish population.[7/] The relatively high value of most anadromous fish and the potential to harvest this product has resulted in numerous regulations imposed to reduce fishing efficiency. With the functions lacking that normally are performed by resource ownership, the fish reproductive stocks have been protected by regulated inefficient fishing methods. Operating through the production function, regulated inefficiency provides the means to assure that market demand and market supply are equal and also consistent with physical productive capabilities of the resource. It is this cost, which is borne directly by the consumer, that is the price of a competitive industry at fishermen level with easy entry and lack of ownership of the resource.

With ownership attributes of resource allocation lacking, unless prevented by regulation, any return attributable to the fish resource will be appropirated as a profit, entice excess resources

---

7/ For a detailed discussion of this process of achieving equilibrium, particularly where the fishery is subject to international use, see: The economic theory of a common property resource, H. Scott Gordon, The Journal of Political Economy 62: 124-142. April, 1954. The fishery: The objectives of sole ownership. Anthony Scott, Journal of Political Economy 63: 116-124. April, 1965. Common property resources and factor allocation. J. A. Crutchfield, The Canadian Journal of Economics and Political Science 22: 292-300. August, 1956. The Commonwealth in Ocean Fisheries, Francis T. Christy, Jr., and Anthony Scott, Baltimore, Johns Hopkins Press, 1965, p. 6-16; and discussion by Jewell J. Rasmussen, American Economic Review, 61: 1341-1343, 1966.

into fishing, and be used to pay for these unneeded resources. Where resource use is under national control, one obvious alternative is to make certain that economic extinction occurs somewhere close to the desired sustainable physical reproductive capability of the resource. This simply requires passing regulations to reduce efficiency to the point where the equilibrium fish population is at a satisfactory level. This regulated inefficiency carries a high cost to society, however, in terms of wasted resources committed to fishing.

Regulated Inefficiency

Many efficient harvesting devices have been outlawed from the Columbia River and have been replaced by inefficient fishing methods. Seines, which were used by Washington and Oregon fishermen, were banned along with set nets used in fixed locations such as the entrance to spawning streams. Traps, which at one time were important in the annual Columbia River salmon catch, also were outlawed. A particularly ingenious device, the fish wheel, first appeared in 1879 and achieved considerable popularity before being outlawed.

Fishing seasons that are regulated to prohibit fishing during periods of peak salmon runs in order to assure optimum escapement to upstream spawning areas also seriously reduce efficiency.

Several variations of this technique are used. For example, the typical method assuring adequate escapement for fall chinook spawners is to close the fishing season as the fish run nears its peak. This is shown, using hypothetical data, in Figure 3.

By closing the season during the peak of the fish run, it is possible to allow all who want to fish to participate during open seasons. A slight variation of this is to allow additional fishing for brief periods of time during the peak of the run. Several important consequences of this method of fishery management can be demonstrated through reference to Figure 3.

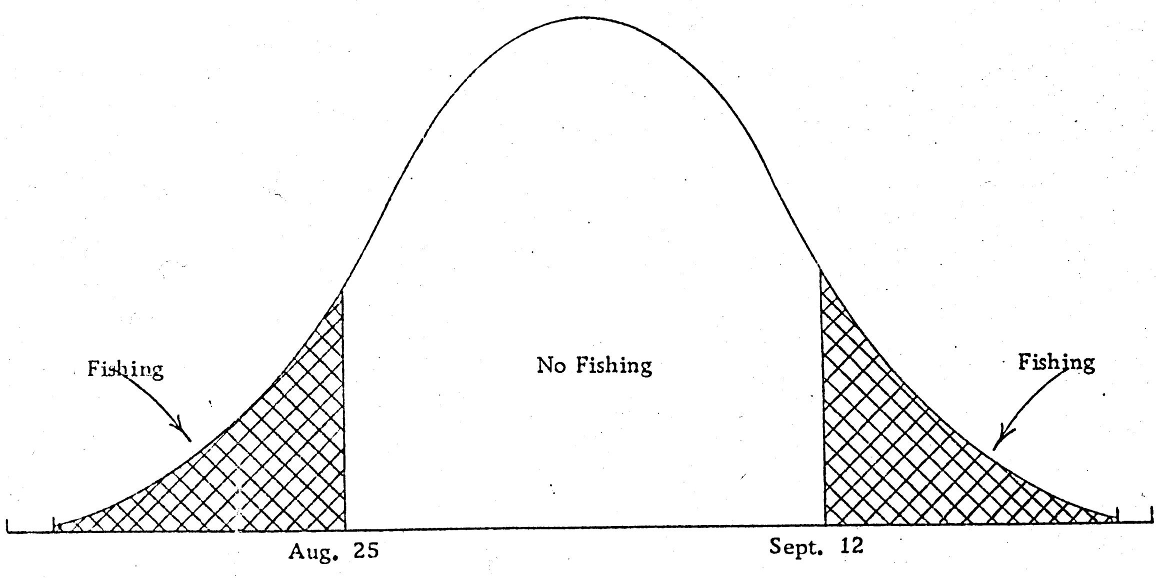


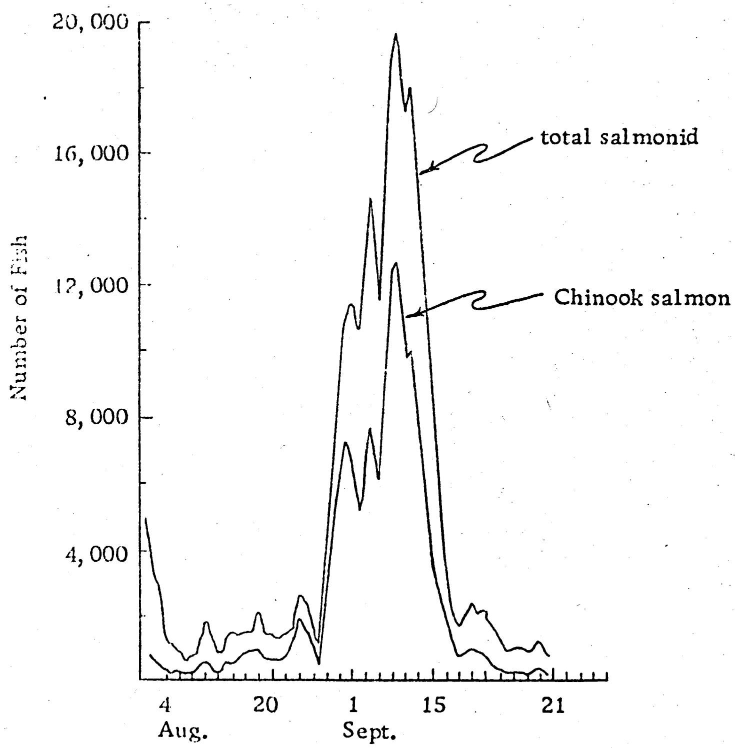
Figure 3. A theoretical harvest of fall run Chinook salmon in the gill-net fishery with fishing season controlled to assure optimum escapement of spawners.

To begin with, fewer resources could achieve the same harvest by limiting the number of fishermen and allowing the remaining effort to be applied with maximum efficiency to the entire fish run. In addition, this pattern of seasons often further retards efficient use of resources due to lack of prior knowledge of when fishing will be allowed. This reduces the ability to shift fishing labor and equipment to other uses when fishing is not permitted. The number of days of open gill-net fishing is also misleading relative to influence on fish harvest, since an extra day at the beginning of the peak fish run (i.e., the point shown as approximately August 25), may be worth much more than several additional days of earlier fishing.

Another result of this pattern of fishing seasons is the tendency for maximum fish runs upstream to occur in short periods of time. Figure 4 shows the 1965 distribution of chinook salmon and total salmonids passing Bonneville Dam for a period of time comparable to that used in Figure 3. By taking into account the necessary time for fish to migrate to Bonneville Dam (about 140 miles upstream), the effect on upstream migration of fishing seasons of the type shown in Figure 3 is demonstrated in Figure 4 which is based on actual fish counts.

In addition to reduced economic efficiency, management problems can also result from migration occurring in sharp peaks. The runs to some tributary and mainstream locations may be affected by this fishing pattern to a greater extent than others and consequently future fish runs may be reduced.

Figure 4. Chinook salmon and total salmonid fish passage at Bonneville Dam during August and September, 1965.



Another variation of the management technique shown in Figure 3 is to allow the entire desired escapement to reach upstream areas that are closed to all but Indian fishing before opening the commercial gill-net season. This method assures that the necessary reproductive stock will escape the commercial gill-net fishery. In addition to committing excess resources to a reduced portion of the run, rather than fewer resources to the peak of the run, this method has the additional disadvantage of encouraging harvest farther upstream.

Most fish will be harvested near the mouth of the Columbia using the method shown in Figure 3, whereas the latter variation will result in many fish landed upstream which affects quality and processing. However, this latter method is used primarily for spring run chinook destined for spawning areas far upstream, and thus is less detrimental to quality than would be the case for fall run chinook that enter the river relatively close to spawning condition. The serious effect on quality prevents use of this method for the fall run.

Under present conditions, the gillnet harvest is usually the final, most effective, and in some cases the only adjustment that controls the level of escapement. Changes in sport fishing requirements or ocean commercial fishing take longer periods of time and are less adaptable to selective adjustments in most cases.

Limited Entry and Economic Theory

Regulated inefficiency leads to a waste of current product of fish resources. This can be avoided only if some form of limited entry is instigated to prevent excessive exploitation and consequently lost productivity. For common property resources it is necessary to substitute limited entry to perform the functions normally executed as the result of resource ownership.

With entry to the fishery limited, it would be possible to use the most efficient technology and fishing methods available as well as provide a stimulus for development of new technology. There is poor understanding of the concept of limited entry at present by those involved directly in fishing and, to some extent, by those involved in management of fish resources.

With limited entry, resources wasted through regulated inefficiency could be applied to improving productive capabilities of the fishery or for any other desired use. Much of the objection to limited entry can be traced to confusion between the case of competitive market structure with easy entry and resource ownership, and that of competition, free entry but with the normal functions of ownership inoperative. This difference and its influence on fishery management policies can be explained in terms of production principles.

Following the normal order of theoretical development, physical input-output relationships need first be specified. For the fishery this requires the use of biological and related data to establish potential sustainable yields. The physical sustainable yield is influenced by the deteriorating effects of river basin development, and by efforts to mitigate and, where possible, improve fishery output. Management policies can also influence sustainable yield.

For example, the practice of heavy harvest during short fishing seasons may exploit some stocks of the fishery far more than others (see Figure 4).

Another important factor relative to the level of sustainable physical yields is the selectivity of the gear used for fish harvest, and the loss, if any, to fish stocks incidental to fish harvest. The importance of this factor in the Columbia River case can be attributed primarily to the large troll and sport harvest.

Based on these input-output characteristics, a production function can be postulated that first increases at a decreasing rate, eventually reaching a point where additional fishing effort will reduce the level of sustainable physical yield. Production function of this type was demonstrated by TPP in Figure 2. Considerable progress has been made in specifying production relationships, but much remains to be done to be able to predict and control fish populations.

The biological basis for this type of production function results partially from the fact that predation by man is offset to some extent by reduced natural loss in anadromous fish stocks (i. e., the reduction in the size of the fish population is offset by natural mortality and increased growth of fish due to such factors as improved food supplies). However, fishery management decisions and public investment programs are far more important in the Columbia

River case. These relationships, in physical terms, can be seen by referring to Figure 2.

Similar relationships in value terms are presented in Figure 5. In this case it is assumed that market price is not influenced by relatively small changes in quantity landed. These simplifying assumptions relative to actual conditions will be clarified in the following chapter. It is useful to mention here, however, that the Columbia River contributes about five percent of the total United States salmon harvest.

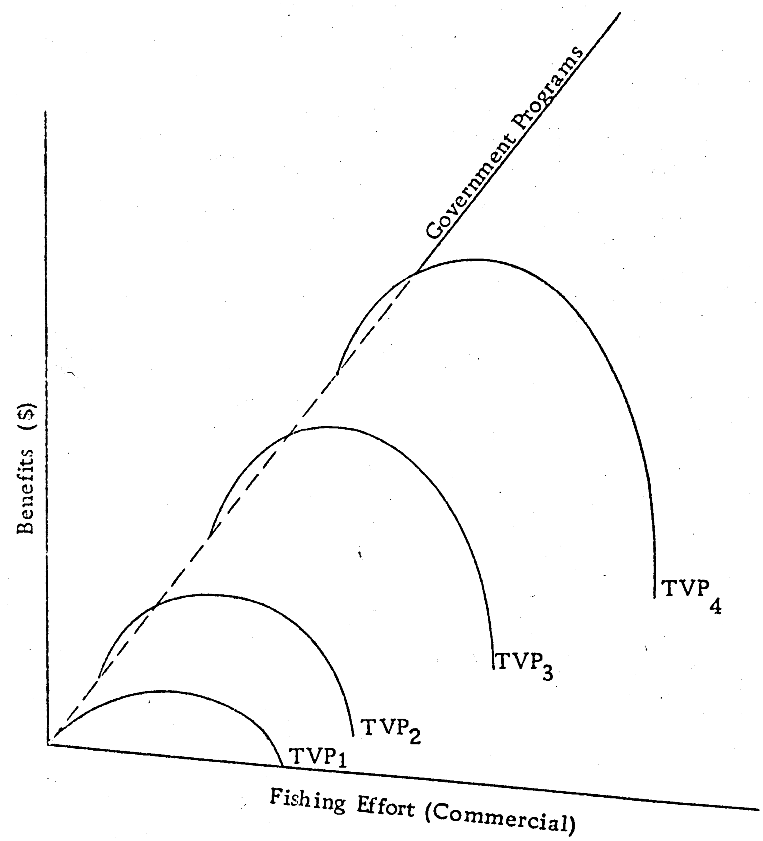


Figure 5. Relationship of yield, fishing effort, and government programs, in value terms.

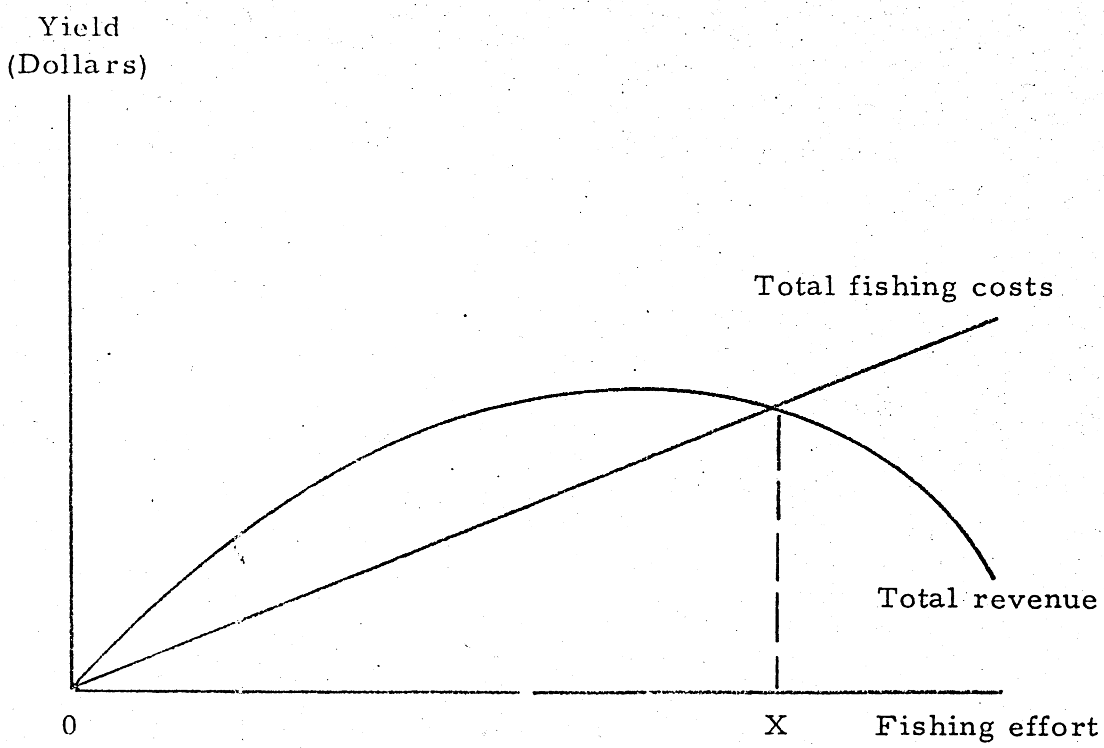
Given the efficiency of natural fish stocks and an index indicating the costs of fish harvest regardless of gear used or area and time of fishing, it would be possible to specify the potential current output consistent with some level of government programs of a particular type if all other factors, such as food supplies, predators, and similar items, remained unchanged. Of course, these "other factors" do not remain unchanged, resulting in complications in fishery management due to the long period required for adjustments and extreme natural variability in fish populations. But this does not alter the concept underlying some desired physical yield if an optimum level of physical output can be specified according to economic criteria. This specification, of course, needs to be based on actual or estimated market prices.

Optimum yield, according to economic welfare criteria, requires maximization based on the application of the usual economizing principles given physical, technological, and price data. This requires conversion of physical yield and fishing effort to dollar values in terms of revenues and costs. Response patterns to the process of regulated inefficiency can be demonstrated by assuming a given level of Government programs in Figure 5. This permits the conventional two-dimensional diagram to be used.

For simplicity, it is also assumed that identical units of fishing gear are used, and that these are obtainable at the same cost (resulting in a linear cost function); that prices received by fishermen are not affected by output (resulting in a revenue function of the same shape as the physical yield function); that all economic and biological adjustments are complete, thus eliminating errors due to lack of sufficient information on the part of fishermen; and that stochastic variation in fish population can be ignored.

Based on these assumptions, value functions are demonstrated in Figure 6. These are probably a good first approximation of the case that actually exists for the Columbia River anadromous fishery. Any additional fishing effort is usually obtained simply by lengthening the fishing season, which results in use of the same fishing gear but for longer periods of time; or, in the case of commercial trolling, vessels may be diverted from trolling for other species such as tuna, if salmon trolling becomes particularly profitable. Thus, a linear cost function is sufficiently realistic for purposes of outlining the basic principles involved. The Columbia River contribution to Pacific Coast fisheries is sufficiently small that the assumption that output does not affect price may hold in general, although years of large or small total runs may affect prices more or less than proportionately with landings due to local processing limitations. In this case, the revenue function would depend on price elasticity of demand, but the principles involved are essentially the same.

Figure 6. Total receipts and fishing costs.



In Figure 6, the total revenue curve is equivalent to a single TRP curve in Figure 5. For simplicity, the relationships demonstrated in Figure 5 and associated adjustment patterns will be considered individually relative to a single TRP curve using conventional two-dimension diagrams.

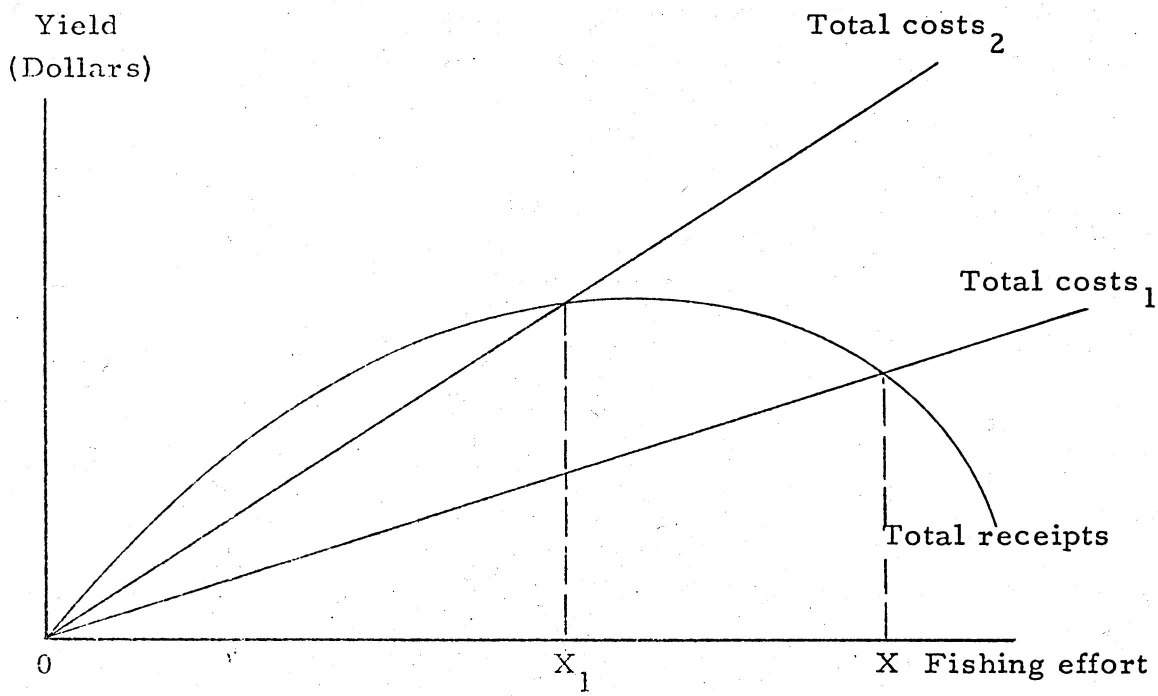
With unlimited entry, fishing effort and output for commercially harvested fish resources will occur at OX in Figure 6. In this case, rent that would normally accrue to the resource owner would simply be dissipated to pay for excess fishing equipment and labor committed to fishing. At this level of output, total receipts are equal to total fishing costs, including the normal return to owners of fishing equipment. Since there is no method for rent to accure, the return normally resulting with resource ownership is divided among the fishing firms.

The size of this "unaccrued" rent is determined by market price and efficient fishing costs. This provides the basis for the estimating method used in Chapter IV. This section is intended only to illustrate how the historical pattern of catch and fishing regulation may have developed. However, it should be noted that the validity of the method used in this study for estimating the value of commercially-harvested fish does not depend on the adjustments that are assumed to have lead to past catch rates. Neither is it the objective of this study to show how the optimum equilibrium for the fishery could be determined. Only the process of adjustments to changes in market price of fish, fishing costs and supply capability are considered here. It will be seen in the following chapter that the present estimating method is limited to historical data and thus the maximum return is not necessarily evaluated.

Over time, market prices have tended to increase, primarily due to population growth and the added competition for fish resources resulting from a rising demand for sport fishing. As pointed out in earlier sections, fishery management policies responded by using regulated inefficiency to increase production costs (i. e., fishing costs) to the point consistent with the desired physical harvest.

By increasing fishing costs through regulated inefficiency, the level of output under conditions of open entry to the fishery can be balanced with the physical capacity of the resource to renew itself. Thus, given market prices and fishing costs resulting from required inefficiency, a long-run equilibrium will exist, since the price of the final product will equate the quantity demanded with the physical capabilities. There is no incentive for additional resources to be committed to or eliminated from fishing. By causing fishing costs to rise, market allocation results in some population equilibrium. This situation occurs for example, at an output associated with fishing effort at OX_1 in Figure 7.

Figure 7. Total receipts and increasing fishing costs as a means to reduce number of fish harvested.



The effect on the equilibrium level of "sustainable physical yield" due to an increase in demand over time (resulting from, for example, population growth) or a reduction in fishing costs (such as might occur from increased supplemental fish production or new fishing technology), will depend on the initial conditions as well as on the direction and magnitude of change. Given the initial level of sustainable yield, an increase in demand will raise the total receipts curve, but the total receipts and total physical product curves could continue to have the same general shape.

An increase in demand, with output at some given level of sustainable physical yield, will result in an increased return to fishermen in the short run, and consequently increased fishing effort. With an increase in fishing effort, the rent that normally would accrue with resource ownership will be dissipated in payment of excess resources committed to fishing. The price advance that increases short-run profits and thus fishing effort can alter the division of product over time. Unless prevented by regulation, this increase in fishing effort will require dipping into the capital stock at the initial equilibrium level. As a result, long-run adjustments could bring forth a reduced level of output, even though fishing costs and effort have increased.

A similar result could be found by tracing the adjustments resulting with a cost-reducing innovation. The initial increase in profit could likewise lead to increased effort and declining yield over time. However, with either increased fish prices or a cost-reducing innovation, long-run adjustments lead to an increase in fishing effort, and thus a reduction in the level of capital stock unless prevented by regulation. In response to the threat to the capital stock of the fishery, as outlined in earlier sections, regulated inefficiency has been widely used to maintain physical output at a level specified by noneconomic criteria.

An important result concerns the fact that economic adjustments with free entry tend to result in increased fishing costs and reduced yield, while noneconomic objectives can lead to increased costs and constant yield. Fishing costs in either case will be influenced by the yield per unit of effort which in turn is dependent on efficiency of gear and fish population. The difference between the two methods can be traced primarily to the means used to increase costs and the resulting production function. With excessive investment in more efficient or equally efficient fishing methods, the physical output will fall over time. On the other hand, excessive investment in inefficient equipment, or further limitations on efficiency of existing methods allows a constant yield to be maintained except for natural fluctuations in fish populations.

Summary of Economic Adjustments

Response patterns to the process of regulated inefficiency can now be summarized by referring to Figure 5. The value productivity potential of the fishery can be increased either by a shift in the demand function, by additional Government programs, or by increased regulated inefficiency to the extent this alters the natural productivity of the fishery (i. e., a change in the long-run yield through additional investment in reproductive fish stocks).

As pointed out in connection with Figure 2, the extent of shifts resulting from a given expenditure depends on the type of additional Government programs. For example, programs designed to continue historical fish runs may not obtain maximum possible physical or value productivity from a given level of investment.

Response due to increased regulated inefficiency has been discussed in preceding sections where a given production function (including some level of public programs) is considered. By referring to Figure 5 the interrelationship between these variables can be seen.

An increase in consumer demand (e. g., due to more consumers over time), would result in an entirely new value productivity surface that is higher at every point than that shown in Figure 5. This will lead to a short-run profit to fishermen due to increased value yield per unit of effort. This short-run profit will entice additional firms to enter using existing fishing methods and thus increase the total cost of regulated inefficiency. Since present fishery management policies balance market price with physical productivity through changes in fishing costs, an increase in market value means that per unit fishing costs must also rise to prevent harvesting of the reproductive stock.

A more common result is for declining physical output over time to be cancelled to a large extent by increased value productivity. This permits a fairly gradual exit of firms and creates a somewhat misleading impression of stable employment for the industry. As a result, regulated inefficiency has required only mild increases which have been achieved in recent times primarily by the subtle shift from gill-net to troll gear (see Appendix Table 7).

An additional result of present management policies is the potential to require society to pay twice for increased physical productivity resulting from Government programs. If all factors remain constant while Government expenditure programs are increased, the increased output would support additional fishing effort. If market price is unchanged, most of the return on the increased expenditure on the fishery will be dissipated to pay for inefficient fishing methods. Thus, society could be forced to pay twice for improved output due to management policies based on regulated inefficiency. The cost of resources to improve output and the cost of regulated inefficiency must both be paid by society. This has not been an obvious problem to date since most expenditure programs have aimed at maintaining--not improving--output of these fish resources. In reality, however, there is little difference between wasting the benefit of a natural resource to pay for inefficient fish harvest and the benefit of a public program to bear this cost.

Although the value of sport fishing has been neglected in this discussion concerning price and output adjustments, this factor, too, must be given adequate consideration. In this case the product is fishing rather than fish. Inclusion of sport harvest affects the economic theory presented to this point primarily by reducing the fish population available for commercial harvest. A consideration of multiple products of different values and demand elasticities is also needed, but this is postponed and included with the empirical results in Chapter VI.

Resource waste in fishing methods (i. e., wasting the value of current product), as well as investment decisions, influence output and benefits from fishery resources. Whenever known technology is ignored in producing a desired consumer product, the nation is poorer, and its standard of living is lower to the extent resources are wasted through needless inefficient production.

Alternative methods of fishery management and the benefits of limited entry are included in this study only to the extent that they affect evaluation of potential benefits. It will be useful, however, to summarize some of the more important results and difficulties to be expected with alternative methods of achieving limited entry.

Alternative Methods of Limiting Entry

Because market pricing has not been used in the past to control use of the fishery, this method is often rejected as unworkable. However, this method of limited entry could conceivably be introduced by imposing a tax or charge on fish harvested. The market value of fish resources would be determined automatically provided the charge for fishing adjusted fishing effort to desired level of harvest. This would provide the means to simultaneously allocate products between sport and commercial fishing according to the desires of consumers (assuming that a charge would also be levied for sport fishing). Preservation costs could be levied, to the extent desired, according to the benefit principle of taxation, and thus the appropriate amount of enhancement or preservation expenditures could also be automatically determined, using the normal allocation functions of market prices.

In view of the apparently high desire to preserve Columbia River anadromous fish, the key to solving this allocation problem would lie in setting the charge for the right to fish such that investment in the capital stock of the fishery and in artificial production facilities would match physical supply capabilities of the fishery with consumer demand.

Market pricing would reflect consumers' desires, fishing and processing efficiency, time of harvest, fishing method, species, area landed, and similar factors. Determination of the correct charge for fishing rights could simultaneously determine the catch to escapement ratio, eliminate inefficient fishing gear, and result in a market price for fish where demand determines the level of necessary investment expenditure to bring forth the desired supply. Thus, market prices would adjust expected returns and consequently investment in the fishery such that physical supply capacity would equal effective demand at this price. This can be contrasted to the existing situation where increased fishing costs are utilized to equate demand with the physical supply capacity with investment determined by noneconomic factors.

With present management policies, investment is not related to consumer demand, although this fact alone simply prevents the level of investment from being tied directly to consumer preferences. But when coupled with the waste of all net benefits, including those from supplemental facilities, through management policies based on regulated inefficiency, the consumer can be required to pay twice for a portion of the run, in addition to waste of net benefits of natural production.

While it is conceptually possible to use direct market pricing to guide production and product distribution, many social, legal, and institutional barriers render this solution as highly unlikely.

It would also be costly, since the contribution of the Columbia River to various Pacific Coast fisheries would have to be carefully ascertained through some system of sampling and recovery. The necessary facilities for administration and enforcement of payment of fishing charges would likewise be expensive. In addition, many changes in harvesting, processing, and marketing might result, which would stir strong opposition from vested interests in maintaining the status quo. Unless sport fishermen were also charged for the right to fish, correct product distribution would not result, and strong social arguments can be presented in favor of continuing sport fishing under the present system which allows equal access to all. Where fishermen from other nations use the resource, international agreement would also be needed. In spite of limitations in using this method, a partial solution to the problem, based on this method, might prove feasible.

As an alternative to direct market pricing, it has been suggested that waste of resources be eliminated by restricting inputs used for fishing. This method would operate through the supply function to reduce fishing costs by replacing regulated inefficiency with a limit on inputs. Instead of restricting output by requiring inefficient fishing methods, limited inputs with more efficient harvest methods would be used. Limited entry, by limiting inputs, could be based on a system of franchised fishing rights. One possibility would be to use existing drift rights for Columbia River gill-net fishermen in addition to a limited number of franchises for other gear.

If imposed by direct regulation, complete success requires that the administrating body allocate resources committed to fishing, so that the maximum contribution from all resources is obtained. This would require a policy sufficiently flexible to match men and equipment committed to fishing with new developments such as changes in consumer preference patterns and fish populations. At the same time, development and implementation of new technology and the effect of this on fishing costs and methods would also have to be taken into account. Division of product between sport and commercial harvest would have to be based on estimated relative values that consumers would be willing to pay if the products were sold in the market.

An important difference between these alternative methods is the group likely to reap the benefits from limited entry. With control of inputs into the fishery, it is likely that a very high capitalization value would quickly be placed on franchised fishing rights. This could result in a windfall gain for those initially holding these rights. With limited entry by charging for the right to fish, the saving from efficient fishing methods could be used to offset the cost of public investment in supplemental production facilities or used for any other purpose. Additional investment might also be deemed justified, due to mitigation expenditures, but this would modify, not negate, the argument concerning potential benefits of limited entry through direct market pricing.

For the purpose at hand, however, it is immaterial how society utilizes these potential benefits of limited entry. Nor is it necessary as a prerequisite for evaluating the magnitude of these potential benefits that they be utilized at all. As a matter of fact, it is conceivable that in the short run it may not pay society to avoid waste of resources resulting from regulated inefficiency. For example, if equipment has no alternative use and displaced labor would be placed on welfare roles, the benefits available from the fishery might appropriately be used as a quasi-unemployment insurance in the short run. This form of underemployed resources could be preferred to unemployed resources. Nonetheless, a definite benefit results from the fishery resources being used that is independent of the choice by which society chooses to use these benefits. However, there is no indication of any such rational decision making to support current waste through regulated inefficiency. Waste of current product value can be traced basically to ease of establishing and continuing this form of economic organization.

The problem under immediate consideration is not how to eliminate the waste of current product values in payment of excess resources committed to fishing, nor to consider all the potential ways that the products can be put to use. The purpose of Chapter III is simply to establish how this waste comes about, and that potential benefits exist if this waste is eliminated. A clear understanding of the fact that the commercial harvest could be accomplished with only a fraction of the inputs committed to fishing under present management policies is, however, a fundamental prerequisite to estimating the potential value of the Columbia River anadromous fishery. Based on this premise, methods of estimating the value of commercial and sport fishing will be considered in following chapters including a discussion of resources actually committed to harvesting Columbia River anadromous fish.

Summary

Although fishery resources are scarce goods to society, they are considered as free goods to the individual fishermen using them.

Where common ownership of the resource exists, future productivity will not be considered in determining the present level of resource use. With no assurance of the right to share in future products, individual fishermen will be concerned only with maximizing the value of resources under his control. In many cases fishing techniques are sufficiently efficient that when combined with strong market demand for the product, the future productivity of the fishery is jeopardized.

In order to prevent destruction of the fishery, management policies have been based on noneconomic criteria and require regulated inefficiency. Regulated inefficiency causes fishing costs to rise in order to assure that the fish harvest is consistent with the physical supply capability of these resources. Although costs are not controlled directly, restrictions set by the regulatory agency take effect through the production function, consequently changing fishing costs. Market price for Columbia River production is influenced by harvest from other areas, but production costs can be varied to assure that demand will be equated with physical supply capabilities.

Limited entry could replace regulated inefficiency as a means of protecting future productive capabilities of fishery resources. It is not necessary for the purpose of the present study, however, to indicate how limited entry can best be implemented. The purpose of this chapter was to clearly establish that the current level of fish harvest could be accomplished using only a fraction of present inputs, if known efficient harvesting techniques could be used without reducing the reproductive capabilities of the fishery. How society seeks to use these potential benefits, or if they are used at all, is not a prerequisite to estimating the benefits of commercially-harvested fish resources.

CHAPTER IV

BENEFITS FROM COMMERCIAL FISHING

Problems concerned with the coexistence of anadromous fish in the face of river basin development, economic growth, and population expansion have been pointed out. The objective involved here is to compare the costs of programs intended to overcome these problems with the benefits which society can anticipate from providing the necessary facilities to permit continued coexistence of anadromous fish and development of the power and other water resource products. With existing fishery management methods, however, only zero net benefit can be expected from the commercial fishery. The reason for this is fishery management policies based on the principle of regulated inefficiency. This was the central topic of Chapter III. Thus, the value of the fishery must be formulated on an a priori basis.

Available methods for estimating the value of both sport and commercially-harvested fish resources are limited to static conditions. The appropriate economic rate of investment and market price and supply responses will, therefore, be considered only in general terms, with data for a specified time period providing the basis for evaluating benefits. Cost data and physical supply capabilities will be based on historical results, with no attempt to determine the extent costs might have been reduced or supply potential improved if past fishery management policies had relied on economic criteria to a greater extent. Fluctuation in fish populations due to natural or random causes will also be omitted by assuming use of expected values.

Before turning to the problem of estimating the potential net benefits attributable to fish resources, the return on capital and labor provided by fishermen using present inefficient fishing methods will be considered. The gross value of commercial fishing at ex-vessel prices (i. e., price received by fishermen) will also be established. Following this description of existing conditions, methods of estimating potential benefits from commercial fishing will be considered.

Present Columbia River Fishing

Nearly all salmon landed by U. S. fishermen were taken on the Pacific Coast. In 1964, for example, total U. S. commercial salmon catch was 352, 321, 000 pounds, with all but 75, 000 pounds of this catch originating in Pacific Coast fishing areas. During this same year, the Columbia River contributed 18, 698, 000 pounds to the Pacific Coast commercial catch, or 5. 3 percent of the total. The Columbia River commercial catch of salmon and steelhead in 1965 was taken 58 percent by troll gear and 42 percent by gill-net gear. This is nearly the reverse of a few years previous. In 1948, for example, only 33 percent was taken by troll gear and 67 percent by gill-net (see Appendix Table 7). These figures do not include a minor commercial percentage taken in the Indian fishery nor the important sport harvest.

Returns to Fishermen

Catch, income and expense data were obtained for several categories of Oregon salmon and steelhead commercial fishermen to provide an estimate of the average returns to fishermen for their capital investment and labor used in harvesting Columbia River anadromous fish. These data are limited in two ways. First, all fishing areas to which Columbia River spawned fish contribute were not sampled. However, this is probably only a minor limitation of the data. Although fishermen are typically not an extremely mobile group, it is likely that important differences in net returns between different geographic areas would be eliminated over relatively short periods of time by labor and capital movement.

A second limitation may be more important. Many fishermen take Columbia River fish in conjunction with the harvest of other species. Particularly important are combined salmon-crab and salmon-tuna trolling operations. The relative predominance of salmon in these and other combinations varies from nearly all salmon to only a minor percentage of salmon. The share of income in these diversified operations, that is due to harvest of salmon, cannot accurately be determined after the fact, since fishermen do not normally isolate items of income and expense according to species harvested. While estimates could be obtained, it is likely that serious memory biases would exist. Since this aspect is of minor importance to the central purpose of the study, no effort was made to measure efficiency of salmon harvest in diversified fishing operations.

The basic catch data for Oregon fishermen were obtained by means of complete enumeration of all Oregon fishermen and out-of-state fishermen landing fish in Oregon. This was combined with income and expense data to indicate returns to fishermen using present harvest methods. However, it is emphasized that this does not represent an income figure for fishermen, since data relates only to Columbia River harvest. Individuals may have been involved in other activities for much of the year since, for example, the gill-net season in 1965 comprised only approximately 80 days (Appendix Table 8).

The Data Sources

Data cards for 1964 and 1965 for all fish landings in Oregon were transferred to magnetic tape. Data by individual fisherman number were subsequently summarized for all fishing operations in 1965 in total pounds landed of each species for each fisherman. Selected fishing operations were summarized for 1964. These data were summarized to indicate catch by specie and by individual fisherman.

From the above data it was possible to select, by fisherman number, a sample of 35 high-catch Oregon trollers and three categories of Oregon gill-netters. The gill-net categories were divided into a high-catch group, apparently fishing full time, a lower-catch group, also apparently fishing full time (based on number of days fish were landed), and a group selected by members of the Oregon Fish Commission, based on past reputation as "high-liner" or excellent gill-net fishermen. Duplication between the latter category and that included in the previous two groups was eliminated. The average catch data for each of these categories is summarized in Table 7.

Income and expense data on these same fishermen were obtained from the Research Section of the Oregon Tax Commission. Identity of all individuals was concealed by assigning a new number to each fisherman, and cross-reference between Fish Commission numbers and those assigned by the Tax Commission was known only by the latter group. The items of income and expense for each of these groups are added to the catch data for that group in Table 7.

Table 7. Catch, net return, and items of income and expense for Oregon gill-netters and troll fishermen[1/]

	Catch	Average number of fishing days	Bus. profit or loss	Total receipts	Cost of labor	Mat. and sup.	Other costs	Depre-ciation	Taxes on bus. & prop.	Rent on bus. prop.	Repairs	Ins.	Legal & profes. fees & comm.	Int. indebt.	Other expenses
B[2/]	19,677	37.7	3,169	5,874	78	1,469	23	305	45	64	312	39	10	7	351
C			5,200	11,896	380	3,057	0	1,009	73	66	877	192	15	43	891
A	31,401	63.1	4,660	8,413	265	1,482	16	465	88	103	529	87	23	12	683
T	19,837	31.8	3,668	8,000	261	1,373	265	675	59	175	867	136	43	40	438

Investment Data

	Vessels	Vehicles	Other	Total investment
B	1,465	247	103	1,815
C	5,328	691	1,190	7,208
A	2,185	389	939	3,612
T	5,846	269	182	6,297

1/ Source: Oregon Fish Commission at Portland and Clackamas, Oregon, and Oregon Tax Commission at Salem, Oregon. (Catch in pounds and income and cost figures in dollars.)

2/ Category B is low catch gill-net fishermen; Category A is high catch gill-net fishermen; Category C is "high liner" gill-net fishermen selected by members of Oregon Fish Commission; and Category T is troll fishermen.

It can be seen in Table 7 that both Category A and Category C gill-netters were considerably more profitable than trollers or Class B, the lower-catch gill-netters. Category C obtained by far the highest total receipts from fishing for Columbia River anadromous fish. It must be remembered that data on trollers does not include any diversified operations.

The small investment values shown in Table 7 indicate that much of the fishing equipment has been in service for many years. Since these investment data indicate only the original purchase price, changes in market value are not included. An indication of market value of equipment used by gill-netters is available from a survey conducted by the Columbia River Fishermen's Protective Union in 1965. This survey of 36 fishing operations indicated an average investment, based on market values, of $5,998 in boats, $933 in nets, $2,100 in dock facilities (for those having dock facilities only), and $1,482 in drift rights (for those holding drift rights only.)[8/]

A reasonable return on the market value of investment is a justifiable economic cost. However, this would not alter the total return to fishermen. If this adjustment were taken into account, the portion of income derived from labor would be reduced while that from return on investment would be increased, but the total would remain

8/ Investment data furnished by the Columbia River Fishermen's Protective Union, 1965.

unchanged. Since the total return only was desired, no attempt was made to determine return by components of labor and capital.

Catch Attributable to the Columbia River

Columbia River spawned salmon are taken in coastal waters from northern California to Alaska, in the inland Columbia River, and subjected to harvest by other nations, particularly Canadians. With the mixing of stocks in the ocean, determining the proportion of catch originating in a particular area depends on some method of marking a sample of fish and recovering these marked fish, or on the ability to recognize peculiar characteristics that distinguish origin of harvested fish.

Only limited data are available to indicate the percentage of the catch in any area that can appropriately be attributed to Columbia River origin. Two principal methods can be used to develop data of this type. Fish can be captured in selected ocean fishing areas, tagged, and released. These tags are then recovered in the gill-net fishery or spawning areas after the fish return to their native river to spawn. A second method involves marking young fry prior to entering the ocean, and then recovering these fish for tabulation at processing facilities and from sportsmen. This latter method, for example, was used in evaluating the production of fall chinook at 12 hatcheries operated in connection with the Columbia River

Fisheries Development Program. However, capturing young fish originating outside of hatcheries presents a major obstacle to extending this method to use on "wild" fish. Furthermore, many young fish are destroyed or impaired by the marking process, which introduced an important bias in the results. This death loss in an experiment by Wahle[9/] on sockeye salmon was estimated at 38.4 percent. Cleaver (10) evaluating this loss in connection with the fall chinook study mentioned above, found death loss resulting from marking may have ranged from 51 to 64 percent.

The most reliable data available on the Columbia River contribution of chinook salmon to Pacific Coast Fisheries has been estimated by Jack Van Hyning (88). (See Appendix 22 for hatchery contributions.) These estimates are based on ocean tagging studies with subsequent recovery in the spawning rivers. The results of this work are included in Table 8, and the tagging studies on which the estimates of chinook salmon distribution are based are summarized in Appendix Table 9.

The validity of ocean tagging studies with subsequent recovery in spawning rivers is affected by varying ratios of recovery in alternative areas due to factors other than origination. Especially

---

9/ Roy Wahle, Bureau of Commercial Fisheries, Portland, Oregon (unpublished research).

Table 8. Estimated percent of commercial catch of anadromous fish attributable to the Columbia River [1/]

State and region	Chinook salmon	Coho salmon	Chum salmon	Sockeye salmon	Steelhead trout	Shad
			Percent			
Oregon -						
Coastal troll catch	47.0	45.5				
Columbia River troll catch 2/	80.0	59.7				
Columbia River gill-net catch	100.0	100.0	100.0	100.0	100.0	100.0
Washington -						
Puget Sound troll catch 3/	50.0	11.3				
Coastal troll catch	65.0	11.3				
Columbia River troll catch 2/	80.0	80.3				
Columbia River gill-net catch	100.0	100.0	100.0	100.0	100.0	100.0
Alaska -						
Southeastern troll catch	45.0	---				
British Columbia, Canada -						
District 2 troll catch	25.0	---				
Areas 21-27 troll catch	45.0	1.1				
California -						
Coastal troll catch	---	37.7				

1/ Source: Percentages for chinook salmon for areas other than Columbia River are estimates by Jack M. Van Hyning (88). Percentages for coho salmon for areas other than the Columbia River are estimates by the Columbia River Program Office Staff, Portland, Oregon; based on a study by the Washington State Department of Fisheries on the 1963 brood of marked coho from the Washougal hatchery.

2/ Caught at the mouth of the Columbia River.

3/ Caught in the Pacific Ocean and landed in the district.

where hatcheries are present, or there is an intensive fishery in the river, the recovery percentage in one river may outweigh that in others. If one race of chinook is more vulnerable to ocean harvest, this also can alter the level of recoveries returning to fresh water to spawn. Age differences have also been found to be important. In a particular region, fish from one river system may tend to be mature while those from another immature at tagging, and thus subject the latter to a longer period of ocean harvest. (88)

In recent years, the commercial coho salmon catch has increased in importance in the production of the Columbia River. Part of this increased output apparently can be traced to hatchery activity and part to an over-all trend toward improved production for this species. At present, the contribution of the Columbia River to the commercial coho salmon catch in Pacific Coast fisheries is estimated on the basis of sampling from one hatchery for a single brood year. Additional hatchery fish have been marked, but insufficient time has elapsed for these fish to be landed and marks tabulated. For the present, estimated percentages must be based on the limited information indicated above. This data also is included in Table 8.

In addition to the commercial chinook and coho salmon catch in Pacific Coast fisheries, Table 8 also includes all of the inner Columbia River catch of commercial landings of chum salmon, sockeye salmon, steelhead trout, and shad. Although minor quantities

Table 9. Commercial catch of anadromous fish attributable to the Columbia River, 1948-1965 1/

Year	Chinook	Coho	Other salmon and steelhead	Shad	Total
			Thousand pounds		
1948	24, 410	3, 226	2, 534	395	30, 565
1949	18, 567	2, 400	1, 383	437	22, 787
1950	16, 452	2, 844	1, 849	687	21, 832
1951	21, 806	3, 372	1, 908	426	27, 512
1952	20, 671	3, 934	2, 479	378	27, 462
1953	19, 534	2, 849	2, 297	277	24, 957
1954	15, 693	2, 053	2, 014	246	20, 006
1955	19, 513	2, 607	1, 647	285	24, 052
1956	18, 231	3, 378	1, 159	245	23, 013
1957	16, 093	3, 327	1, 024	150	20, 594
1958	14, 607	1, 779	1, 518	194	18, 098
1959	12, 025	1, 603	1, 362	132	15, 122
1960	9, 873	1, 140	1, 138	170	12, 321
1961	9, 474	2, 203	892	406	12, 975
1962	10, 602	2, 957	821	895	15, 275
1963	11, 007	3, 545	1, 038	859	16, 449
1964	11, 783	6, 095	515	305	18, 698
1965	12, 514	7, 756	518	351	21, 139

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Department of Fisheries of Canada, and percentage summarized in Table 8.

of these fish may be landed in other areas, insufficient evidence exists to justify attributing any additional amounts to the total quantity of fish originating in the Columbia River.

By multiplying the total catch landed in each area (8, 81) by the percentages shown in Table 8, the total pounds of fish attributable to Columbia River origin were determined. This commercial catch is presented in Table 9. A more detailed breakdown by areas is given in Appendix Tables 10 and 11. As shown in Table 9, the catch attributed to the Columbia River declined to a low of 12,321,000 pounds in 1960, but since that date there has been a marked increase in catch. The catch of coho salmon has been particularly important in this improved productivity. This reversal in the downward trend in catch may be an indication of success of programs initiated to maintain anadromous fish runs.

Gross Economic Value of Commercial Fishery

Programs aimed at maintaining salmon production affect virtually the entire Columbia River run. As a result, the gross value of the commercial harvest is the ex-vessel price received by fishermen. This is the total revenue received by fishermen for their labor, management, and capital used in landing Columbia River anadromous fish. Nonanadromous fish such as sturgeon, even though landed commercially, are excluded since production does not depend on programs to preserve anadromous fish runs. Shad, on the other hand, are included in the catch since it is likely that fish passage facilities are beneficial to this species.

A value for the British Columbia, Canada, commercial catch is also included. Although this benefit does not represent a return to United States citizens, fish originating in Canadian waters are taken in American fisheries and provide income to U. S. fishermen. This reciprocal supply situation, due to intermingling in the ocean, is considered sufficient justification to include the contribution of the Columbia River to the British Columbia commercial catch in the total value attributable to the Columbia River.

The gross value of the Columbia River commercial fishery, at the fisherman level, is presented in Table 10. These figures are based on the estimated percentage of the catch taken in each area (8, 81) and the method discussed in the previous section to isolate the Columbia River contribution. The gross value of the commercial Indian catch, however, is excluded. The Indian fishery is discussed separately in a later section. More detailed data on the catch, by area, for chinook salmon is given in Appendix Table 12 while comparable data for coho salmon is listed in Appendix Table 13.

The data in Table 10 represents the gross value of the commercial fishery to fishermen only. However, several possible modifications may affect these gross values. Troll fish are normally dressed

Table 10. Gross benefits derived by fishermen from commercial catch of anadromous fish attributable to the Columbia River, 1948-1965 1/

Year	Chinook	Coho	Other salmon and steelhead	Shad	Total
			Thousand dollars		
1948	5, 298	691	382	25	6, 396
1949	3, 522	345	163	29	4, 059
1950	3, 922	641	284	45	4, 892
1951	5, [illegible]77	680	364	34	6, 455
1952	4, 823	660	479	38	6, 000
1953	4, 372	474	400	30	5, 276
1954	3, 797	384	368	22	4, 571
1955	5, [illegible]	562	324	26	6, 082
1956	5, 456	847	263	27	6, 593
1957	4, 627	678	247	12	5, 564
1958	4, 799	518	400	19	5, 736
1959	3, 789	453	358	11	4, 611
1960	3, 641	444	314	14	4, 413
1961	3, 788	661	250	39	4, 738
1962	4, 509	863	245	109	5, 726
1963	4, 379	890	284	39	5, 592
1964	4, 456	1, 778	146	15	6, 395
1965	4, 415	2, 154	147	16	6, 732

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior and Department of Fisheries of Canada, and percentages summarized in Table 8.

immediately after landing, while fish landed on gill-net gear are sold on a round basis. As a result, troll fishermen perform some of the functions that would be included as processing for gill-net fishing. There is a considerable difference in the price per pound between fish landed by troll gear and those taken in gill-nets, reflecting primarily this "processing" function by troll fishermen. There may also be a quality differential included in price, although this advantage in quality may be counteracted by a lower quality product resulting from taking immature fish on troll gear.

In addition, processing firms can provide services or perform functions normally included in fishing, such as providing buying stations or "tender" vessels to collect fish. A part of the fishing equipment might also be provided, such as nets. Loyalty to a particular processor may also be secured by payment of a bonus that would not be reflected in ex-vessel prices, and consequently omitted from the total gross value of commercial fishing.

Gross value may be understated in some cases where processors transfer potential monopsonistic funds to fishermen in competing for limited supplies of raw product harvested under regulated inefficiency. [10/] This transfer may result either by reducing fishing costs, by furnishing additional services or by directly supplementing

---

10/ For example, see (79, p. 25).

income through a bonus or similar technique. This has been estimated to amount to as much as 10 to 15 percent of the gross values shown in Table 10, but sufficient evidence is unavailable to confirm or reject this conjecture.

It should be noted, however, that this is not simply a transfer of benefits from secondary to primary benefit categories. Monopsonistic processors concerned about potential entrants normally would be forced to pass any possible profits on to consumers in the form of lower retail fish prices. In this case, competition for supplies of raw product by all processors provides a stimulus to transfer potential profits back to fishermen and increase the need for regulated inefficiency by reducing fishing costs rather than reducing retail fish prices. As a result, this represents a potential transfer from consumers to fishermen and expands the incentive to commit excess resources to fishing through actions of processing firms.

Net Benefits of Commercially-harvested Fish

Estimation of the net economic value, ideally would permit comparison of net fishery benefits with similar figures for other products.

Senate Document 97 (52) sought to accomplish this goal. In the absence of market prices, this document recommends that the value of fishing be derived or established by subtracting associated costs from the increase in market value. Since the entire anadromous fish run is affected by Federal programs, and runs above all high dams would be eliminated without passage facilities, the gross value of the entire fishery is involved.

Associated costs are defined as those costs necessary to make the immediate product available for use or sale (52, p. 11). In this case, associated costs can be considered as the cost of landing fish. If a return to fishermen is included as a cost in the usual manner, the expected net return for the fishery will be zero, since fishing costs will equal ex-vessel fish prices received by fishermen because of the economic organization that exists. Entry or exit of fishermen over time will assure that the marginal unit earns only a return equal to opportunity costs. Thus, the net economic value of commercial fishing, if calculated according to the method defined by Senate Document 97, will be equal to zero. The value each fisherman places on his own resources will assure that fishing costs will equal ex-vessel market price if all economic adjustments are complete.

One possible alternative to this method would be to define the return to fishermen for labor, management, and investment as the net value of the fishery. This method of estimating net benefits has at least some limited official acceptance as an interim method of establishing values of commercially-harvested fish resources for use in comparison with the value of other water uses. This net return to fishermen indicates a special type of value to the region. This is not equivalent, however, to determining the regional value of the fishery which would include inflows and outflows to and from the region that are associated with fishing activity. 11/ This figure does indicate the value of employment in fishing although this has only limited usefulness, even in regional analysis. Throughout this report, the value of the fishery to society (i.e., the nation) has been emphasized and this continues to be the value of central concern. Determining the return to fishermen, however, provides a useful starting point for indicating potential benefits from reducing or limiting resources presently committed to fishing.

The estimated catch of Oregon gill-netters and specialized trollers is given in Table 7. A simple average of gill-net Categories A and B indicates that a good, full-time fisherman landed 25,539 pounds. All low catches, however, were excluded from these two categories. This figure is also supported by estimates by the Columbia River Salmon and Tuna Packers' Association (1965) that placed the catch of a better-than-average, full-time fisherman at 24,000 pounds.

11/ For examples of a regional approach, see (16, p. 5-15; and (23).

The 1965 catch of anadromous fish was 21,139,000 pounds (Appendix Table 14). Of this total, 8,997,000 pounds (43 percent) were landed by gill-nets. This total includes the 1965 shad catch of 351,000 pounds. If the total catch is divided by 25,539 pounds, the average catch for good, full-time gill-netters, it can be seen that 352 full-time equivalent fishermen would have been necessary to land the total catch. 12/ An equivalent figure for 1964, based on the same average catch, is 289 full-time fishermen and in 1963, 266 full-time equivalent fishermen would have been necessary, operating under existing legal constraints, for gill-net fishing.

The above method, using the average troll catch of 19,677 pounds (Table 7), can also be used to indicate the number of full-time equivalent fishermen necessary to land the annual harvest taken by this gear. Total catch, number of full-time equivalent fishermen, total gross value, total fishing costs, and net returns to fishermen using both troll and gill-net gear, is summarized in Table 11 (excluding the return for the Indian fishery).

Of course, many more fishermen actually participated than the number indicated in Table 11. Many fish only part-time or occasionally, while others combine salmon fishing in several areas

---

12/ A full-time fisherman is one fishing essentially all of the open commercial season.

Table 11. Total catch, costs and returns to Columbia River troll and gill-net fishermen

	Unit	Gill-net			Troll 1/			Total		
		1963	1964	1965	1963	1964	1965	1963	1964	1965
Total catch (Appendix Table 14)	Thou. lbs.	6,799	7,373	8,997	9,650	11,325	12,142	16,449	18,698	21,139
Full-time equivalent fishermen 2/	No.	266	289	352	486	570	612	752	859	964
Gross value (Appendix Table 15)	Thou. dols.	1,868	2,078	2,451	3,724	4,317	4,281	5,592	6,395	6,732
Total fishing costs (based on Table 7, using full-time equivalent	Thou. dols.	415	415	550	1,182	1,386	1,488	1,597	1,837	2,038
Total returns to fishermen	Thou. dols.	1,453	1,627	1,901	2,542	2,931	2,793	3,995	4,558	4,694
Average income per full-time equivalent	dols.	5,462	5,630	5,401	5,230	5,142	4,564	5,313	5,306	4,869

1/ Includes specialized troll operations only.

2/ The number of full-time equivalent fishermen differs from year to year with the change in total catch. This could result from entry and exit of part-time and occasional fishermen, shift in fishing units from other areas, or a shift from fishing for nonanadromous species (e. g., less emphasis on tuna and more on salmon in diversified trolling operations).

such as Alaska and the Northwest, or combine salmon fishing with the harvest of other species. Tuna and crabs, as pointed out earlier, are particularly important in this latter case. In addition, fishing may also be combined with nonfishing activities, even though the individual fished, essentially, full-time, since the gill-net season in 1965 was only about 80 days (Appendix Table 8).

The average receipts per full-time equivalent fisherman, shown in Table 11, are somewhat greater than the business profits indicated for similar Oregon categories in Table 7. This could be a result of profit differences between fishing areas, variations in gear used, catch rates, labor costs, and similar factors.

A greater share of both chinook and coho salmon are normally taken by troll gear than by gill-nets, although to a lesser extent for chinook harvest. In the Oregon case, however, in 1965 only one percent of the chinook harvest (48,508 pounds) was taken on troll gear, while about 66 percent of the coho landings were taken by trollers (48). This compares with 50 percent of the chinooks and 75 percent of the coho for the entire Columbia River harvest (Appendix Table 14). This situation can be attributed primarily to the fact that Columbia River coho salmon normally migrate south while chinook salmon turn north of the Columbia (see percentages in Table 8).

At any rate, the data in Table 11 are intended to provide only a reasonable estimate of the existing total return to commercial fishermen associated with harvesting Columbia River anadromous fish. While this may be of special interest in regional problems, it does not indicate the potential value to society that could be obtained if regulated inefficiency were replaced with limited entry. In other words, the net returns of Table 11 provides an estimate of the actual employment in the region as contrasted to estimating the potential net benefits to society.

Estimated Potential Net Value from Commercial Fishing

The basis for estimating the potential net value of commercially harvested fish resources of the Columbia River was established in Chapter III. Regulated inefficiency has been used to prevent depletion and possible destruction of the fishery. The free entry, common property nature of this form of economic organization allows the value of the resource to be dissipated to pay for excess labor and equipment committed to fishing. Thus, the value that would appear as rent with resource ownership is misappropriated to pay for additional fishing effort made necessary through the use of inefficient fishing methods.

It has been suggested by Crutchfield that the value of commercially-harvested fish resources can be estimated by the difference between efficient and inefficient fishing methods (18). This is equivalent to estimating the cost to society of regulated inefficiency. This is the amount that society could save if a public "owner" limited use of the fishery and allowed efficient production methods to be used. Although a public agency functioning as "resource owner" would be equivalent to a monopolist, this estimated value is distinguished from the ordinary concept of rent by exclusion of any possible return resulting from artifically created scarcity. This value has been designated as "social surplus" or yield of a natural resource by Gordon.

> "In this case we are maximizing the yield of a natural resource, not a privileged position, as in standard monopoly theory. The rent here is a social surplus yielded by the resource, not in any part due to artificial scarcity, as in monopoly or rent." (31, p. 141).

The "social surplus' possible from the fishery at any point in time is equivalent to the cost to society of regulated inefficiency for that specific time period, according to the method suggested by Crutchfield. It is the value of the resource that is dissipated to pay for unnecessary resources in fishing.

Empirical application of this method requires that fishing costs, using the most efficient known methods to achieve the desired harvest must be estimated. [13/] This amount is then deducted

---

13/ For an example of implemention of this method, see (25, p. 256-267).

from fishing costs, using existing harvesting methods, and the potential savings is designated as the net value of the fish resource. This saving can be used by society for any desired purpose, or not used at all, without altering the conclusion. It should be noted, however, that this saving could actually be realized, if desired. For example, as outlined in Chapter III, by imposing a tax and eliminating all but emergency restrictions on fishing methods or by limiting inputs.

Since this estimating method depends on determining the difference between cost of efficient and inefficient harvest of a given physical yield, an automatic adjustment mechanism is necessary to match inefficient fishing costs to any long-run changes in the total revenue situation. This means that fishing costs resulting from regulated inefficiency must be dependent on equilibrium market price.

It was pointed out in Chapter III that fishermen are competitively organized. The fishing industry at fisherman level is characterized by small firms, no one firm influences price, entry is easy although exit may be limited at times by lack of alternatives, and the product is essentially homogenous. Fishing costs will include a return on all inputs owned by fishermen equal to that which could be earned by these inputs in the open market.

When all fishermen are considered as a group at any particular time, it is the value that the marginal fisherman places on his own resources, particularly his own labor, that will guarantee that fishing costs will always equal the market price provided sufficient time is allowed for all adjustments to be completed. While the value of the resources owned by any individual fisherman may be a constant at a particular point in time, if all fishermen are taken into account, this factor becomes a variable. Furthermore, over time, this value will vary even for the individual fisherman, due to changes in alternatives available both within as well as outside of the fishing industry, changes in social characteristics such as age and education of fishermen, and changes in preferences of individuals.

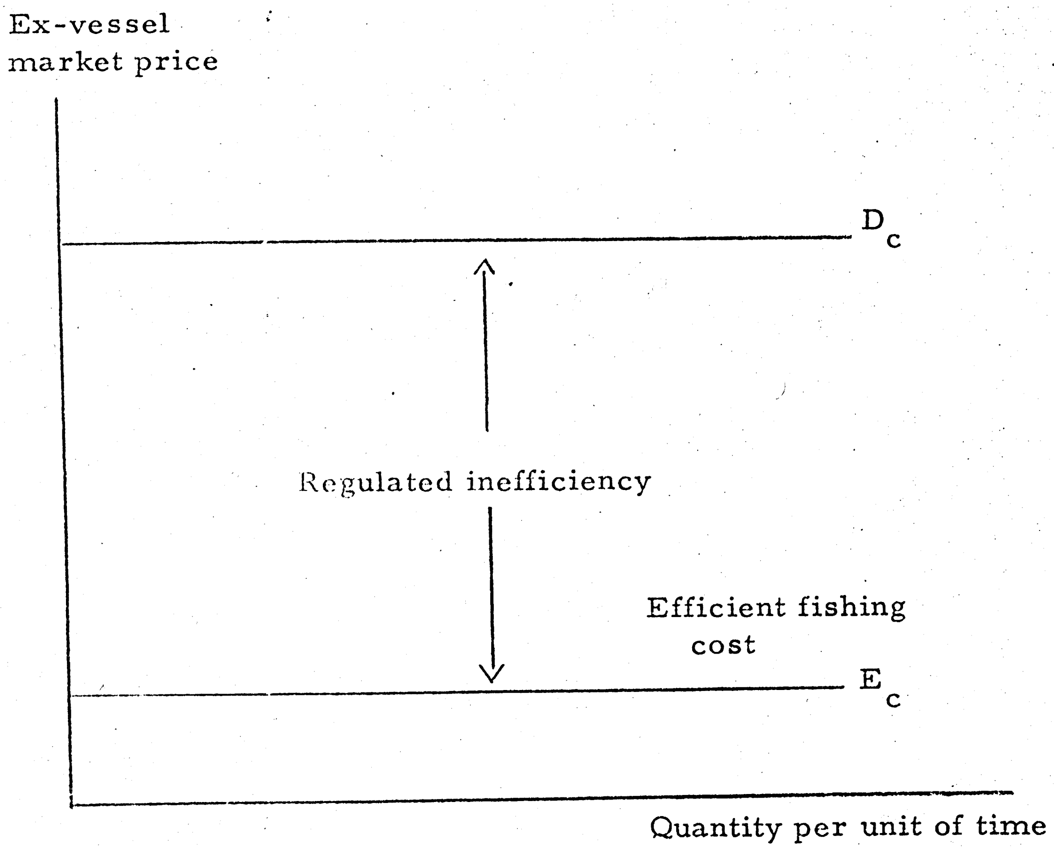
As typical of a competitive industry, the entry or exit of firms over time will eliminate any profit or loss, with the marginal unit earning only its opportunity cost. At the same time, however, profits may vary around zero in the short run, due to imperfect knowledge and natural fluctuations in fish populations.

Since the fishing industry at the fisherman level approaches a purely competitive market structure with easy entry, the ex-vessel market price fishermen receive is also the cost of fishing if a return to fishermen is included as a cost in the usual manner. The difference between existing ex-vessel price (i. e., existing fishing costs) and the cost of harvest, if the most efficient method known were used, depends on fishing technology and market price.

However, the quantity involved depends on physical yield as determined by past investment decisions (i. e., investment in both reproductive stock and supplemental facilities through government programs). The difference between efficient and inefficient fishing methods, therefore, represents the potential saving to be expected by society if regulated inefficiency were replaced by limited entry and if market prices and physical yield capability of the fishery is given for a particular time. This is an expected value due to stochastic variations in fish populations. The importance of these limitations to the estimating method will be considered fully in a later section.

This short-run situation, with given supply and demand conditions as indicated above, is demonstrated in Figure 8. Variations in market price due to quality, area, or other market conditions, are ignored for the sake of simplicity in the assumption of a single market price. In Figure 8, D_c represents the market price for salmon and other anadromous fish. E_c is the cost to one firm to land fish, assuming that, except for emergency restrictions, fish could be landed in any area desired, at any time, and by any type of gear. In other words, except for regulations, E_c represents the cost to land fish if all existing technology could be used by fishing firms without restrictions, other than emergency measures to provide for unforeseen threats to fish populations. It should

Figure 8. Hypothetical short-run ex-vessel market price, efficient fishing costs, and potential rent



also be noted that existing total fishing costs do not need to change due to limited entry. If a tax were imposed, for example, the cost of regulated inefficiency would simply be replaced by the tax. If inputs were limited by franchise, the value of the resource could be capitalized into the value of the franchise.

If regulated inefficiency should be replaced by an ad valorem tax based on pounds of fish landed, the average cost curves of the fishing, operating under competitive conditions, would be expected to have the same minimum point as that previous to imposition of the tax. With variable costs much more important, however, responsiveness of firms should be increased, which could improve control over the level of harvest. An increase in output might also result if fish were harvested at near-optimum maturity as they approached or entered spawning streams. Any reductions in reduced commercial landings of immature fish would likely be neutralized to some extent by increased sport fishing, if intensity of ocean commercial fishing was reduced or eliminated. However, trolling either by specialized or by diversified commercial firms or by modified sport vessels during peak periods might remain competitive.

Fishing Costs, Using Known Technology

Empirical research or actual implementation is needed to determine the most efficient method of landing Columbia River anadromous fish, if all known technology were available for use and all restrictions, such as seasonal limitations, were eliminated. Expenditures for this type of research are limited since the only reason for determining the least-cost method of fishing is to provide the means of estimating the value of commercially-harvested fish. No improvement in efficiency is actually being proposed for implementation.

In spite of these limitations, it is possible, based primarily on historical information, to indicate tremendous potential improvements in fishing efficiency. It should be realized, however, that the methods suggested in this study might not prove to be optimum if subjected to a more careful investigation that could be supported by empirical testing.

Methods of capturing fish that have been proven successful on the Columbia River and outlawed in connection with regulated inefficiency over approximately the last 80 years provides one useful source of information. However, these data are limited by new developments in fishing technology, river navigation, channel changes, relocation of processing facilities, and similar factors. Another possibility is to estimate fishing costs, based on current operations in other areas. A final possibility is to estimate costs, where this can be accomplished at a cost justified for research not actually proposed for implementation, and where sufficient reliability can be assured without empirical testing. All these methods are used in this study.

Many types of fishing gear have been used in the Columbia River in the past, prior to being outlawed in the process of enforcing regulated inefficiency. In addition to season and area closures to control fish landings, gear limitations were first introduced, with subsequent legislation imposed eliminating certain types of gear. Purse seines were prohibited by 1917. Fish wheels were banned in Oregon in 1927, and in Washington by 1935. Traps and seines were eliminated above Cascade Locks. The length of gill-nets was reduced. All of these gear limitations were consistent in both Washington and Oregon by 1935. Commercial fishing in the upper river was restricted to five miles above Bonneville to the mouth of the Deschutes River and eventually eliminated entirely except for the Indian catch. At present only gill-net, dip-net, and sport gear is allowed on the Columbia. All commercial harvest except the Indian catch is restricted to the area from the mouth to five miles below Bonneville. Of course, troll gear on the ocean in recent years has taken approximately 60 percent of the catch and reduced the importance of the river fishery (Appendix Table 14).

Available data on each type of gear will be briefly summarized, in order to indicate its effectiveness in harvesting the Columbia River run. From this data, an efficient method of fishing will be selected and costs estimated. Although this method may not represent optimum efficiency, it will at least provide an estimate of the cost of regulated inefficiency.

Fish Wheels

Fish wheels, with their enormous potential to operate at low costs, are one example of an efficient fishing method. In this contraption:

"The salmon were guided into revolving wheels (kept in motion by the current) and down a chute into a large bin on the shore. Some wheels had long leads of piling running out into the river directing the fish into the wheel's range. The wheels were 9 to 32 feet in diameter. Automatic contrivances, they were cheap to operate and vastly efficient. One wheel could take as many as 3,000 salmon a day." (45, p. 27)

While this gear is inexpensive to operate, its effectiveness in harvesting an important share of the total run is severely limited by the availability of suitable sites, as well as by appropriate stream flows. Several fish wheels have been constructed in recent times for research or fish propagation, including diversion during dam construction. An extremely complete historical record on the operation of fish wheels, as well as data on modern wheels constructed for research or similar purposes, is available in Fishwheels of the Columbia:

"During the period from 1879 to 1935, there were at least 79 known different stationary wheels on the Columbia. Perhaps seven of these can be considered truly outstanding, as they caught well every year, were dependable, and set or nearly achieved records; they were the real bread-and-butter machines. In the Dalles-Celilo area, five stationary wheels were in this category . . . In the Cascades region Warren Packing Company's wheels 16 and B-1 were the best." (Table 12) (21)

Donaldson and Cramer, quoting from the Oregon Voter's Pamphlet issued prior to the general election of November 2, 1926, noted, among other things, the following statements (21):

Table 12. Historical catch of selected fish wheels

Wheel	Total catch	Ave. per season	Years of operation	Best yr's. catch
	Pounds	Pounds		Pounds
No. 5 (The Dalles-Celiio)	4, 625, 776	145, 993	1893 & 1898 thru 1927	417, 855
Tumwater No. 1 (The Dalles-Celilo)	2, 374, 072	74, 190	1896-1927	290, 365
Cement (The Dalles-Celilo)	1, 352, 726	64, 415	1906-1926	154, 940
Tumwater No. 2 (The Dalles-Celilo)	988, 197	36, 660	1897-1926	114, 670
Cyclone (The Dalles-Celilo)	984, 288	44, 740	1912-1934	225, 165
Wheel 16 (Cascades)	966, 573	40, 274	1909-1934	122, 238
Wheel B-1 (Cascades)	933, 310	40, 580	1909-1933	97, 640

"10. The fact fishwheels take a small percentage of the total catch means nothing. It does mean something, however, that a single fishwheel has been known to take 24 tons of fish in 24 hours, which is as many tons as the average gillnet fisherman could take in four years of continuous labor each season."

Donaldson and Cramer conclude the following:

"In retrospect, the long, drawn out and recurring fish fights on the Columbia were not fought for conservation, as the window dressing depicts. The compelling reasons were economic, with each side striving to catch as many fish as possible, with the low-cost wheel production on the upper river being particularly irritating to the lower river operators." (21)

From this discussion, it can be noted that fishwheels, especially the stationary type, were low-cost, efficient contrivances, but were limited to available sites. Many of these sites are now flooded by the pools formed behind dams. If fish could be harvested by any desired method, undoubtedly some fish would be taken by wheels, especially during the early runs. The portion harvested by this means would be accomplished with great efficiency. Available sites, stream flows and water conditions, and timing of present runs would be important factors influencing the effectiveness of this gear.

Trolling

Another interesting point about the historical data presented above is the troll catch that is shown in Table 13. In 1925, troll gear accounted for over 17 percent of the fish landed, although numerous types of other gear were legal. Of course, these figures refer only to the Oregon catch, and thus are not percentages of the total run. Also much more of the run was probably taken in the river in 1925 than at present, influencing the proportion taken by Oregon fishermen. These troll catch figures, support Van Hyning's discussion of Silliman's tagging work, where he notes:

Table 13. Historical data, Columbia River, commercial catch by gear, 1925 1/

Gear	Pounds	Percentage
Gill-net	11, 745, 416	59.62+
Troll	3, 386, 558	17.19+
Traps	191, 739	.97+
Set nets	76, 235	.37+
Wheels	1, 214, 720	6.16+
Seines	2, 943, 047	14.93+
Indians	142, 042	.17+
Total	19,699, 757	99.98

1/ Source: (21)

"During the period 1926-45 he estimated that the troll catch of Columbia River chinook ranged from 5.0 to 10.6 million pounds, while the river catch ranged from 12.4 to 21.8 million pounds. While this can be considered, at best, only an order of magnitude estimate, it indicates that the offshore catch was significant, even in those early years--perhaps one-half of the inside catch." (88)

The natural traits of salmon that require them to return to fresh water at maturity subjects these species to potentially efficient harvest methods. Troll gear, on the other hand, operates while fish are widely dispersed in the ocean and of varying degrees of maturity. However, troll gear operates on mixed stocks of several year populations, and is able to initiate fishing on available stocks prior to other types of gear. Thus, more efficient gear takes advantage of the natural tendency for anadromous fish to conglomerate in shallow rivers at maturity, while troll gear harvests from mature and semi-mature stock with the advantage of harvest prior to the time when the fish population is subjected to the more efficient methods.

The maximum yield possible from any level of investment in the fishery will, of course, be reduced to the extent that fish are taken prior to maturity except where natural mortality and over-all yield of the fish population run counter to this. Furthermore, the efficiency of less costly means of taking fish may likely be reduced to the extent that population available for harvest in a given time period (e.g., per day, per turn of a fishwheel, per drift of gill-net, etc.) is reduced by prior troll harvest.

To an important extent, troll gear also competes with the sport fisherman as well as effecting other means of commercial harvest, similarly to the effect of sport gear. Both harvest from several year populations, and from mixed stock. Thus, troll fishing may influence the important quality variable in sport harvest.

<u>Fish Traps</u>

Fish traps have been used in recent times for research purposes and as a means of diverting fish for propagation. Details on construction design, materials, and effectiveness of fish traps were furnished by John Broughton.[14/] Broughton Brothers had constructed over 100 traps during the era when these were legal, plus traps for research and similar purposes in more recent times.

Fish traps represent an extremely low-cost means of taking fish and would have considerable potential if they were legal. Changes in the river channel, navigation requirements, and similar factors would, however, have to be taken into account in appraising their efficiency.

Seines

Beach seines were also effectively used before being outlawed. Here again, lack of data concerning available sites, and effectiveness of this gear under existing conditions, severely limits any conclusions that can be reached. In general terms, a portion of the landing would probably fall prey to this gear if it were legal, depending on availability of sites. This gear would also be effective at the mouth of the river.

Purse seines, which were first to be eliminated in the Columbia River (1917), are widely used in other areas, and might be extremely effective, if legal, for present fishing operations. Although operating cost data is available from other fishing areas,

---

14/ Bureau of Commercial Fisheries, Brewster, Washington.

along with the effectiveness of this gear in these areas, it is questionable if meaningful estimates can be developed from this data that could reliably be transposed to indicate expected results, if this gear were legal in the Columbia River.[15/]

In general terms, purse seines might potentially be optimum, particularly for landing fall chinook. A large proportion of this run originates in the lower tributaries, including those returning to hatcheries that are often located in the lower river. The quality of many fall chinook deteriorates rapidly upon entering fresh water. As a result, harvest in the vicinity of the Columbia River mouth could preserve quality at least for fall chinook. In 1966, the estimated size of the total chinook run returning to the Columbia River (including escapement to lower tributaries) was 695,567, of which over 55 percent were fall chinook; comparable percentage for 1965 was over 58 percent, and over 54 percent in 1964.[16/] Thus, this gear potentially could affect a large share of the important chinook salmon harvest, even if used only for fall chinook.

15/ Cost data on Puget Sound operations were developed by William F. Royce, et. al. (58). For example, Table 3, p. 37. However, the difference in type of fishing and species harvested, restricts usefulness for indicating likely results for Columbia River harvest--particularly in appraising the effectiveness in landing fish.

16/ Based on estimates by Oregon Fish Commission, Clackamas, Oregon..

Gill-nets

Although gill-nets are currently legal gear in the Columbia River, their efficiency has been curtailed by legislation. Fry considered salmon traps, fishwheels, beach seines, and gill-nets in California's Sacramento River, and concluded that:

> "Gillnets were the only gear which proved successful for many decades in the inland waters of the Central Valley. Legislation reduced their effectiveness through the years, and gillnet fishermen had to be content with salmon that had escaped the expanding troll fishery. Finally, in 1957 salmon gillnetting was outlawed completely. A small gillnet fleet could be very effective if it operated to take the maximum sustainable yield for the lowest reasonable cost.
>
> "By doing away with lengthy closed seasons and by using nylon or monofilament nets (which have been proven much more effective) and mechanical net pullers, a fleet of 50 boats, manned by good fishermen, could land the same poundage . . ." (6, 463, 000 pounds, landed in 1946, the largest gill-net catch for which detailed records are available.)
>
> "The 50 boats would be needed only during the peak months of September and October . . . The cost of purchasing, maintaining, and operating such a fleet would be about $323, 000 per year . . . The gross income at 1959 prices, about $3, 324, 000 per year, would yield a net profit of over $3, 000, 000 per year." (25, p. 266)

Since the California catch, by law, must be harvested entirely by troll gear, the above estimates indicate that 90 percent of the gross value of the fish resources could be attributed to regulated inefficiency. That is, the ex-vessel fishing prices (i. e., existing cost of fishing) of $3, 324, 000 could be reduced to $323, 000, for a net saving (eliminating regulated inefficiency) of $3, 001, 000. (25, p. 265)

If 50 boats were used to land a catch of 6, 463, 000 pounds, each boat would be responsible for 129, 600 pounds. If this is compared with Columbia River Category A, gill-netters with a catch of 31, 401 pounds (Table 7), it can be seen that considerable gains would be necessary in efficiency for comparable results in the Columbia River. Fry proposes vessels that would cost $6, 460 per year for operation, maintenance, and depreciation, of which $3, 300 is for fishermen's labor (25, p. 264). Thus, operating costs of $3, 160 are considerably higher than the $1, 990 per year for Category A Columbia River gill-netters. It is interesting to note, however, that it is almost equal to the $3, 165 for Category C gill-netters, the "high-liners" for whom catch data is lacking.

Fry also expects nylon or monofilament nets to be used (which are illegal in Washington, Oregon, and British Columbia, Canada) as a means of increasing efficiency. He states that monofilament nets "have been used in other areas, and took from two to more than three times as many fish as nylon nets, with which they were competing." (25, p. 262) However, apparently the greatest advantage of monofilament nets comes in clear water. No general consensus was found in discussions with management agencies concerning potential gains from using this gear in the Columbia River.

While it seems highly likely that a limited number of "highliners" could harvest the entire Columbia River run (with trolling prohibited), it is virtually impossible to determine the effectiveness of this means of harvest without supporting empirical tests. It seems possible, however, that the entire Columbia River anadromous fish run could be harvested by this means, at a saving of 90 percent of the present costs resulting from regulated inefficiency. This would be similar to the results found by Fry in the Sacramento River (25, p. 265). In this regard it should be recalled that the present method of setting seasons, as pointed out in Chapter III, often permits fishing only when the peak of the run has not yet entered the river, or after peak populations have already escaped to upstream spawning areas. A few days of efficient harvest during the peak of the run could be equal to several times this amount of time in terms of total fish landed, where fishing takes place only when peak runs are not in the river. Thus, cost per unit of effort might fall considerably if a limited number of fishing units were permitted to operate during peak runs.

If troll fishing were prohibited, a much larger run would likely be subjected to each unit of gill-net effort although this would be neutralized to some extent by increased take in the sport fishery. Furthermore, with fish landed commercially only at maturity, as they approached or entered spawning streams, the total yield would be expected to increase. The improvement of catch in the sport fishery would influence the important, although as yet unmeasured, quality variable, and might increase the value of the sport fishery to a much greater extent than any resulting reductions in the value of commercially-caught fish.

In addition to all other limitations imposed on gill-netters, the present method of setting seasons prohibits not only efficient fishing, but suppresses incentives for attracting fishermen to enter and remain in this fishery. The number of gill-net licenses has been declining (Appendix Table 8) and many of those presently involved are part-time or occasional fishermen. A similar situation has also been noted in the Puget Sound area:

> "The casual nature of the gillnet fishery, with its emphasis on part-time operation, is clearly indicated by the following figures. Twenty-five percent of the respondents obtained income from other fishing. About 19 percent had income from other types of fishing and more than 54 percent earned some income from nonfishing jobs during the years 1959-1961. The number who drew unemployment compensation ranged from 17 percent in 1959 to 25 percent in 1961."
>
> "It was also interesting to note that the average age of the gillnetters surveyed was forty-nine years; apparently this is no longer an attractive occupation for younger men. If income were increased, we expect that the gillnet fishery will be able to recruit and hold younger men." (58, p. 42)

The Columbia River has a unique system of "drift rights" which could possibly provide a starting point for initiating limited entry for all gill-net harvest. By improving the legal stature of this institution and restricting the number of drifts, a system of effective limited entry might possibly be initiated. Although an interesting possibility, this subject involves many social and legal problems that are outside the scope of the present study.

Other types of gear in addition to those discussed above have historically accounted for minor harvests in the Columbia River or elsewhere and might also be used if legalized. No attempt to be inclusive is intended at present, however, and these minor types of gear are not considered. As pointed out earlier, either empirical testing or actual implementation would be necessary, to arrive at more than tentative conclusions.

Fish Trap at Bonneville Dam

One obvious method, with tremendous potential efficiency for taking fish, that has not been considered to this point, is a fish trap at the first dam. This method, however, would require transportation of harvested fish to existing processing facilities, or relocation of these facilities. Particularly in the case of the important fall chinook run, a serious deterioration in quality would result if harvest were delayed until fish reached the Bonneville Dam area, a distance of approximately 140 miles above the mouth of the River. Furthermore, other harvest methods would be necessary for fish entering tributaries below Bonneville (see Figure 1), such as the Willamette, Klaskanine, Cowlitz, and other rivers unless traps were constructed at dams or major tributaries.

For present purposes of determining the value of fish resources (i. e., the cost of regulated inefficiency), this method of taking fish has at least one very positive advantage. Not only can cost of efficient harvest be determined, but the effectiveness of this method is obvious. All, or any portion, of fish originating above the dam could be taken. Furthermore, if all types of gear were legal it would be useful to have a method of taking fish not needed for spawning, that might escape the lower river fishery due to error in establishing an appropriate harvest level (i. e., charge for the right to fish, or optimum amount of gear for a large and unexpected fish run). A trap at Bonneville Dam could, thus, provide more flexibility in determining the desired harvest levels. For example, harvesting levels could typically be set at conservative levels, and necessary adjustments made at the trapping facility. This unit could also be used for taking fish of relatively minor economic importance, such as shad (see Table 10) and also for the removal of scrap fish under certain conditions.

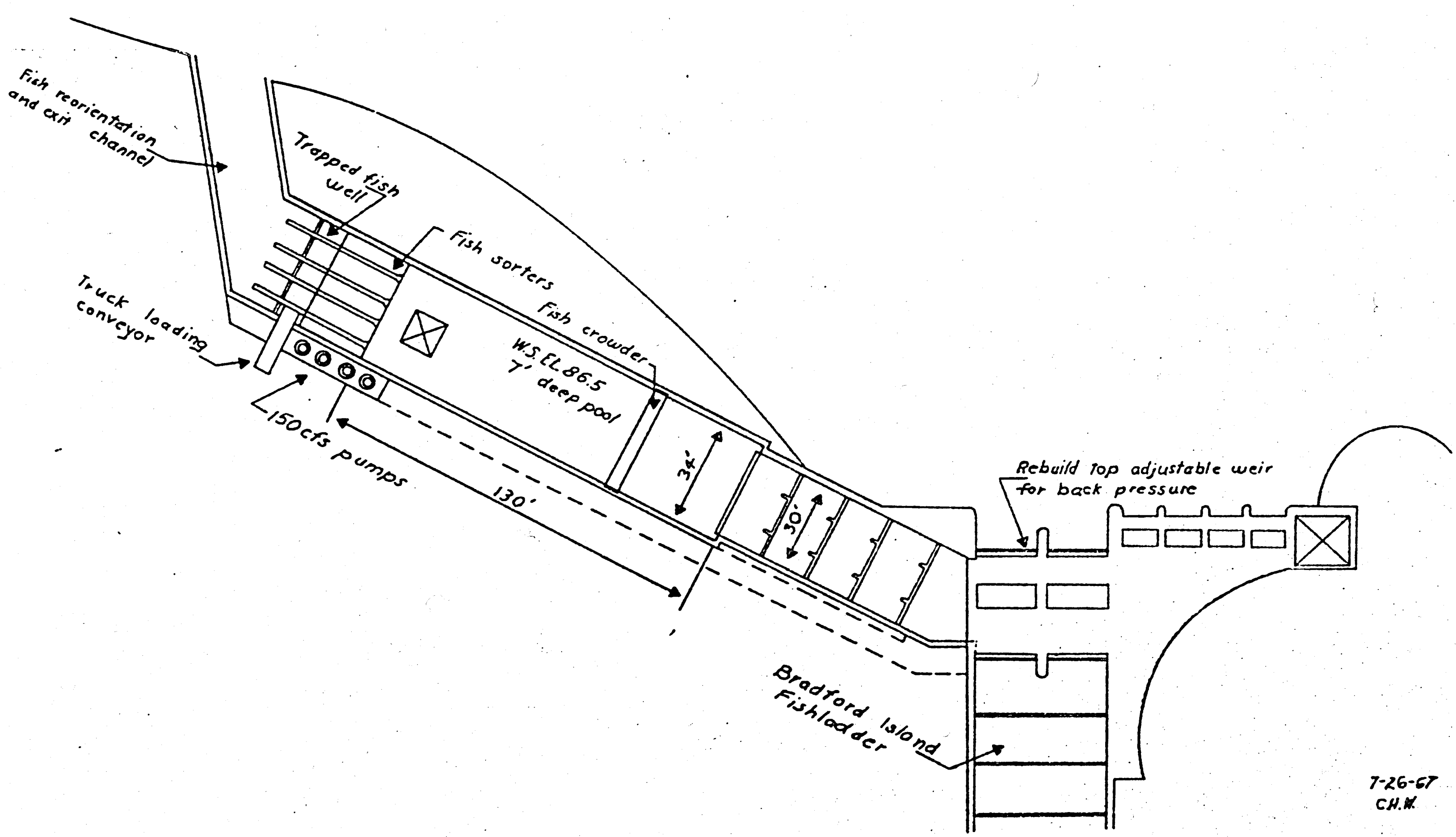
Due to the advantages listed above, particularly the ability to estimate accurately the effectiveness of this facility in landing fish, costs of constructing the necessary facilities were determined along with estimates of operation and maintenance expenditures.

It is again emphasized that data are not being developed to support a proposal to construct a trap at Bonneville Dam. This study is intended to estimate the potential value of fish resources that could be obtained in money terms, if so desired. At present the only goal is to indicate the amount of money that could be derived from fish resources, not to suggest that society would achieve greater welfare if these funds were derived. This would require consideration of existing benefits, cost of adjusting to a new method under political, legal, and social constraints that would exist, potential alternative uses for fish resources that might improve over-all welfare, and the effect of implementation on division of benefits between the Northwest region and the nation. Data of this type, and evaluation of acceptable alternatives, are beyond the scope of the present study.

Cost and Efficiency of Trapping Facilities at Bonneville Dam

Cost of constructing trapping facilities on both the Washington shore and Bradford Island fishladders was estimated, along with expected costs of operation and maintenance. Detailed data relating to these estimates are included in Appendix B. A brief sketch of the facilities is shown in Figure 9. Only preliminary estimates were justified, since these facilities are not actually being considered for construction. As a result, all cost estimates and

Figure 9. Hypothetical fish trapping facilities at Bonneville Dam



facility designs are only approximations that would be subject to change if actual construction was being proposed. However, sufficient accuracy has been maintained to provide a good approximation of anticipated costs of taking fish by this method.

Construction costs for these trapping facilities, annual amortization, and annual operation and maintenance costs are presented in Table 14. Amortization is based on a three percent discount rate and an expected useful life of 100 years. Since the replacement of all mechanical parts every 20 years is included in annual operation and maintenance estimates, the design and construction materials justify this expected useful life for the facility.

Table 14. Estimated cost of constructing and operating fish trapping facilities at Bonneville Dam 1/

Facility	Estimated construction costs	Annual amortized cost 2/	Annual operation and maintenance	Total annual expense
Bradford Island	$550,000	$18,018.00	$ 79,000	$ 97,018.00
Washington Shore	270,000	8,845.20	35,000	43,845.20
Total	$820,000	$26,863.20	$114,000	$140,863.20

1/ Detail on cost estimates and design is presented in Appendix B. Based on cost estimates by Bureau of Commercial Fisheries, Columbia River Fisheries Development Program Office, Engineering Section, Portland, Oregon.

2/ Amortized at 3% for 100 years.

The entire run could not be harvested at Bonneville, even if desired. Approximately 30 percent of the fall chinook run, about 90 percent of the important coho run, and virtually all of the presently unimportant chum salmon run originates in the lower river. In many cases, only rough estimates of lower river runs are available. These lower river runs could, if desired, be efficiently landed by fish traps in the rivers or at dams which exist on many of the lower tributaries.

If even 40 percent of the value of the run was landed at Bonneville, a trapping facility would still be vastly efficient. This would exclude the lower river run, most of the fall chinook run due to quality deterioration and harvest by other gear. The gross value of Bonneville landings could be approximately determined simply by taking 40 percent of the gross value indicated in Table 10. This, of course, assumes that 40 percent of the value and not 40 percent of the fish would be landed by trapping at the dam. The expected cost and returns from landing fish by trapping at Bonneville Dam are shown in Table 15 for the commercial harvest from 1960 to 1965.

The costs of operating trapping facilities at Bonneville Dam do not include any additional amount necessary to move the raw product to existing processing facilities. Over time it is likely that facilities might move closer if this harvest actually took

Table 15. Costs and efficiency of hypothetical Bonneville Dam fish trapping facilities

Year	Total gross value	Bonneville gross value	Bonneville harvest cost	Cost of regulated inefficiency	Percent regulated inefficiency
1960	$4,413,000	$1,765,200	$140,863	$1,624,337	92.0
1961	4,738,000	1,895,200	140,863	1,754,337	92.6
1962	5,726,000	2,290,400	140,863	2,149,537	93.8
1963	5,592,000	2,236,800	140,863	2,095,937	93.7
1964	6,395,000	2,558,000	140,863	2,417,137	94.5
1965	6,732,000	2,692,800	140,863	2,551,937	94.8

place. In any event, this transportation cost would be of only minor importance, although the relocation of processing facilities, if this occurred, would have an important effect on the communities involved.

Cost of Regulated Inefficiency

Although it is not possible to determine the optimum combination of gear that might be used if all existing technology could be legally employed, sufficiently efficient techniques exist to suggest that at least 90 percent of the present cost of fishing can be attributed to regulated inefficiency. In other words, if total welfare could be improved by transferring resources from fishing to other uses, probably 90 percent of the resources currently committed to harvesting Columbia River anadromous fish could be shifted to other lines of employment without reducing the total harvest.

This estimated cost of regulated inefficiency could be further tested by empirical evidence, and to a considerable extent by estimated results, if costs were justified by proposed implementation. The purpose at present, however, is only to use this data as a basis for estimating the value of the resource. As a result more extensive research in this area is not justified.

If ex-vessel market prices are taken as representative of gross value, it is possible that, using the entire ex-vessel market price as the value of potential benefits to society, may be fully justified. In fact, it is conceivable that more than 100 percent of present ex-vessel market price should be considered as the value of potential net benefits if gross value is not adequately represented by the market price. The reason why this might occur was mentioned earlier and will be considered fully in Chapter VI.

When all factors are taken into account, it appears that using 90 percent of the gross value to represent potential net value for a static time period will provide a reasonable estimate, although more evidence of the cost of regulated inefficiency would be highly desirable. If values for more than a stationary time period are desired, it is necessary to consider the determinant of the rate of investment in the fishery and market demand conditions. Investment will affect both market price and supply capability, over time. However, due to the relatively minor importance of the Columbia

River harvest, in relation to the total Pacific Coast catch, the influence on market price may be negligible.

Investment and Estimated Net Potential Benefits

Two major types of investment affect the level of physical supply capability of the fishery, and thus the expected sustainable physical yields as demonstrated in Figure 5. One of these is investment in reproductive stock of the fishery (i. e., escapement ratio). These decisions at present are based almost entirely on biological criteria. Spawning area, or "nursery" capacity, of the river system has been the limiting factor. The second type of investment is Government programs.

Even though application of economic theory to fishery management problems in general is excluded in this study, it is important to understand the consequences of omitting the level of investment in evaluating benefits (i. e., the limitations resulting from accepting an estimating technique that is incapable of encompassing this data). While the equilibrium sustainable yield for an open seas fishery may be determined by exploitation of capital stock, for the Columbia River anadromous fishery maximum sustainable yield is influenced primarily by investments of several types in the supply capabilities of the resource as pointed out earlier (Figure 5).

To avoid confusion, it is important to distinguish between investment controlling the long-run supply capability of the fishery and investment in extracting the benefits possible from using the fishery. The function of ownership, discussed in Chapter III, does not affect these two types of investment decisions in the same way. As pointed out in Chapter III, for renewable natural resources, one basic function of ownership is to enable the discounted values of future products to be included in investment decisions affecting the level of current use. Resource ownership would also control the level of investment in the facilities to extract the benefits of the fishery.

Thus for renewable resources, ownership can function to indicate the appropriate level of investment (natural and supplemental) that will maximize potential benefits from these resources over time and also function to limit the investment (resources committed to fishing in this case) in utilizing the resulting benefits. The latter function of ownership is evaluated in this study as the cost of regulated inefficiency. The former (i.e., long-run supply capabilities) is taken as given and is the result of past decisions based primarily on noneconomic factors.

Net Value of Commercial Fishery

The basis for determining the net value for the commercial fishery has been established, using the method suggested by Professor Crutchfield. It has been estimated that approximately 90 percent of the gross value of the fishery is probably expended in the process of regulated inefficiency. That is, if no legal, social, or institutional barriers prevented use of all known technology, any given commercial harvest could probably be achieved with about 10 percent of the resources committed using present fishing methods. An optimum combination of fishing gear cannot be determined short of costly empirical research, trial and error, or actual implementation. However, historical and estimated cost data suggest that adequate technology exists to support this estimate.

As a result, the net economic value of the commercial fishery is estimated at 90 percent of the existing gross values determined by physical supply and consumer demand. The limitations of the data, as well as the estimating techniques, have been pointed out. However, the net potential benefits estimated by this method are believed to be reasonably accurate within the limitations under which estimates of this type must be made. It will be demonstrated later that it would be possible for net benefits to exceed gross benefits as represented by the ex-vessel market price paid to fishermen.

Net Economic Value of Columbia River Indian Fishery 17/

The value of the Indian catch above Bonneville Dam must be taken into account in determining total benefits. The Indian fishery is treated separately from other commercial values due to the unique fishing rights granted to the Indians by the Federal Government and the special use of the product taken in this fishery. For example, one-fifth of the average 1947-1954 catch of over two million pounds was estimated to be retained for personal use. (79, p. 31) However, with construction of The Dalles Dam, the Celilo Falls dip-net Indian fishery was eliminated. In 1964, it was estimated that the Indians caught 67, 500 salmon and steelhead (758, 600 pounds) in the Bonneville-The Dalles area, a 26 percent increase over the 53, 500 pounds of salmon and steelhead landed in 1963. In addition, 258, 600 pounds of chinook and coho salmon were distributed to the Indians in 1964 through Oregon and Federal salmon hatcheries. (79, p. 31-32).

In 1965, it is estimated that over a million pounds were harvested in the Indian fishery (Appendix Table 16) for commercial

---

17/ It is possible that the Indian commercial catch may be included to some extent in value and catch data listed as commercial fishing' (Tables 9 and 10). Some duplication is likely, but all data is approximate as explained in connection with Table 8. Thus, the entire value and catch of the Indian fishery is assumed to be additional to the commercial harvest of Columbia River production.

sale, an additional 220, 000 was retained for subsistence, and approximately 20, 000 pounds sold to tourists. The estimated gross value of this catch was $344,200. Detail on this gross estimate is presented in Appendix Table 16.[18/]

Summary

The estimated gross value of commercially-harvested anadromous fish in 1965 includes $6, 372, 000 for commercial catch plus $344, [illegible]20 in the Indian fishery. A method for establishing potential net benefits associated with these fish resources has also been developed. However, it will be demonstrated in the following chapter that total potential net benefits associated with commercial fishing require inclusion of an estimated value for a hypothetical transfer from sport to commercial harvest. As a result, summarization of total potential net benefits from commercially-harvested fish is postponed until Chapter VI.

18/ Denny Miller, Bureau of Commercial Fisheries, Columbia River Fisheries Development Program Office, Portland, Oregon. All data are preliminary estimates from a continuing study of the Columbia River Indian Fishery. Unpublished data.

CHAPTER V

EVALUATING NET BENEFITS FROM SPORT FISHING

For commercially-harvested fish, the gross values for a particular market period and supply situation are established through the process of market pricing. Net benefits from sport fishing, on the other hand, must be estimated entirely without market pricing to provide guidance. In spite of this limitation, it can be argued that in some respects more progress has been made in developing a reliable estimating technique for sport fishing than is the case for benefits associated with commercial fishing.

The estimated total sport catch of salmon and steelhead attributable to the Columbia River is based on the percentages of the total catch of various Pacific Coast areas indicated in Table 16. The estimated percentages of Columbia River salmon and steelhead taken in various Pacific Coast areas are based on the same studies used to estimate the contribution of commercially-harvested fish. Thus, any weaknesses and limitations imposed by these percentages on the economic analysis of the commercial fishery apply with equal force to sport-caught anadromous fish.

An additional problem exists for sport fishing, since the percentages for chinook salmon were intended to provide the basis for estimating the commercial harvest only. However, percentages

Table 16. Estimated percentages of sport-caught salmon and steelhead attributable to the Columbia River 1/

Area	Chinook salmon	Coho salmon	Steelhead
Washington:			
Columbia River and tributaries	100.0	100.0	100.0
Ocean	65.0	30.5	---
Columbia River mouth	80.0	80.0	---
Neah Bay	50.0	---	---
Oregon:			
Columbia River and tributaries	100.0	100.0	100.0
Ocean	47.0	60.0	---
Columbia River mouth	80.0	60.0	---
Idaho:			
Columbia River and tributaries	100.0	---	100.0
California:			
Ocean catch	---	11.4	---

1/ Chinook salmon percentages estimated by Jack M. Van Hyning, Marine Research Supervisor, Oregon Fish Commission, Clackamas, Oregon. (For detail on sources, see Appendix Table 9.) Coho salmon percentages for areas other than the Columbia River and tributaries are estimates by Columbia River Fishery Program Office staff, Portland, Oregon, based on a study by the Washington Department of Fisheries on the 1963 brood of marked coho from the Washougal hatchery.

used for commercial trolling should provide reasonable estimates. Areas where only a minor amount of sport catch is expected to originate in the Columbia River are omitted because of insufficient data.

The reliability of data on the total sport catch, which is based on sampling techniques, also has some variability. However, sampling of most sport fisheries has improved considerably in the last few years, and current data from most areas can be accepted with considerable confidence.

Historical data on sport catch of chinook, coho, and steelhead salmon in various Pacific Coast areas are presented in Appendix Tables 17, 18, and 19. The total sport catch for all species and areas in 1965 is summarized in Appendix Table 20. The Columbia River contribution to each area is indicated by the percentages listed in Table 16. By applying these percentages to the total catch in each area, the Columbia River contribution was determined by area for each specie. The contribution to each area in 1965, determined by this method, is presented in Table 17. This shows that a total of 928,599 Columbia River salmon and steelhead were landed on sport gear in 1965. Of this catch, 62.4 percent were coho salmon, 21.7 percent were chinook salmon, and 15.9 percent were steelhead. Sport fishing in the Columbia River and its tributaries accounted for 27.4 percent of this harvest, the mouth of the river produced 24.1 percent of the sport landings, while 47.9 percent were taken in the ocean from northern Washington to northern California.

Table 17. Total 1965 sport catch of salmon and steelhead attributable to Columbia River by area and species 1/

Area and species	Oregon 4/	Washington	Idaho	California	Total coho	Total chinook	Total steelhead	Area total
Columbia River and tributaries:								254,545
Coho	10,000 2/	4,200 2/			14,200			
Chinook	42,267 2/	50,309 2/				92,576		
Steelhead	41,129	87,640	19,000				147,769	
Columbia River mouth (Ocean) 3/								
Coho	43,813	143,022			186,835			
Chinook	12,342	30,218				42,560		
Ocean:								
Coho	198,593	177,040		2,338	377,971			
Chinook	4,463	62,225				66,688		
Total	352,607	554,654	19,000	2,338	579,006	201,824	147,769	928,599

1/ Based on Table 16 and Appendix Table 20.

2/ Division of catch between coho and chinook are estimates--see Appendix Table 20.

3/ Many Oregon residents apparently land fish on Washington shore due to more favorable conditions for small recreational boats.

4/ See p. 143 for data source.

Gross Economic Value of the Columbia River Sport Fishery

The gross economic value of the Columbia River sport fishery was calculated by extrapolating data obtained from a comprehensive study of the 1962 Oregon salmon-steelhead sport fishery (6). Although more accurate results could have been obtained by a monthly survey of all Columbia River sport anglers, the additional cost in terms of both time and money prohibited such an undertaking. However, for the following reasons, this extrapolation of Oregon data is expected to produce reliable results:

1. The Oregon study determined that income was positively associated with sport fishing taken, and Washington residents have a higher per capita income than Oregon, as indicated below: (85, p. 15)

	1962	1963	1964	1965	1966
Washington	2,593	2,622	2,714	2,906	3,280
Oregon	2,374	2,472	2,600	2,761	2,938

2. As shown in Table 17, Washington and Oregon anglers took 97.7 percent of the total 1965 Columbia River sport catch.

3. During the course of the study, observation of sport fishing indicates that Washington's well-equipped sport fishermen participate at least to the same extent as their Oregon counterparts.

Based on the foregoing, it was assumed that the average expenditure per salmon-steelhead from the Columbia River is the same as the average expenditure per salmon-steelhead recorded by Oregon anglers during 1962. Although this may be conservative due to price increases and expanded per capita disposable income, this method will provide a reasonably accurate estimate of the gross value of the Columbia River sport fishery.

Oregon anglers spent an estimated $18 million on salmon-steelhead during 1962 (6, p. 27-28). If the charge for the right to fish is assumed to be zero, which was the actual case, 1,084,000 days of salmon-steelhead fishing were predicted in Oregon in 1962 (6, p. 41). The estimated salmon-steelhead catch in Oregon was 351,956 (79, p. 12 and p. 16). Dividing $18 million by 351,956 indicates that Oregon salmon-steelhead anglers spent an estimated $51.14 per fish in 1962.[19/] Based on the assumption that the same amount was spent throughout the Pacific Northwest in 1965, and that Oregon anglers landed 38.0 percent of the fish (Table 17), the gross economic value of the Columbia River sport fishery would be approximately $47 million. This may be a conservative estimate, as pointed out above, due to rising disposable income.

The gross value of the sport fishery, in any case, is not comparable with the gross value indicated earlier for the commercial fishery. The value of commercially-landed fish at retail level

---

19/ The estimated Oregon salmon and steelhead catch should not be confused with estimates relating to the Columbia River contribution to this catch (Table 17).

would come closer to being equivalent to the gross value of the sport fishery. Even in this case, the product of the sport fishery is the recreational value of fishing--not the value of the fish. In any event, for the sport fishery and commercial fishery alike, net values, not gross values are needed.

Net Economic Value of the Columbia River Sport Fishery

Estimation of net economic value of the salmon and steelhead sport fishery, in the absence of market prices, was estimated on the basis of a simulated market. Thus, the "net economic value" was assumed to be the best estimate of the monetary income which could be obtained by a single owner, who could charge sport anglers for his permission to fish for salmon and steelhead.[20/] This is consistent with the approach used to estimate the value of commercially-caught fish. In either case, the function of ownership is introduced. For the Columbia River anadromous fishery, in either case, a governmental agency functioning as owner is clearly implied.

20/ This approach to the problem of measuring the demand for and value of outdoor recreation was first applied by Clawson. Cf. Marion Clawson, "Methods of measuring the demand for and value of outdoor recreation," reprint No. 10, Resources for the Future, Inc., Washington, D. C., February 1959.

The demand function used to determine the value of Oregon sport fishing in 1962 is presented in Appendix C. Based on the demand function, the resource "owner" would maximize the return to the resource by charging a fee of $8 per day. At this price a predicted total of 390, 300 days of fishing would be taken by Oregon anglers. Assuming that fishermen responded to the charge for fishing rights in a manner similar to other variable expenses, the total net value of sport fishing to the resource "owner" would be $8 per day for 390, 300 days, or $3, 122, 000. This was the estimated net value of Oregon salmon-steelhead fishing in 1962.

In order to use this value as the basis for extrapolation to include all sport fishing attributable to the Columbia River, it is necessary to assume that sport-caught salmon and steelhead are of equal value in all fishing areas. The basis for this assumption has already been established.

Since 390, 300 days of fishing would have been taken by Oregon residents in 1962 if the fee for the right to fish had been set at $8 per day (Appendix C), this total number of days can be divided by the average success to determine the number of fish that would be landed. As indicated earlier, an estimated 351, 956 salmon-steelhead were landed in Oregon during 1962 (79, p. 12 and p. 16). Dividing total days (1, 084, 000) by this number indicates that 3. 08

days were required for each salmon-steelhead caught in 1962.[21/] If we assume that the demand curve does not shift due to reduced fishing pressure associated with imposition of a charge for the right to fish, the predicted number of days taken, at a charge of $8 per day (390, 300), can be divided by the average days per fish (3.08) to estimate the reduced sport catch. This division yields an estimated total catch of 126, 721 fish, if a charge for fishing of $8 per day had been imposed over and above other expenditures necessary for sport fishing.

The total value of the sport fishery to a profit maximizing resource "owner" was indicated to be $3, 122, 000. Dividing this amount by the catch per fish at a charge of $8 (126, 721 fish) yields a net value per fish of $24.64. This value is for fishing but fishing obviously depends on the presence of fish. Thus, this is the estimated net value of a sport-caught fish in Oregon in 1962.

The resource "owner" would maximize the return to sport fishing by charging $8 per day, providing 390, 300 days of fishing and 126, 721 fish. The net value of the 1962 Oregon salmon-steelhead sport fishery to the resource "owner" under these

---

21/ Fishing days per fish landed can also be estimated from Brown, et. al. (6, p. 43) Appendix Table 1. In this case, 2.785 days of fishing were necessary for each fish landed. This means that 389, 228 fish would have been the total Oregon catch estimated on this basis.

conditions is predicted to have been $3, 122, 000. Under actual conditions, however, a charge of zero price per day was imposed for the right to fish (license fees are not intended for this purpose), and 1, 084, 000 days and 351, 956 fish were predicted to have been taken by Oregon anglers. The net economic value to the resource owner in this case is zero (i.e., a zero charge for 1, 084, 000 days fishing provided).

It is important to correctly interpret the meaning associated with the above net value estimates of Oregon salmon-steelhead sport fishing in 1962. If the resource "owner" desired, and had the ability to discriminate among users, those fishermen willing to pay $8 per day, or more, for the right to fish, could be charged (i. e., discriminating only among those above or below this point on the demand curve). A total net value of $3, 122, 000 would then be obtained. In this case, those willing to pay $8 per day to fish would be charged and the remainder would be allowed to fish free of charge. The average value per fish, under these conditions, is $8.87 per fish (i. e., $3, 122, 000 divided by 351, 956 fish). The average value for the right to fish is $2. 88 per day.

Unless some other disposition is provided for additional fish taken by fishermen unwilling to pay $8 per day for the right to fish, this is the only possible interpretation that can be associated with the value of a sport-caught fish predicted by the above method.

As a result, a resource "owner," desiring to maximize profit, would transfer 225, 235 fish (i.e., 351, 956 at zero charge less 126, 721 at a charge of $8) from the Oregon sport fishery to the commercial fishery. This is a point commonly misunderstood by fishery biologists and other noneconomists attempting to estimate value of the sport fishery and the associated level of demand. For example, a value of $6 per day for fishing rights is suggested by the Department of the Interior Departmental Manual on Water and Related Land Resources (86, p. 700.2.5 B (4)). However, this value cannot be correctly used unless some basis is available for estimating total days taken at this charge per day. Using estimated days at zero charge, which is the only information actually tabulated by fish and game agencies, severely over-estimates the value of sport fishing. Furthermore, disposition of unneeded sport fish, if a charge were imposed (i.e., transfer to the commercial fishery) must also be taken into account.

To indicate the importance of this problem, it is necessary to determine the total number of fish to be theoretically shifted from sport to commercial harvest for the purpose of evaluating total potential benefits from combined maximization of sport and commercial fishing. The first step in determining this estimate is to establish a value for the 1965 Oregon sport fishery, since this is the latest year with all necessary statistical data tabulated.

The 1965 Oregon Sport Fishery

Based on the demand equations presented in Appendix C, and the assumption that preferences underlying these functions remained stable, the demand for salmon-steelhead sport fishing in Oregon was derived, based on changes in per capital income (85, p. 15) and increased population (84) that occurred between 1962 and 1965. Ten points, including a finite maximum, resulting from derivation of this demand curve are presented in Table 18. This maximum will again occur at a charge for the right to fish of $8 per day.

In 1965, the resource "owner" would have charged $8 per day for the right to fish, and provided 449, 863 days, with the Oregon salmon-steelhead sport fishery earning a predicted net economic value of $3, 598, 904. During 1965, an estimated 576, 142 salmon and steelhead (Appendix Table 20) were taken by Oregon anglers in 1, 249, 456 fishing days.[22/] These estimates, therefore, indicate that 2. 1687 days were required for each salmon and steelhead landed.

Based on this knowledge of the demand for salmon-steelhead fishing, the resource "owner" could have maximized profit by

---

22/ See section on data limitations for estimating sport values (p. 143) for clarification of source of catch data.

Table 18. Predicted number of salmon-steelhead fishing days taken in 1965 by Oregon fishermen at various assumed increases in charges for fishing rights 1/

Assumed increase in fishing costs	1965 Predictions					
	Days taken	Net economic value	Number of fish landed on sport gear 2/	Fishing days per fish	Average revenue per fish	Marginal revenue per fish
0	1,249,456	0	576,142 3/	2.1687	0	
						-15.92
1	1,099 679	1,099,679	507,068	2.1687	2.17	
						-13.75
2	967,855	1,935,710	446,283	2.1687	4.33	
						-11.59
3	851,835	2.555,505	392,786	2.1687	6.51	
						- 9.42
4	749,722	2,988,888	345,701	2.1687	8.67	
						- 7.25
5	659,850	3,299,250	304,260	2.1687	10.84	
						- 5.08
6	580,751	3,484,506	267,788	2.1687	13.01	
						- 2.91
7	511,135	3,577,945	235,687	2.1687	15.18	
						- .74
8	449,863	3,598,904	207,434	2.1687	17.35	
						1.43
9	395,936	3,563,424	182,568	2.1687	19.52	
						3.60
10	348,474	3,484,740	160,683	2.1687	21.69	

Continued

1/ Based on the method presented in Appendix C and change in Oregon population from 1962 to 1965 (84) and changes in Oregon per capita income from 1962 to 1965 (85, p. 15).

2/ Assuming existing success of 2.1687 is held constant.

3/ Appendix Table 20 (catch data not based on official estimates--see p. 143).

providing 449, 863 days of fishing. 207, 434 fish (i. e., 449, 863 divided by 2. 1687) and reaped a predicted net economic value of $3, 598, 904. A total of 368, 708 fish should have been transferred to the commercial fishery if total revenue had been maximized (i. e., 576, 142 at a zero charge, minus 207, 434 fish predicted with a charge of $8 per day). Of course, in actual practice 1, 249, 456 fishing days were taken, 576, 142 fish provided, and a net revenue of zero was obtained.

Limitations of Method for Estimating Sport Values

The demand curve derived from the method suggested by Brown, et. al. (Appendix C), automatically takes into account alternative recreational possibilities for consumers surveyed. Since this method is based on actual preferences of anglers, as revealed by their expenditures and fishing patterns, alternative recreational services are included in each point established on the demand curve. An antagonistic reaction to a charge for the right to fish would be possible. However, such a negative effect should dwindle away over time since actual preferences are expressed in the demand curve.

One serious limitation for the present purpose is the static limitation that must be associated with the demand curve predicted for the 1962 Oregon salmon-steelhead sport fishery. This has been avoided by assuming that the preference pattern of individuals has remained constant in Oregon from 1962 to 1965. Extrapolation to the entire Columbia River system must be based on the further assumption that the preference pattern of Oregon anglers is similar to that for sport fishermen in other Pacific Coast areas.

The method of computing the value of the Oregon sport fishery for both a discriminating as well as a nondiscriminating monopolist is given in Appendix C. This method, which is based on the concept of consumer surplus using primarily distance and transfer costs as a proxy for a charge for fishing rights, provides the theoretical mechanism for estimating the total consumer surplus. In actual practice if a monopolist were to function as resource "owner" and charge for the right to fish, there would be no method available to discriminate between consumers of this form of recreation. It will be useful, however, in a later section to consider the case for a discriminating monopolist in connection with determining optimum distribution between sport and commercial harvest of a given potential fish harvest.

Data Limitations for Estimating Sport Values

The estimating method used in this study places special emphasis on Oregon sport catch records. The demand for fishing was estimated in terms of number of days taken. Sport catch records from the Oregon Game Commission were then used to indicate the level of success at zero charge for fishing rights. This success was assumed to remain constant as fishing effort diminished due to the assumed increase in the charge for fishing rights. The success level in 1962 was 3.08 days per fish, but in 1965 only 2.1687 days were required for each fish.

Since the product for the sportsman is fishing, it is possible that the same level of fishing demanded could exist over some range of success levels. In this study, the actual success level is measured historically and independently of the demand for fishing. It is obvious that the less the sport catch with any given quantity of fish taken, the higher the value of each sport-caught fish.

Any error introduced in estimating the value of sport-caught fish would be subsequently magnified since only catch data is available to extrapolate the Oregon value per fish to the entire Columbia River production. Thus, the less the official Oregon catch records for 1965, the higher will be the value of each sport-caught fish and the total potential net benefits from Columbia River anadromous fish.

Some doubt existed concerning a reliable estimate of the 1965 Oregon sport catch. Official data, if biased, appeared to be biased downward which would introduce an upward bias for the entire Columbia River sport catch. Thus, the largest value suggested for the Oregon sport catch, 576, 142 fish, was accepted. This is undoubtedly high, resulting in a conservative estimate for the total net value of the Columbia River sport catch while the total gross value, but not the gross value per fish, may be biased upward.

Extrapolation of Oregon Sport Value to Columbia River Catch

If a charge of $8 per day had been imposed in 1965, each fish taken in the Oregon sport fishery had a predicted value of $17.35. The resource "owner," in order to maximize the value of the resource, would have shifted 368, 708 fish, or 64 percent of the total landed by sport gear, to the commercial fishery.

Similar conditions might not have existed for the entire Columbia River contribution to the Alaskan or British Columbia, Canada, sport catch. Thus, only Washington and Oregon sport values for chinook and coho salmon, and steelhead trout will be used. In addition, the small coho contribution to the California catch (0.3 percent of the total contribution), and the minor steelhead catch in Idaho (2.0 percent) will be included. Using these areas only, and assuming that the demand for sport fishing was similar to that recorded in Oregon, 334, 296 fish would have been landed by sportsmen, 36 percent of the total indicated in Table 17. If the

Oregon value of $17.35 per sport-caught fish is extrapolated to the entire Columbia River system, the net economic value of the sport fishery is estimated at $5,800,036 (334,296 fish at $17.35 each).

The remaining 64 percent presently harvested on sport gear (594,303 fish) would have been transferred to commercial harvest by a profit-maximizing resource "owner." The value of these fish in commercial harvest along with total net benefits from sport and commercial catch is the subject of Chapter VI.

CHAPTER VI

TOTAL BENEFITS AND COMPARISON OF BENEFITS AND COSTS

Net economic benefits need to be compared with costs committed to existing projects and those under construction, in order to indicate results of past and present public programs. Following this, expected future benefits and costs will be considered along with the interpretation of benefit-cost data relative to economic decisions at different stages of program development.

Cost data for existing programs was established in Chapter II. Maximum potential net benefits for existing programs for sport and commercial fishing combined remains to be determined although maximum for each has previously been considered independently. Maximum total potential benefits must be based on the best possible product division between sport and commercial harvest by an assumed revenue maximizing resource "owner." This maximum requires a hypothetical transfer from sport to commercial harvest for the purpose of estimating maximum potential benefits.

It is assumed that the supply of fish is given (determined primarily by noneconomic factors such as the physical limitations imposed by available spawning area, the desire to preserve historical fish runs through supplemental production, and similar factors). Thus, the assumed resource "owner" would not equate marginal revenue with marginal cost in the typical manner necessary for profit maximization. This results in revenue maximization as the objective of the assumed resource "owner" with the supply of fish taken as given.

Hypothetical Transfer from Sport to Commercial Harvest

An assumed revenue-maximizing resource owner for the Oregon sport fishery in 1965 would have transferred 64 percent of the sport catch to commercial harvest as the result of imposing a charge of $8 per day for the right to fish. The reason this is necessary was explained in the previous chapter along with an explanation of the procedure for extrapolating the Oregon value to the Columbia River catch. In this case, it is also assumed that approximately 64 percent of the catch, 594, 303 fish, would be shifted to commercial harvest in order to obtain the maximum potential monetary return from the entire Columbia River run.

The sport catch in 1965 attributable to the Columbia River was estimated to be constituted of 62.4 percent coho salmon, 21.7 percent chinook salmon, and 15.9 percent steelhead (Appendix Table 20). Thus, 370, 845 coho salmon (62.4 percent of 594 303 fish shifted from sport to commercial harvest), 128, 964 chinook salmon (21.7 percent of 594, 303), and 94, 494 steelhead (15.9 percent of 594, 303) are estimated to the amount added to the commercial catch by a nondiscriminating, profit-maximizing resource "owner."

The Oregon Fish Commission estimates the following average weights for each species for 1965: 23/

Chinook salmon . . . . 18.46 pounds

Coho salmon . . . . 8.20 pounds

Steelhead . . . . 7.69 pounds

Using these weights and the number of fish indicated above to be transferred to the commercial catch yields 3,040,929 pounds of coho salmon 2,380,675 pounds of chinook salmon, and 726,659 pounds of steelhead.

Since Washington and Oregon commercial fishermen landed 7,371,000 pounds of chinook from the Columbia in 1965 (Appendix Table 10, valued at $2,411,000 (Appendix Table 12), the average value for Columbia River chinook salmon in 1965 was 32.71 cents per pound for commercially-caught chinook in this area. A similar calculation indicates that coho were worth 27.77 cents per pound (see Appendix Tables 11 and 13), and steelhead were worth 26.85 cents per pound.

The total amount of sport-caught fish to be transferred to the commercial fishery, and the average value if taken in the

---

23/ Staff, Clackamas Laboratory, Oregon Fish Commission, Clackamas, Oregon (interview--unpublished data).

commercial fishery, is listed in Table 19.

Table 19. Estimated number of fish, weight and gross value, transferred from sport to commercial harvest

Specie	Number of fish	Pounds	Average price per pound	Gross value
Coho salmon	370,845	3,040,929	$0.2777	$ 844,465.98
Chinook salmon	128,964	2,380,675	0.3271	788,718.79
Steelhead	94,494	726,659	0.2685	195,107.94
Total	594,303	6,148,263	---	$1,818,292.71

The estimates shown in Table 19 indicate the value that might have been obtained had the resource owner charged for sport fishing rights and allowed those fish normally taken by fishermen unwilling to pay $8 per day for the right to fish to be harvested in the commercial catch. As pointed out earlier in the study, the estimated gross commercial values (Table 19) are dependent on the assumption that the increased supply would not have affected the ex-vessel fish prices received by commercial fishermen. The demand function for these fish, at fisherman level, would have to be determined to avoid this difficulty. In this regard, it should be remembered that the Columbia River furnishes only a small proportion of the total salmon harvest.

Based on the hypothetical transfer from sport to commercial harvest, it is now possible to summarize the total gross benefits associated with commercial fishing. The weight and gross value of commercially-caught fish, the amount, theoretically, to be transferred from sport to commercial harvest for evaluation purposes, and the amount and value taken in the Indian fishery are summarized for 1965, in Table 20.

Table 20. Total estimated weight and gross value of the potential 1965 commercial catch of anadromous fish attributable to the Columbia River with revenue from sport and commercial fishing maximized independently

Source	Estimated weight	Estimated gross value
	Pounds	Dollars
Commercial catch	21,139,000 1/	6,732,000 2/
Transferred from sport catch	6,148,263 3/	1,818,293 3/
Indian fishery	1,324,700 4/	344,220 4/
Total	28,611,963	8,894,513

1/ See Table 9.
2/ See Table 10.
3/ See Table 19.
4/ See Appendix Table 16.

Total Net Economic Value of the Columbia River Anadromous Fishery

The net economic value of the potential 1965 commercial catch, based on 90 percent of the gross value (Table 20), is estimated to be $8,005,062. The net value of the sport catch for this year was estimated at $5,800,036. Thus, the total net economic value of the Columbia River anadromous fishery, including both sport and commercially-harvested fish, is estimated at $13,805,098 for 1965 when the sport and commercial catch is maximized independently. It will be seen later that this value can be increased by shifting additional fish from sport to commercial catch and maximizing the value of both products simultaneously.

It should be noted that where necessary to estimate the value of either the sport or commercial fishery separately, certain cautions should be observed in interpreting the results. In the case of the sport fishery, the total number of fishing days taken at zero cost cannot correctly be multiplied by an estimated value per day for the right to fish. This practice is common among fish and game agencies associated with fishery management. This procedure would be accurate only if based on consumer surplus, assuming that all other product values for the consumer remain constant. Such a procedure, however, is not the basis of present estimates, which confuse the obvious fact that sport fishing is valuable to the consumer, with the illogical contention that the same amount of fishing would be taken with or without the imposition of a charge for the right to fish.

As a result of the above situation, it is common among fishery management agencies to overestimate the total value of sport fishing, even though it is conceivable that they might, at the same time, underestimate the value of sport fishing associated with each day or each fish. For example, the suggested value of $6 per day for fishing rights (86, p. 700. 2. 5 B (4)), officially recommended to fish and game agencies, overestimates the total value of the fishery, but probably underestimates the net value for a day of sport fishing. This is an illogical compromise, since it cannot possibly be used correctly without simultaneously predicting a demand curve to indicate how many days fishing will be taken if a charge of $6 per day is imposed.

On the other hand, the gross value at fisherman level is often used by fish and game agencies, primarily for lack of a better estimate, as the measure of benefits resulting from commercial fishing. This method has been criticized on the basis that it is not possible to compare the gross value of commercially-landed fish with net values of other water resource products. However, it has been pointed out that the ex-vessel market price may not represent the total gross value. Furthermore, it has been estimated that 90 percent of the gross value is expended in the process of regulated inefficiency, and thus potentially could be repeated as net benefits. This is not a form of consumer surplus, but rather the result of matching consumer demand with supply capabilities. Finally, it has been pointed out that the commercial fishery, to be correctly evaluated, must also take into account the value of sport-caught fish taken at zero value, compared to the amount taken with imposition of a charge for fishing rights. In the Columbia River case, this amounted to 27 percent ($1, 818, 293) of the amount normally represented by using ex-vessel market price as indicative of net economic value of commercially-harvested fish.

When all factors are taken into account, it appears that using ex-vessel market prices to represent the net value of commercially-harvested fish where sport and commercial fishing are evaluated independently, is probably a highly conservative estimate of the true net value of the resource landed in the commercial fishery.

Optimum Catch for Sport and Commercial Fishing

Optimum division of the available fish supply between sport and commercial harvest is a prerequisite for maximum return to the assumed resource "owner." Both sport and commercial fishing are necessary for maximum return.

If the entire sport harvest, with imposition of an $8 charge were eliminated, and the product transferred to commercial harvest under the price conditions established in the previous chapter, this sport-harvested product would have a value of only $1, 022, 790 to commercial fishermen. This compares to $5, 800, 036 for the same product when harvested by sportsmen.

The commercial fishery is essential for harvesting fish that cannot be taken in the sport fishery if maximum return is to be realized. The value of the sport fishery clearly implies that fishing rights are a scarce commodity and some fishermen will be denied access. Furthermore, the cost of taking fish on sport gear would prevent total harvest by this means. In the previous chapter the gross value of the Columbia River sport fishery was estimated at approximately $47 million and the net value at $5,800,036. With no charge for the right to fish, an estimated cost of around $50 per fish was necessary to land 30 percent of the 1965 harvest.[24/] Even with a demand shift due to more fish available for sport harvest, which would likely increase the net value of the sport fishery, commercial fishing would still be essential to harvest excess not taken on sport gear and where sport and commercial fishing does not compete for the resource.

Economic Optimum Product Division

The economic market organization involved for the revenue maximizing resource "owner" follows that typically found where

---

24/ The 1962 Oregon survey yielded an estimated gross expenditure per sport-caught fish of $51.14 (79, p. 12). It is assumed that an approximately equivalent expenditure existed in 1965. Fishing costs would likely have been higher in 1965 due to national price trends. However, fishing success was apparently also greater in 1965 which would have lowered gross cost per fish since most sport fishing expenses are not success related. Gross fishing costs are important only to indicate that these costs would prohibit harvesting the entire production on sport gear.

dual products of unequal price elasticity exist, along with the ability of the "owner" to isolate the two markets and practice price discrimination. However, only the ability to discriminate between sport and commercial fishermen is considered for division of the available fish supply according to economic criteria. Since no practical method exists to discriminate among sport fishermen (i.e., include consumer surplus), this is not taken into account. Economic division of the available fish supply, therefore, is determined by potential revenue maximization using existing knowledge.

It is recognized that a resource "owner" with the ability to do so would probably find it beneficial to shift the demand for sport fishing by changing the quality of this form of recreation where commercial harvest is competitive. This possibility is also omitted due to lack of information concerning the influence of quality on the demand for sport fishing.

It is also likely that the reduced number of fishermen resulting from imposition of a charge for fishing rights would automatically result in higher quality sport fishing. This would be due to factors such as more fish available or reduced congestion in fishing areas. Thus, a potential demand shift factor, associated with changes in the quantity demanded, is also ignored.

Equating marginal revenue in the usual manner ideally would be based on information concerning the important, but as yet unmeasured quality variable on the demand for sport fishing. Since the value of sport fishing is dependent on the presence of fish, the value of sport fishing in this study has been assumed to be equivalent to the value of sport-caught fish. This assumption is necessary in order to relate the value of sport fishing, which has been estimated, to the value of sport-caught fish, which has not. However, this assumption also relates average revenue and marginal revenue of sport-caught fish to the success level (for example, see Table 18). The number of days necessary to land each fish is held constant (e.g., 2.1687 in 1965) while the charge per day of fishing is assumed to increase. Thus, the average and marginal revenue associated with sport-caught fish is influenced by the variable charge per day of fishing and the constant success.

The relationship of sport and commercial fishing is demonstrated in Figure 10. If the fishery had been controlled in 1965 by a resource "owner" seeking to maximize revenue from sport and commercial fishing independently, the sport fishery would have provided 42.1 percent of the net economic value, but taken only about 10.2 percent of the fish (by weight). The sport fishery also harvests primarily coho salmon (62.4 percent of the 1965 sport catch) and steelhead trout (15.9 percent) -- the relatively lower valued species compared to the favored chinook salmon. This reduces still further the natural competitive situation between sport

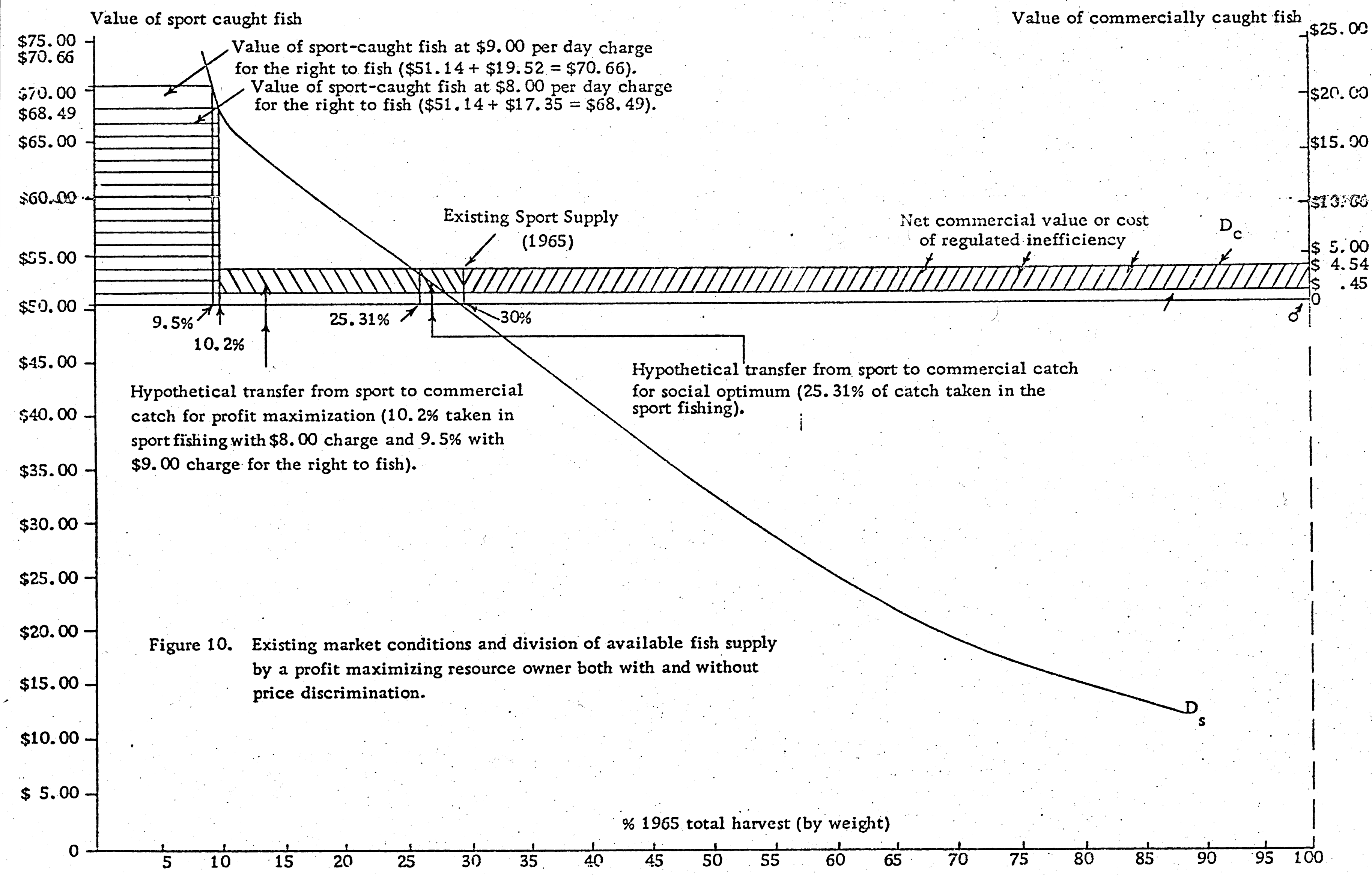


Figure 10. Existing market conditions and division of available fish supply by a profit maximizing resource owner both with and without price discrimination.

and commercial harvest.

Commercial fishermen, on the other hand, would have harvested 89.8 percent of the fish (by weight), but provided only 57.2 percent of the total estimated net economic value in 1965.25/ Maximum revenue, as pointed out above, requires both sport and commercial harvest and in the proportions indicated. A total of 31,997,760 pounds were taken by sport and commercial fishermen combined in 1965. In the absence of revenue maximization 9,606,663 pounds were taken by sportsmen (30.0 percent) and 22,391,097 pounds (70.0 percent) were taken in the commercial catch (including the Indian landings). A revenue maximizing resource "owner" would have marketed 10.2 percent of this amount (3,458,400 pounds) in the sport fishery in 1965 and transferred 19.8 percent (6,148,263 pounds) of the total harvest from sport to commercial catch. As the result of this shift the expected monetary income from the sport fishery would increase from zero to $5,800,036. This shift is also demonstrated in Figure 10.

In Figure 10, P_o (as explained in Appendix C) is the cost of sport fishing which is assumed to be $51.14 as determined in the

---

25/ Commercial data includes minor shad catch (Table 9 and Table 10) even though no value or catch for this species is included for the sport fishery.

1962 Oregon survey. This represents the necessary expenditures for the average sport-caught fish exclusive of any charge for fishing rights (i.e., the existing situation).[26/] The horizontal axis for commercial fishing, for convenience, is located at P_o in order to demonstrate the relationship between sport and commercial harvest for revenue maximization. The value of commercial fishing is indicated on the right hand axis above P_o with the cost of regulated inefficiency (measured as a static value ex post) taken as the net value for commercially-harvested fish resources. The automatic reduction in the sport catch that is required for revenue maximization (as listed in Table 19) is also illustrated.

Because techniques to evaluate benefits from sport and commercial fishing were developed independently, the need for an additional shift from commercial to sport harvest in order to equate marginal revenue in the usual manner between the two products has not been considered up to this point. Data for this shift were included in Table 18.[27/]

26/ Appendix C demonstrates the procedure for evaluating the entire area under the curve above P_o (i.e., a discriminating monopolist) and the area associated with a charge of $8 per day for fishing rights (i.e., a nondiscriminating monopolist except for discrimination between sport and commercial harvest). This can also be seen with reference to Figure 11 where P_o would be horizontal axis.

27/ Since the value per fish is the same for Oregon or the total Columbia River, marginal revenue associated with each assumed increase in fishing charges is the same.

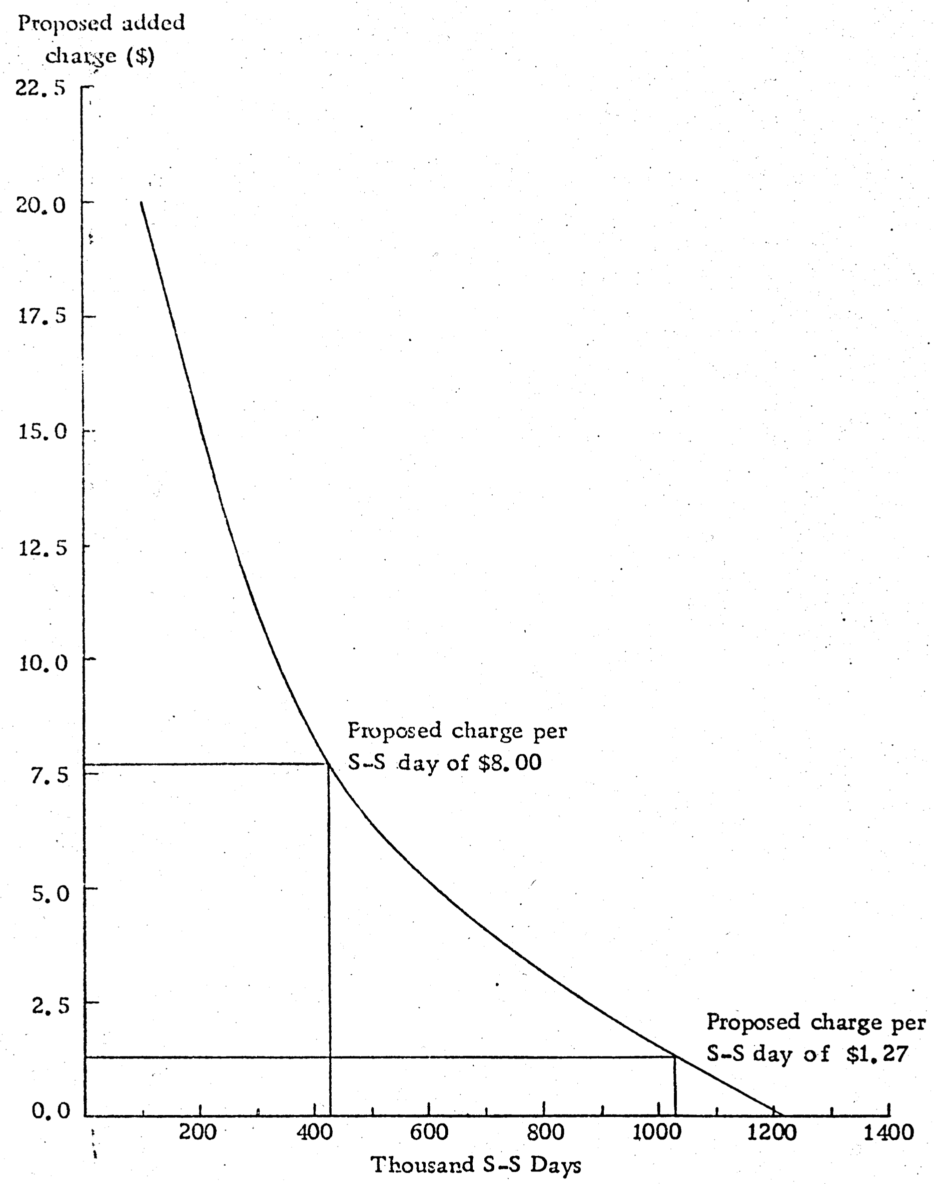


Figure 11. Revenue maximization for the 1965 Oregon sport fishery by a discriminating and nondiscriminating resource "owner".

The method used in this study to estimate potential benefits from commercially-harvested fish is based on the assumption that demand and market price are not influenced by changes in quantity. This perfectly elastic demand situation for commercially-caught fish is represented in Figure 8 and Figure 10 by D_c while E_c is the cost of efficient commercial harvest.

However, sport-caught fish would be of lower value if taken in the commercial catch. Coho salmon and steelhead, which have a lower commercial value, predominate in the sport catch. The higher valued chinook salmon is more important in the commercial catch. The average value of each commercially-caught fish is \$4.54. The average value of each sport-caught fish transferred to the commercial catch is approximately \$3.06 (Table 19). Total revenue, therefore, would be increased if all fish valued at less than \$3.06 to sportsmen were transferred to the commercial catch.

With the 1965 success level at 2.1687 days per fish, maximizing revenue would require a charge of \$9 per day for fishing rights. With only dollar unit changes considered, it would pay the nondiscriminating resource "owner" to charge at least \$9 per day as long as marginal revenue per fish was less than \$3.06, assuming that Oregon data is representative of the entire Columbia River sport catch. This is only an approximate answer since marginal revenue of the two products is not equated exactly.

However, as explained earlier, marginal revenue in this case is associated with fishing success. If this limitation did not exist, it would be useful to equate marginal revenue from sport-caught fish at $3.06. This modification is omitted since only an approximate solution is possible with existing data.

At a charge of $9 per day for fishing rights, the nondiscriminating resource "owner" would receive $19.52 per fish, furnish 294,273 fish (9.5 percent of the total catch) to the sport fishery for a net return of $5,744,209. This division between sport and commercial catch is also shown in Figure 10. A total of 704,326 fish would be transferred to the commercial catch with a value of $3.06 each for a total net value of $2,155,238. The value of the commercial catch when commercial and sport fishing are maximized simultaneously is listed in Table 21.

When revenue from sport and commercial fishing is maximized simultaneously by the nondiscriminating resource "owner," sport catch would be worth $5,744,209 and the commercial catch $9,231,458. The total value of the Columbia River production would be $14,052,521 which is $247,423 more than that resulting when revenue from sport and commercial harvest is maximized independently. However, marginal revenue of the two products were not equated except to the closest dollar unit since measurement error associated with success level would likely exceed a

Table 21. Total estimated weight and gross value of the potential 1965 commercial catch of anadromous fish attributable to the Columbia River with revenue from sport and commercial fishing maximized simultaneously

Source	Estimated weight	Estimated gross value
	Pounds	Dollars
Commercial catch	21,139,000 1/	6,732,000 2/
Transferred from sport catch	7,286,488	2,155,238
Indian fishery	1,324,700 3/	344,220 3/
Total	30,290,188	9,231,458

1/ Table 9.
2/ Table 10.
3/ Appendix Table 16.

more accurate adjustment for revenue maximization.

Social Optimum Product Division

Optimum product division may vary considerably depending upon the method used to estimate total net benefits. For practical reasons it has been assumed up to this point that the resource "owner" lacked the ability to discriminate among users of sport fishing or to shift the sport demand function through quality changes. Optimum "social" division of a given fish supply for a particular time conceivably may be more accurate if it assumed that the monopolist has the ability to discriminate among current users. The term "social" is not meant to imply that consumer surplus does not represent a valid economic value. However, this terminology is used here to distinguish between values derived by assuming a nondiscriminating monoplist versus a discriminating monopolist.

An important distinction between the method of estimating the value of sport and commercially-harvested fish is the maximization of a scarcity position for sport fishing. The estimating technique used for sport fishing assumes that a monoplist would function as owner and thus seek to benefit not only from the value of the resource (i.e., "social surplus"), but also to reap potential benefits from artificially created scarcity in the typical manner of monopoly theory.

A more optimum social distribution might result by assuming that the resource owner has the ability to practice price discrimination in supplying current sport fishermen. The theoretical product division in this case is indicated by reference to Figure 10 and Figure 11. The computations for the optimum social product division is presented in Appendix Table 21. The social optimum according to the criteria of consumer surplus indicates that 25.31 percent of the total Columbia River production should have been harvested by sportsmen in 1965 compared to 30 percent with existing product division. Both social and economic optimum, therefore would require that present sport harvest be reduced.

The relationship between a discriminating and nondiscriminating resource "owner" (i. e., monopolist) for the Oregon catch is demonstrated in Figure 11. The nondiscriminating monopolist would charge $8 per day for sport fish where revenue from sport and commercial fishing is maximized independently. The discriminating monopolist would charge a minimum of $1.27 per day for fishing rights with 1,055,646 fishing days predicted for 1965.

These same figures can be extrapolated to the entire Columbia River production by the same method used for the nondiscriminating monopolist. A revenue-maximizing, discriminating monopolist would have charged a minimum of $1. 27 per day for fishing rights with 25. 31 percent of the total Columbia River production (811, 701 fish) estimated to have been taken by sportsmen in 1965. By discriminating (i. e., capturing consumer surplus), the sport catch in 1965 would have been worth an estimated $15, 908, 254 (Appendix Table 21) including the value of fish shifted to the commercial catch. This transfer would result by eliminating those fishermen unwilling to pay at least $1. 27 per day for fishing rights. If the value of fish shifted to commercial catch ($422, 587) is excluded, the sport catch for the discriminating monopolist in 1965 would have been worth $15, 485, 667. This compares to $5, 800, 036 for the nondiscriminating monopolist maximizing revenue of sport and commercial fishing independently and $5, 744, 209 when revenue from the two products is maximized simultaneously.

The social and economic optimum would be the same if there were a feasible means of capturing consumer surplus. The net economic value of the Columbia River anadromous fishery to a discriminating resource "owner" would have been $22, 276, 852 in 1965 for the sport, commercial and Indian catch. However, this value is likely to overestimate the economic importance due to the need to evaluate consumer surplus as a partial solution to consumer welfare assuming all other products are not influenced. Thus, this value would tend to overestimate the economic value even if it were feasible to capture consumer surplus. However, it is sufficient to exclude this case as the economic optimum due to lack of practical means to discriminate. Thus, this value is used only to indicate an approximate optimum division of the available fish supply between sport and commercial catch from a social point of view.

Only an approximate solution is presented since marginal revenue from sport and commercial fishing are not equated exactly. The marginal sport-caught fish for the discriminating monopolist would be worth $2. 75 ($1. 27 per day charge for fishing rights multiplied by 2. 1687 success) while the marginal value of this product in the commercial catch would be $3.06. No additional adjustment is presented, however, due to potential measurement error in determining the success level. Success of 2.1687 days per fish indicates that at least $1.41 should be the minimum charge in the sport fishery for the discriminating "owner." The success level would have to fall only to 2.409, however, for this minimum to be $1.27. Measurement error and data limitations, which were explained in Chapter V, are likely to exceed any additional accuracy possible through this adjustment. As pointed out earlier, without more information related to fishing success, only an approximate solution is possible to indicate optimum division between sport and commercial harvest for either economic or social optimum.

Even this approximate solution can be criticized because of insufficient evidence on fishing success to relate demand for fishing to demand for sport-caught fish. The additional adjustments to maximize revenue from sport and commercial fishing simultaneously (Table 21) may be useful to indicate economic optimum division of the available fish supply. However, since demand for sport-caught fish has not been predicted, this adjustment will be omitted from benefit-cost comparisons. The automatic shift from sport to commercial catch as the necessary prerequisite for maximizing sport fishing revenue, however, is included.

Thus the potential net benefits for a nondiscriminating, resource "owner" who maximizes revenue from sport and commercial fishing independently, as summarized in Table 20, will be used for comparison of benefits and costs. This is more nearly representative of potential net revenue that society could obtain from these resources in terms of estimated market values based on predicted demand for sport fishing and actual demand, measured historically, for commercial fishing.

Current Benefits and Associated Costs

Current benefits and costs of Government programs to maintain these benefit levels are compared in this section. It should be noted that continued dam construction requires that future costs be increased just to maintain current benefit levels. Unless some mitigation expenditures are forthcoming, new dams would reduce existing levels of fish production.

For this reason, and also to maintain continuity of the programs involved, all costs were included in Chapter II. A total of $248,765,900 has been invested in facilities to maintain Columbia River anadromous fish runs (Table 5).

Application of economic analysis to past investment decisions can accomplish little more than to determine if these decisions, which were based primarily on noneconomic criteria, might also have been wise according to economic criteria as well. However, no action can follow from conclusions to the contrary, as far as altering past investment decisions. Critical evaluations of past decisions are useful only as a basis for present and future policy formulation in fishery management and as a basis for future public programs.

Cost Subject to Control and Alteration

There are a number of expenditures categories that are subject to control and change at present or in the future. These are operation and maintenance expenditures for existing facilities, construction costs for planned future projects, and alternative use value for existing facilities. Another important category, although it is beyond the scope of the present study, involves application of economic principles to production decisions in order to reduce operating costs of existing facilities. Possible salvage value of existing facilities where alternative uses are lacking is also of minor importance. Another relatively minor factor is potential savings in fixed costs for private firms if efforts to preserve these fish resources were abandoned.

Operation and maintenance costs have been increasing annually, due to additional facilities, additional research requirements as each new dam complicates existing conditions, and due to price trends of recent years. Average operation and maintenance costs for the periods 1962 to 1965 are used to determine the appropriate value for this category (Table 5). These include operating and maintenance costs not only for existing facilities, but for all facilities presently under construction as well (except for the Wells project). Projects under construction are listed in Appendix Table 1, and projected completion dates for these projects are presented in Appendix Table 25. Average operation and maintenance, research, and evaluation expenditures for 1962 to 1965 for existing projects and those under construction is $9, 136, 000 (Table 5).

Construction costs for planned future facilities were presented in Table 6. Of course, conditions change over a time, and these particular facilities may never be constructed, and costs may be either higher or lower at the time of actual construction, if this occurs. However, based on existing knowledge and conditions at the time of these projections, $86, 246, 300 will be required for future projects, with an annual amortization of $2, 729, 350 and annual operation and maintenance expenditures of $1, 364, 900 (Table 6).

Alternative use value of existing facilities varies with the type of facility. Fish ladders at the dams constitute by far the largest category of investment. There is no alternative use for these facilities and little, if any, salvage value.[28/] This is true also for planned future expenditures. The salvage value of passage facilities may, in fact, be negative if maintenance or removal are the only alternatives. Fish hatcheries, on the other hand, can be converted from production of anadromous fish to production of resident fish in many cases. However, an accurate estimate of this alternative use value would require the services of several types of technicians specifically evaluating each site.

A total of $26,052,000 has been committed to construction and management in the Columbia River Fisheries Development program (Appendix Table 2). However, this includes sums spent for improving natural habitat, removing stream blockage, constructing fish screens, and similar activities of benefit primarily to anadromous fish only. A total of $11,552,250 (including 1967 planned expenditures) has been spent on hatchery construction through this program. Mitigation expenditures at the dams through various agencies and private firms have also gone for construction of hatcheries and spawning channels in addition to some state funds. The alternative use value of these facilities, however, is unknown.

28/ An exception of minor importance is production of shad--a relatively low value anadromous fish that apparently suffers little, if any, from dam construction. However, the value of this fish probably would not equal the variable costs of operating the fish ladders.

Facilities with an alternative use value have been partially depreciated. Only the present value can be considered for alternative use unless market value exceeds the book or partially depreciated value. Even the value determined in this manner does not represent the true alternative use value, since some facilities for anadromous fish will have no value in production of resident fish. Conversion costs to the alternative use must also be considered in determining alternative use values. Taking these factors into account, along with the approximate funds originally committed to construction of facilities that have potential alternative use, a value of $8, 000, 000 is believed to be a reasonable estimate of the present alternative use value of facilities constructed to preserve anadromous fish runs. This would require an annual amortization of $372, 320 at three percent for 35 years. This latter figure was selected to represent the average useful life expected for these facilities where original amortization would be based on 50 years. Facilities constructed through the Columbia River Fisheries Development Program have been built (or converted) since 1949. Where facilities were funded through mitigation associated with dam construction, the dates will generally vary in relation to the time when the dams were constructed.

Salvage value, if any, would be too low to consider, and likely in total might be negative. In other words, it would probably cost society more to maintain or remove existing facilities than their salvage value is worth, if efforts to preserve the fishery were abandoned.

Some fixed factors for private utility firms, such as taxes and insurance, would be eliminated by abandoning effort to preserve fish runs. Interest expense, like annual amortization for public investment, has meaning only if society continues to operate these facilities. If efforts to maintain fish runs were abandoned, the costs for society in terms of resources committed to existing facilities are already fixed, regardless of who bears the cost. If private firms imposed interest and amortization costs on power users where fish passage facilities were abandoned, this would simply represent a transfer of the burden of past decisions from one segment of society to another.

While insurance, taxes, and similar factors would be reduced, they would represent a relatively small annual cost. Taxes could, of course, be obtained either by increasing rates or the taxation base. Thus, elimination of these facilities from tax roles does not necessarily assure a tax reduction. Due to the difficulty of estimating this value, no annual cost is included for this category.

Based on the foregoing, estimated costs that are subject to control and change at present or in the future are summarized in Table 22.

Table 22. Expenditures subject to control or change in present or future time periods

Cost category	Approximate annual amount
Operation and maintenance	$ 9,136,000
Future projects--annual amortization	2,729,350
Future projects--annual operation and maintenance (Table 6)	1,364,900
Alternative use value	372,320
Total	$13,602,570

The total annual costs shown in Table 22 represent all expenditures that are subject to control and change at the present time. These are the only factors that can appropriately be included in an economic analysis aimed at indicating the maximum expenditure justified for maintaining these fish resources, based on maximization of consumer welfare according to economic criteria. However, examples will be given later indicating that these costs might possibly be reduced through greater concern for economic principles in guiding production and investment decisions.

Further, these costs are applicable only so long as no new investments occur. Once an investment is made, the amount involved is no longer subject to control and change. The investment then becomes given data as far as current or future policies are concerned. Thus, the analysis in this study involves present and future actions, but is valid only as long as factors presently subject to control remain in this status.

Expenditures for research, operation and maintenance, and replacement are not expected to continue at the levels indicated in Table 5. Opportunity cost of water used in fish ladders will increase and operation and maintenance costs will also likely climb for existing facilities. However, it is expected that productivity of future expenditures may be improved due to cumulative effect of knowledge gained from past efforts. When all factors are considered, costs of preserving the fishery are estimated at $15 million annually. This compares with $13, 602, 570 listed in Table 22.

Much of the increase in future operation and maintenance expenditures have already been included in the future projections of Table 22. Thus, total annual expenditures of $15 million should be sufficient to take into account increased costs arising from changes in price level, more intensive use of water supplies, and similar factors. This represents costs necessary to maintain present productivity levels in the future. Although future costs are included in current benefit costs ratios, future benefit levels will be considered separately. The reason for this is the fact that future value productivity may increase even if future physical productivity is constant or even declines. It is necessary, however, to consider likely future physical productivity of these fish resources as the first step towards estimating future benefits.

Current Benefit--Cost Ratios

Present decision making must involve at least present and future costs, but not costs no longer subject to control and change. Thus, this section compares 1965 benefits with costs subject to change in 1965 (i.e., factors involved in decision making.)

Benefits from the Columbia River anadromous fishery in 1965 are estimated at $13, 805, 098 (see p. 152). Annual costs subject to control and alteration for facilities constructed or under construction is $9, 508, 320 (Table 22 less future costs). All economic costs subject to either present or future control have been estimated at $15, 000, 000 annually. This includes all costs listed in Table 22 and an additional amount for increases in operation and maintenance costs of existing facilities to the extent not already included in Table 22.

Two benefit-cost ratios are mentioned in passing, although neither is relevant to decision making concerning economic justification of this public program. Annual costs subject to control in 1965 ($9, 508, 320), compared to benefits for 1965 ($13, 805, 098), yield a benefit-cost ratio of 1.45 to 1. However, if 1965 benefits are compared with all expected future costs necessary to maintain current physical productivity levels ($15, 000, 000), costs exceed benefits with a ratio of 0.92 to 1.00.

However, population growth and rising disposable income is likely to make future value of the fishery higher although productivity remains constant or even falls. Thus, insufficient information has been provided at this point on which to base decisions relating to economic justification for this public program. Since future values depend on current as well as future preservation programs, future benefit must also be included. Future benefits, however, depend on the likely success of the over-all public program to preserve the physical productivity of Columbia River anadromous fish. Thus, it is necessary to appraise likely future success of this program as a first step in estimating future benefits.

Future Productivity of the Fishery

Productivity of the fishery, both in physical terms (Table 9) as well as in value terms (Table 10) has been increasing since 1960. However, most of the projects under construction at the present time, or planned in the future, will affect important runs originating in the Snake River or its tributaries. The combined effect on these runs and on over-all output cannot be determined prior to completed construction of the new facilities.

To indicate likely future conditions, it is useful to consider the results that have been achieved through expenditures to preserve a portion of existing runs by providing passage facilities at dams, and the results of effort to mitigate losses elsewhere through construction of supplemental production facilities. This latter effort has primarily centered on the Columbia River Fisheries Development Program, while the former has been undertaken mostly through providing fish passage facilities and fish-passage research to make these facilities more effective.

It is difficult, if not impossible, to isolate the results of all supplemental programs such as screening, removal of stream blockage, and similar efforts to improve production of existing fish stocks and remaining natural habitat. Specific checks on these programs, such as spawning area counts, indicate that they have been successful. It is even more difficult to estimate how much success can be achieved in this manner in the future, but the Willamette Basin is an example where potential work of this type provides tremendous encouragement. Additional data on success of these activities may be available in the future through a study currently under way, involving Federal and state fish and game agencies. This study will evaluate future supply potential and anticipated demand.[29/]

Hatchery operations, another major supplemental program, has been evaluated in recent years through an extensive marking

---

29/ Walter Ray, Bureau of Sport Fisheries and Wildlife, Portland, Oregon, is chairman of this study group.

and recovery program involving 12 hatcheries. The results of this work have particular importance due to the potential to replace lost natural productivity through hatchery operations.

<u>Success of Fish Hatchery Projects</u>

Both chinook and coho salmon have been produced in Columbia River hatcheries with considerable success in recent years. An extensive program to determine the output of 12 hatcheries producing fall chinook salmon, through funds provided by the Columbia River Fisheries Development Program, was launched with the marking of an important portion of the broods of 11 of these 12 hatcheries. This evaluation study began in 1961, and essentially complete harvest records are now available for the 1961 brood. Fall chinook salmon are available for harvest from two years old to five years old, with a few reaching six or more years.

The time and geographic distance involved in fish migrations made this evaluation study costly, both in terms of time and money. Recovery of these marked salmon required stationing personnel at processing plants throughout the Pacific Northwest; British Columbia, Canada; and southeastern Alaska, in order to tabulate marked fish taken in normal fishing operations. Results for only one brood year (1961) are available due to the two to five year life span of the chinook salmon. This data is presented in Appendix Table 22.

Benefits from Hatchery Production

The physical catch data listed in Appendix Table 22 can be converted to value figures based on the information developed in earlier chapters. This catch data indicates a total sport catch of 32, 319 fish and a commercial catch of 179, 700 fish. Following the method developed in the previous chapter, a profit maximizing resource "owner" would elect to transfer a portion of the sport catch to commercial harvest. Using the average results obtained earlier for a nondiscriminating, resource "owner" maximizing revenue from the products independently, 64 percent of the present sport catch of 32, 319 fish would be shifted to commercial harvest. Thus, only 11, 635 fish (36 percent of 32, 319) would be retained for sport fishing.

Using the average value per sport-caught fish of $17. 35 (see p. 145) yields an estimated value of $201, 867. 25 for sport-caught, hatchery fish, assuming profit maximization as the objective. It should be noted, however, that since chinook salmon are probably the most highly valued species for the sportsman, using the average value for all sport-caught fish provides only a very conservative estimate.

Since only 11,635 fish would be harvested on sport gear, 200,384 fish would be available for commercial harvest. This total includes 179,700 fish presently taken in the commercial fishery and 20,684 fish transferred from sport to commercial harvest for profit maximization.

Catch data listed in Appendix Table 22 shows that 2.8 percent of the 1961 brood were taken as two years old (1962 harvest) and 3.4 percent as five years old (1966 harvest). A few will also appear in the 1967 harvest as six year old fish, but this amount will be insignificant based on historical data. Average price data does not fit two year old fish which are discounted for size and price and data are not available for five year old fish (1966). Due to minor importance of these extremes, the entire value for the 1961 harvest is based on 1964 (three year old) which are weighted 65 percent of the total harvest and 1965 data (four year old) which are weighted 35 percent of the total. The actual percentages, as shown in Appendix Table 22, are 61.4 percent three year old (plus 3.4 percent two year old) and 32.4 percent four year old (plus 2.8 percent five year old) which provides the above weighting factors. This simplification reduces calculation of gross value for the commercial catch and perhaps improves accuracy as well. The above method eliminates the extremes that do not fit into average price data which is all that is available for 1963 to 1965.

Catch weights for fall chinook salmon are not available for all areas of harvest. Furthermore, other than specific identification as by marks, fall chinook salmon would be classified only as chinook salmon if taken on troll gear at immature weights. Data from the Oregon Fish Commission indicates that the 1957 to 1966 average weight of gill-net landed fall chinook was 20.3 pounds for early fall run and 16.4 pounds for late fall run. Most hatchery fish returning to fresh water would be in the early fall run. Of course, many fish are taken on troll gear prior to returning to the river at maturity. The 1957 to 1966 average weight reported by the Oregon Fish Commission for all chinook salmon, therefore, is possibly more representative of the weight of hatchery fish. This average was 17.21 pounds in 1964 and 18.46 pounds in 1965. Thus, 0.65 (17.21) plus 0.35 (18.46) yields an average weight for the 1961 brood of 17.65 pounds per fish.

With the total commercial catch estimated at 200,384 fish at 17.65 pounds per fish, the total potential commercial harvest from the 1961 brood of hatchery fall chinook salmon was 3,536,778 pounds.

By dividing the value of the commercial catch of chinook salmon attributable to the Columbia River (but harvested in all areas) as shown in Table 10, by the commercial catch as shown in Table 9, the average price per pound for all chinook salmon in all areas can be estimated. This average figure is used to represent the price of all weights, quality, and locations where these fish are marketed. The average ex-vessel price determined by this method is 32.71 cents for 1965 and 37.82 cents for 1964.[30/] The weighting factors used for the average harvest weight are also used for a weighted average price. Thus, 0.65 (0.3782) plus 0.35 (0.3271) yields an average ex-vessel price of 37.03 cents per pound.

The total catch of 3,536,778 pounds can then be multiplied by 36.03 cents per pound which yields an estimated gross value for commercially-caught hatchery fall chinook salmon of $1,274,301. In Chapter IV, it was determined that a reasonable net value for commercially-harvested fish is 90 percent of the total gross ex-vessel value. On this basis the estimated net value of commercially harvested fish produced by these hatcheries is $1,146,871 (90 percent of $1,274,301). When this is added to the estimated sport catch value of $201,867, the total estimated net benefits of fall chinook salmon produced in these 11 hatcheries is $1,348,738. This total net benefit figure can be compared with cost of

---

30/ The value of the Indian harvest above Bonneville is not reported separately since this represents only a small proportion of the total catch and even a smaller share of total value. Fall chinook typically deteriorate rapidly in quality as they move upstream and thus contribute only a minor amount to this value.

constructing, operating, and maintaining these 11 hatcheries to indicate net benefit or loss.

Hatchery Production Costs

Since the 1961 brood was marked at only 11 hatcheries, cost data is based on these hatcheries only.[31/] A total of 51,455,000 fry were released from these 11 hatcheries in the 1961 brood.

The total construction cost of these 11 hatcheries was $7,099,000. Annual amortization calculated at three percent with an expected useful life of 50 years, is $275,910. The annual operation and maintenance costs are $896,637. Operation and maintenance expenditures include administration and general supervision of hatchery operations, technical assistance and engineering associated with hatchery operations, as well as usual operating and maintenance costs. However, general administration of the Columbia River Program, general research, evaluation of hatchery operations and similar general expenditures are not prorated to hatchery operations in the above cost estimates.

Since this cost of production data is shown for one year only, it does not reflect the gains made in hatchery operations. Costs of hatchery-produced fish have continued to fall (see Figure 12) at

---

31/ Data on the Toutle hatchery was not available.

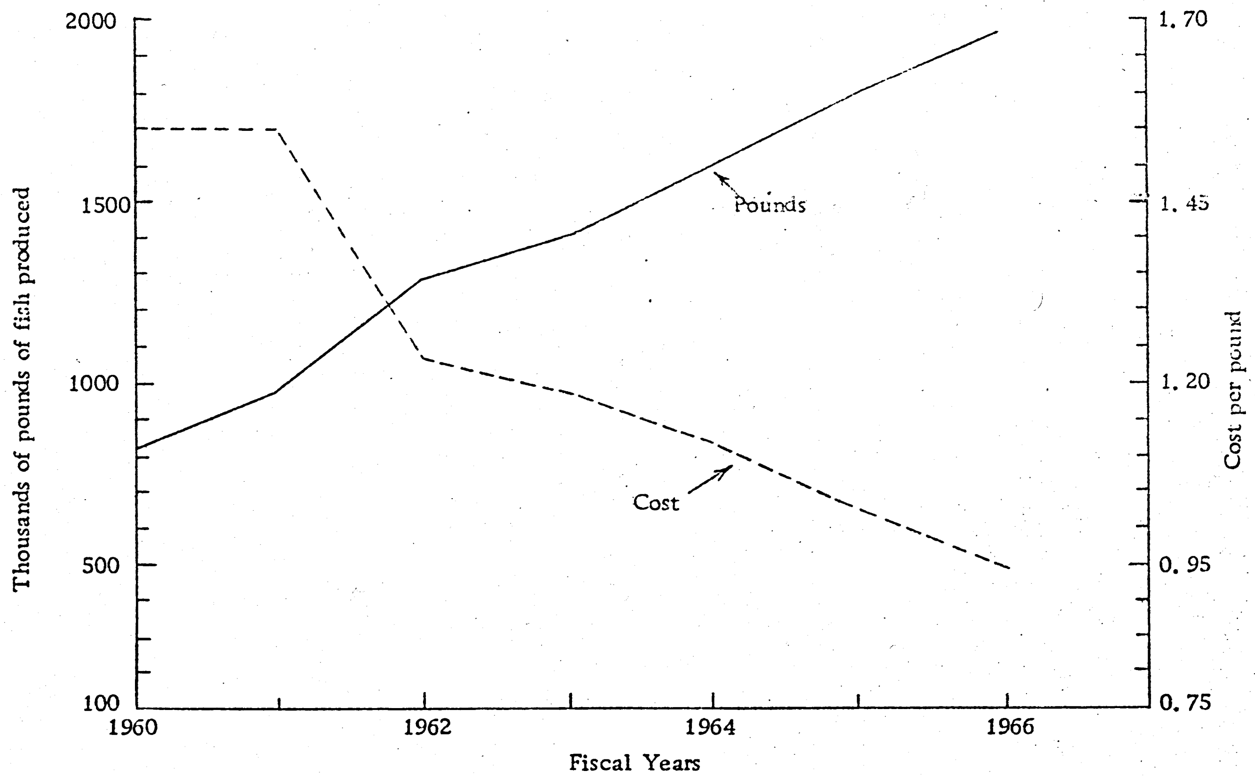


Figure 12. Pounds of fish produced at Columbia River Development Program hatcheries and cost per pound (82, Fig. 1).

the same time that continued success has been achieved in expanding hatchery output at all Columbia River Development Program hatcheries. Although cost data were not obtained for hatcheries operated by state fish and game agencies, these are likely to be equally successful.

Hatchery Benefit--Cost Ratios

Based on total annual operating costs of these 11 hatcheries of $1,172,547, compared with estimated annual net benefits of $1,348,738 yield a benefit-cost ratio of 1.15 to 1. This benefit-cost ratio indicates that hatcheries are able to make an important contribution to justifying continued effort in maintaining Columbia River anadromous fish runs based on economic criteria of maximum consumer welfare. However, several factors should be taken into account. As indicated in Appendix Table 22, nearly a third of the 1961 brood of hatchery fall chinook salmon were taken in the British Columbia, Canada, fishery. This value is included due to the reciprocal contribution of fish originating in United States and Canadian spawning areas. At the same time, it should also be observed that coho salmon typically turn south upon entering the ocean and are available to United States fishermen including the important sport harvest. Table 8 indicates, for example, that 45 percent of the chinook salmon troll catch in Canadian statistical reporting zones 21-27 originate in the Columbia River compared to 1.1 percent of the coho catch. Farther north there is no coho attributable to the Columbia River. On the other hand, 37.7 percent of the California troll catch of coho salmon are spawned in the Columbia while no chinook salmon in this fishery can be traced to Columbia River origin.

Output decisions for hatcheries are often based on desires to maintain historical fish runs. While economic criteria are not the only factors that should be considered, an economic analysis including species, level of output, balance of components and similar factors would be useful information in formulating fishery management policies concerning hatchery operations. Data obtained in this hatchery evaluation study, however, may provide useful background information for bargaining to determine the terms of future international agreements on fishing rights.

Success of Passage Facilities

In many cases, particularly for the Snake River and its tributaries, it is too early to tell if passage facilities at the dams--backed up by the Fish-Passage Research Program--will be successful in preserving an important segment of the fish run. However, available data on this and other areas of the Columbia River Basin provide useful preliminary estimates.

Fish counts over Bonneville Dam, which are available since 1938, indicate that a positive trend exists for the total of all fish species. The actual count showing variability of fish numbers is plotted along with the least-squares trend line in Figure 13. This trend is slightly positive although little importance can be attached to this fact for two reasons. First, as pointed out in earlier sections, adjustments in the length of the gill-net season will allow any desired number of fish to proceed upstream within the limitation imposed by the existing population. Summer run chinook salmon provides an excellent example where this upper limit has been reached. A second important factor is the life span of the fish involved. The estimated trend is influenced by fish populations that no longer affect the size of present runs.

In general, however, fishery management agencies can allow the desired total escapement to proceed upstream except for unforeseen changes in factors such as stream flow conditions and lack of knowledge concerning available populations. The data plotted in Figure 13 indicates that management agencies have succeeded in maintaining the Bonneville count and, over time, the total escapement has even increased slightly.

The escapement to particular areas above Bonneville Dam can be controlled with less success, however, than the Bonneville count. Research results indicate that approximately 10 percent of

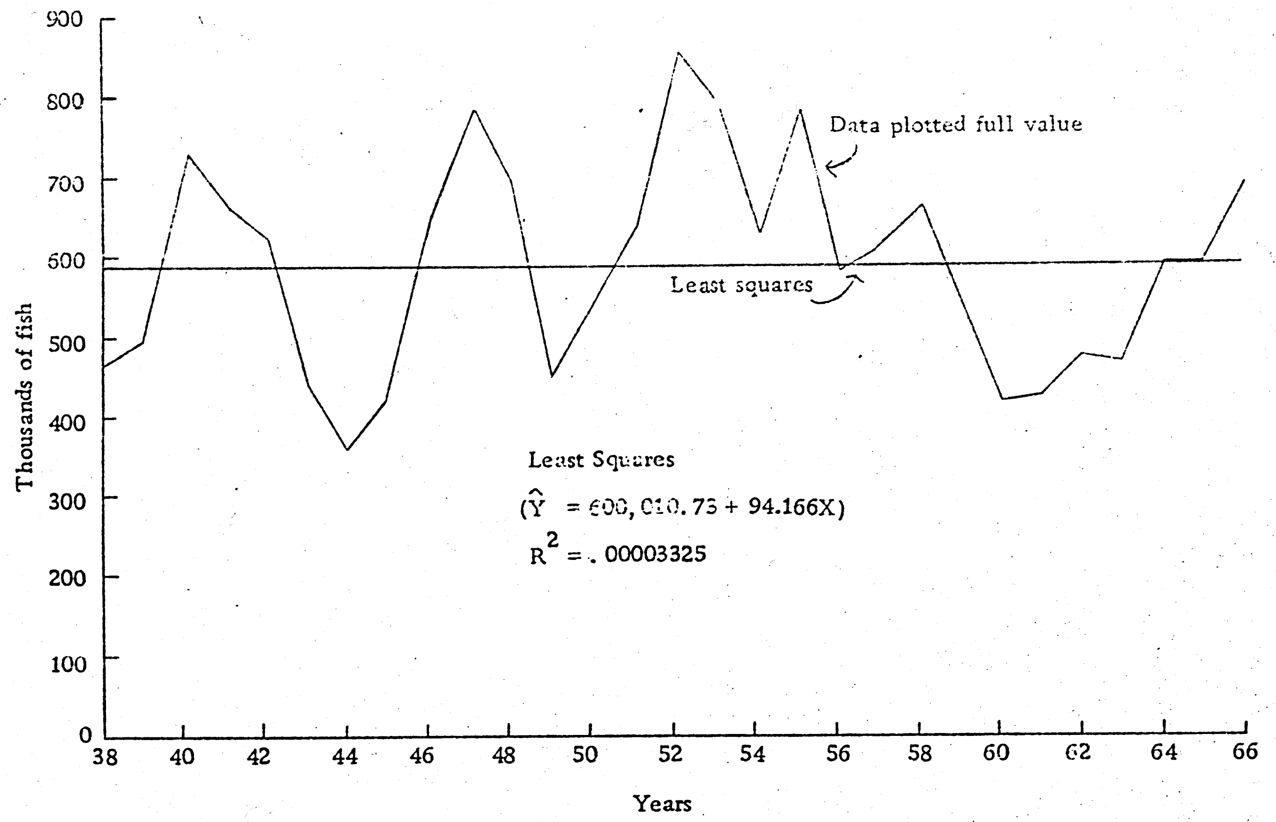


Figure 13. Fish counts over Bonneville Dam, 1938-1965.

all young salmon are lost in traversing each dam where passage occurs via the power turbine system and it is believed that the loss may far exceed this amount under some conditions (59). If this loss affects fish population, then over time it seems reasonable to conclude that a smaller number of fish would originate in upstream areas since all populations are subjected to proportionate fishing intensity in commercial and sport harvest and upriver populations would face increased loss at the dams compared to those originating further downstream.

Thus, over time, losses due to the detrimental effects listed in Chapter I supposedly should result in a shift to increased output in the lower river unless losses are neutralized by increased supplemental production in the upstream areas. However, location of supplemental production facilities has been guided by the goal of improving productivity of the lower river basin area (49, vol. 2, p. 1-2).

In order to indicate changes over time in fish populations originating in various areas above Bonneville dam, the ratio of each species (and spring, summer, and fall chinook salmon) at each dam was calculated relative to the Bonneville count. Since the Bonneville count varies from year to year (see Figure 13), a similar variation would also be anticipated for the counts at each dam above Bonneville. However, the ratio of each species at each dam to the Bonneville count should remain fairly constant and thus changes over time would provide at least preliminary evidence of changes in productivity of various areas of the Columbia River Basin or changes in management policies. In other words, the extent to which passage facilities and mitigation have not neutralized the detrimental effects to fish habitat in the upper river resulting from dam construction, population growth and economic development, could be at least roughly measured in this way.

Areas above the confluence of the Snake and Columbia River are of primary interest since fish originating in these regions are influenced to a greater extent by dam construction and passage facilities. Thus, the analysis of this section concentrated on the upriver mainstream Columbia and the Snake River and its tributaries. Unfortunately, the Ice Harbor data, which provides information on essentially the total Snake River run, is available only since 1962. This limited number of observations and the rapidly changing conditions resulting from new projects severely reduces ability to explain changes that have occurred in this area. As pointed out in earlier sections, most of the dams under construction at present or planned in the future will influence Snake River fish runs (Figure 1 and Appendix Table 25). The Rock Island Dam count, on the other hand, provides information relating to success of passage facilities in maintaining runs in this area that coincides with the period of heavy dam construction.

The Rock Island Count

Fish counts at Rock Island Dam are available since 1933--five years prior to counts at Bonneville Dam. The Rock Island site is far upstream in the main stem Columbia. Two dams with passage facilities are located upstream and six dams with passage facilities are located downstream from the Rock Island Dam. The Ben Franklin site is also below the Rock Island Project. Thus, this dam count involves fish populations that have been influenced by a number of dams with construction continuing upstream (Wells Project) and downstream (John Day), and with future construction planned (Ben Franklin). Because of these changes, the ratio of the Rock Island count of each species relative to the Bonneville count is believed to provide at least a rough approximation of the success of passage facilities and the Fish-Passage Research Program in preserving fish populations in upstream areas.

The ratio of the Rock Island count relative to the Bonneville count is plotted in Figure 14 for sockeye salmon, chinook salmon (all), and for total salmon and steelhead. The relative importance of all of these fish populations is improving over time as demonstrated in Appendix Table 23, where the components of a simple

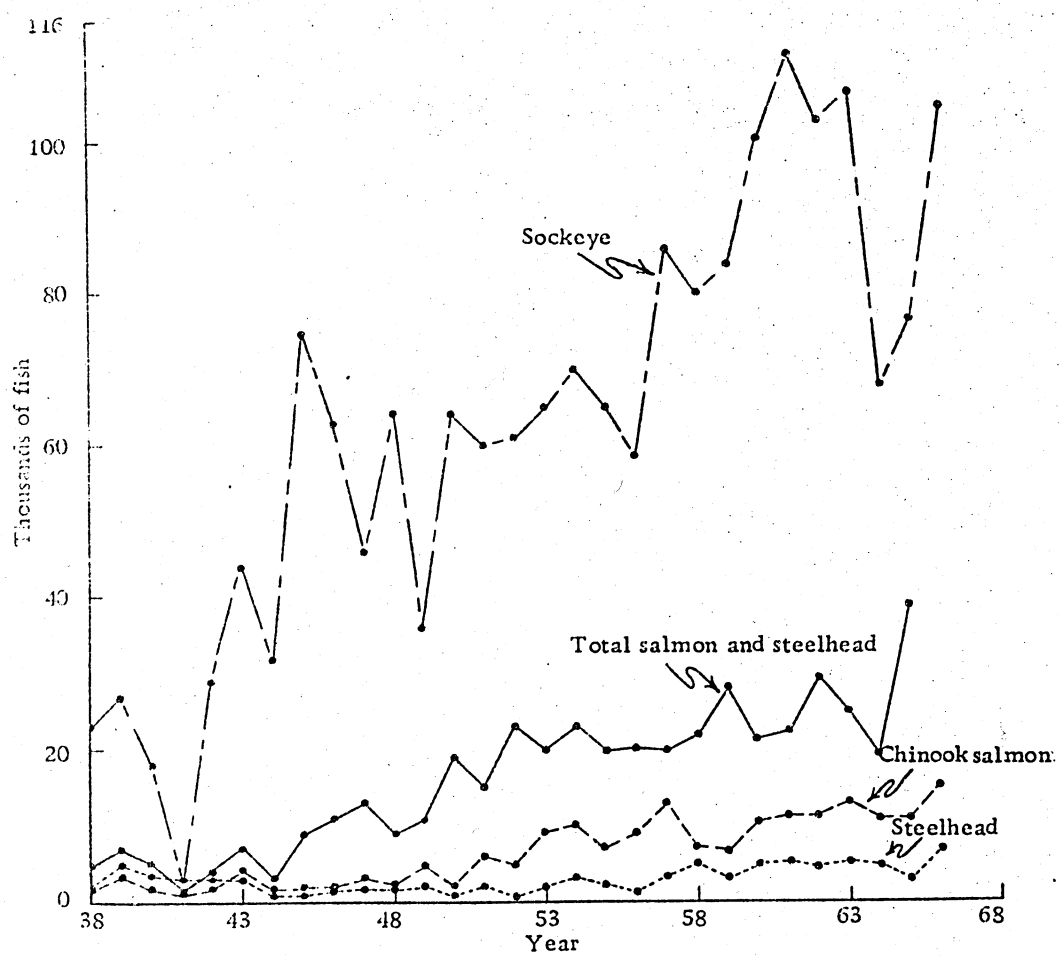


Figure 14. Fish count at Rock Island Dam as a ratio of Bonneville Dam count, 1938-1966.

linear regression for each specie is listed. The trend in each case is positive.

Ice Harbor Count

Although passage facilities and mitigation appear to have successfully maintained the fish runs originating above Rock Island Dam, the same cannot be said at the present time for the runs spawned above the Ice Harbor Dam in the Snake River tributaries. Data are available, in this case, only since 1962, although some fish count data earlier than this based on other counting methods are also of interest.

The fish count for steelhead trout, chinook salmon (all), and for total salmon and steelhead passing Ice Harbor Dam is presented in Figure 15. Statistical components associated with simple linear regression are also listed in Appendix Table 23 for all major anadromous fish species migrating to this area. In this case, populations of all species are declining. With only five observations available for each species (1962-1966), explanation of this situation is severely limited both for statistical measurement as well as suggested explanations based on general knowledge of fish populations.

This decline in fish runs, for example, may be due to natural cyclic trends in fish populations. Another possibility concerns the

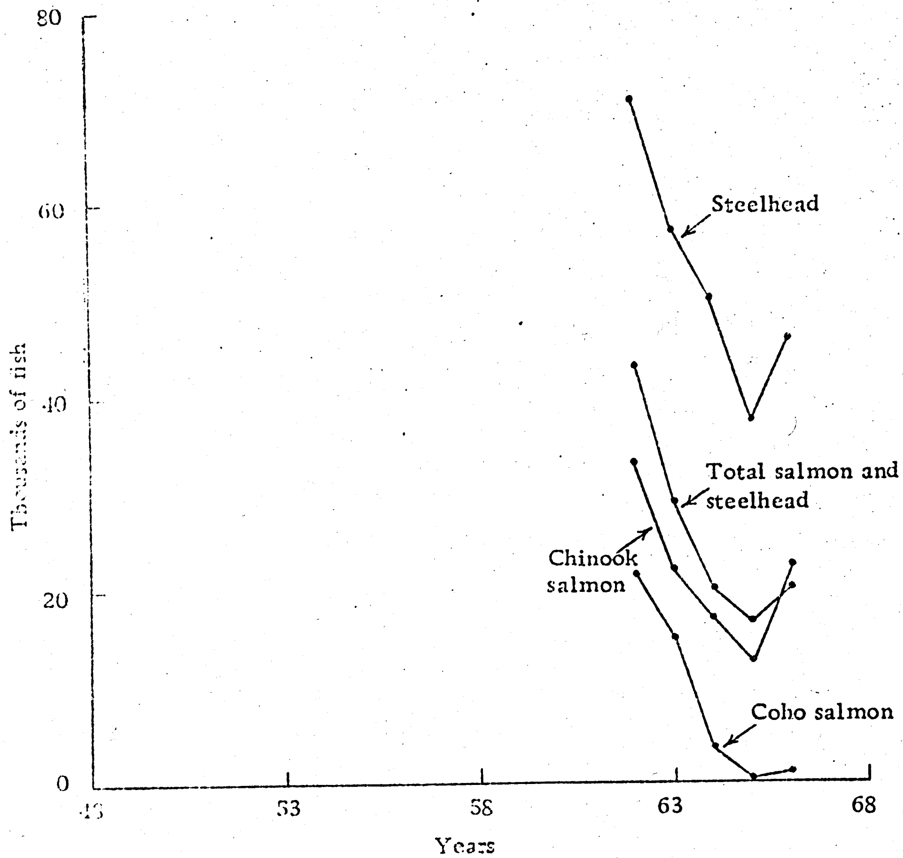


Figure 15. Fish count at Ice Harbor Dam as a ratio of Bonneville Dam count, 1962–1966.

effect of construction activity on fish populations. A third possibility involves resilience in fish populations. Perhaps these decline to low levels and then naturally bounce back for unknown reasons. A fourth possibility that must be taken into account is potential future loss of the important Snake River contribution in spite of all efforts to prevent this. Present declines in fish runs along with future construction planned for this area does not promote optimism at present.

Many unexplained factors influence fish populations. Some of the more obvious include timing of gill-net seasons which affect some populations more than others. Environmental conditions of a particular year or series of years may also influence some species more than others due to time when fish are migrating. Declining runs in one area of the river basin may also influence relative importance of another area. Increased sockeye salmon numbers have been an important factor in recent gains above Rock Island Dam. This run is influenced by control over gill-net seasons. The decline in steelhead trout has been especially important in the Snake River since construction of the Ice Harbor Dam. However, as can be seen in Figures 14 and 15 and Appendix Table 23, all fish species have become relatively more important above Rock Island Dam (over a period of 26 years) and all species have declined above Ice Harbor Dam (fish count available for five years only).

Future Columbia River Production

From the mixed conclusions of the foregoing section, it is difficult to predict future success in maintaining productivity of the Upper Columbia River anadromous fishery. Many problems remain unsolved or only partially solved. Future demand on water resources due to both economic growth and population increase will also be important. An encouraging note is the increase in over-all fish productivity since 1960 (Table 9) which may reflect success in improving runs through fish passage facilities and supplemental research. Future supply conditions, however, depend heavily on demands for other water resource products in the future and funds committed to maintaining or improving anadromous fish runs.

If total physical production of the Columbia River anadromous fishery can be maintained at 1965 levels into the foreseeable future, this estimate would probably be as optimistic as past performance will justify unless extensive future investment is made in research and supplemental production facilities. Future plans for research and implementation by investment in needed facilities has not been included in this study due to lack of planning at the present time for these needs and lack of projected expenditures.

Future Demand

Future demand projections for sport fishing follows the same procedure used in Chapter V. The 1962 Oregon demand function (Appendix C) is used to project future demand based on the following assumptions:

1. Tastes and preferences of individual fishermen are assumed to remain constant over time.
2. Preferences patterns of all Pacific Northwest sport fishermen are assumed to be similar to their Oregon counterparts.
3. Changes in quality are assumed to have no influence on demand for sport fishing.

Based on the foregoing, sport fishing demand was projected for 1980 and 2000. However, changes in income were considered only to 1980, and beyond that time the income variable was held constant. Projections for the year 2000, therefore, are due to expected changes in population only beyond 1980. On this basis, sport fishing demand is expected to increase 179.6 percent by 1980 (due to anticipated increases in population and income) and to increase 248 percent by 2000 (due to expected population increases only after 1980).

Future demand, of course, depends heavily on the quality of fishing, and it is erroneous to assume that this variable is not important. However, lack of measurement of this factor, as pointed out in earlier sections, prohibits its inclusion in future projections. It should also be kept in mind that fish can be transferred from commercial to sport harvest in many cases as a means of controlling quality of sport fishing. Also important are the alternatives available to sportsmen both for other recreational activities and for salmon-steelhead fishing on stocks not of Columbia River origin. (Other limitations associated with this estimating method were listed in Chapter V.)

Without accurate data on future supply, future alternatives, effect of changes in quality, and what quality changes are likely to occur, projections of future sport fishing demand are severely limited. As a basis for tentative comparisons, however, it seems safe to conclude that sport fishing demand is likely to increase in the next few years at a pace similar to the rapid gains of the last few years (see Appendix Tables 17 to 19) and will likely at least double by the year 2000 unless quality deteriorates excessively. The potential to shift fish from commercial to sport harvest reduces the importance of quality deterioration to some extent, although number of fishermen, congestion at fishing sites, and similar factors also affect sport fishing quality.

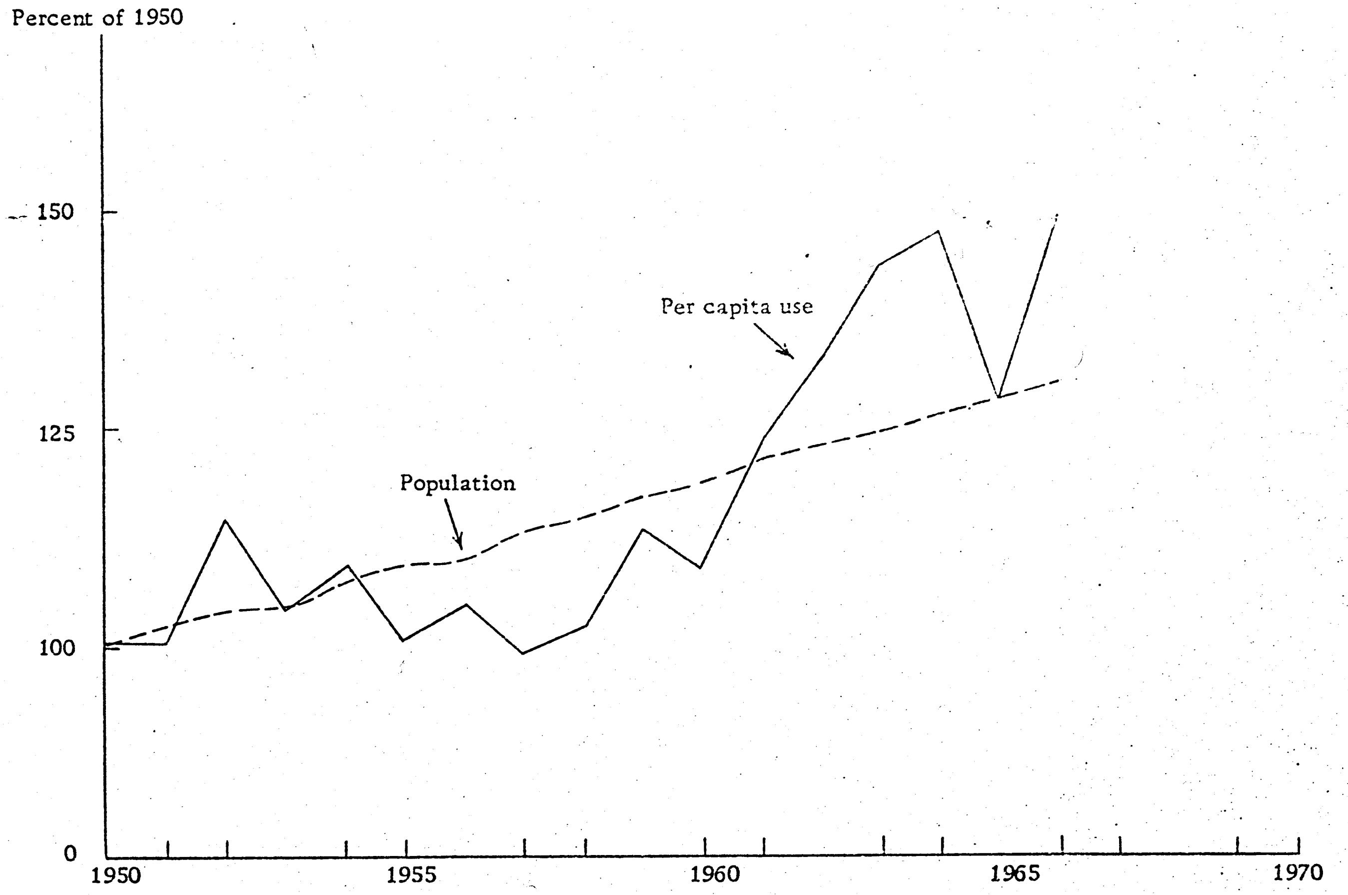
Projected demand for commercially-harvested Columbia

River anadromous fish is based on projected demands for all fish products. Growth in demand for fish products has exceeded population increases in recent years. This is demonstrated in Figure 16.

It is expected that increasing incomes in the future will have a greater effect on per capita consumption of fish than they have in recent years. "Their effects will not be offset in the future to the extent they have been in the recent past by other factors such as declining prices and increasing supplies of poultry, beef, and other animal protein." (83, p. 3) "For planning purposes, a realistic estimate . . . in the year 2000 . . . is an increase of 134% . . ." (83, p. 6) This increase of 134 percent is equivalent to 234 percent of the 1966 consumption of fish products.

Based on these projections, demand for commercially-harvested fish products is expected to keep pace with the increasing demand for sport fishing. The projected demand for sport fishing was 248 percent of the 1962 level while that for commercial products is estimated to be 234 percent of the 1966 consumption figure. This latter figure assumes that consumption of Columbia River anadromous fish products follow predicted national trends for all fish products.

Demand for commercially-harvested fish, like that for sport fishing, however, is influenced by supply and alternative products



Includes edible and industrial products

Figure 16. Comparison of U.S. population and per capita utilization of all fishery products (83, p. 2).

available for consumers. The competitive position of fish products with other protein sources is expected to favor increased demand for fish in the future. Supply from the Columbia River specifically, on the other hand, may limit use of commercial production from this area.

Supply from other sources would not be fixed, particularly for commercial products, resulting in some shift away from Columbia River production since a constant future supply (excluding stochastic variation) has been assumed for the Columbia River. Based on the projected increases in sport and commercial demand, it is estimated that the future demand for Columbia River production (but not necessarily use) will expand by 175 percent of current levels by 2000. This figure is suggested as a reasonable estimate for purpose of tentative comparisons only and is not based on any attempt to measure future supply possibilities from other fishing areas, competitive situation between anadromous fish and other fish products, or similar complex factors that will influence future demand for Columbia River production.

It is assumed that use of commercially-harvested fish products in general will increase by 134 percent by the year 2000. Based on this assumption, a conservative estimate of 75 percent is projected for increase in value productivity for commercially-caught Columbia River production.

However, to the extent that the limited supply is shifted from commercial to sport harvest, this will alter the over-all balance between individual commercial and sport projections. Benefits from sport harvest are expected to increase by 100 percent, and those from commercial production by at least 75 percent. Thus, an over-all estimated increase in value productivity of these fish resources is estimated at 75 percent by the year 2000. This may prove to be a very conservative estimate.

Future Benefit--Cost Ratios

Future benefits are estimated at 175 percent of the 1965 level by the year 2000. Based on this estimate, future benefits are expected to be $24, 158, 922 assuming supply can be held at least equal to 1965 levels. Fixed supplies were projected on the basis that natural fish habitat will deteriorate to some extent due to future dam construction unless supplemental programs are expanded, but this will be cancelled to some extent by continued improvement in the success of current preservation efforts resulting from the effect of cumulative knowledge and continuing research. Research funds were included in annual average operation and maintenance costs listed in Table 5. Additional supplemental programs are likely to improve this supply situation, but these are not planned at present.

Comparison of future benefits estimated at $24, 158, 922, and future costs of $15, 000, 000, yield an estimated benefit-cost ratio of 1.6 to 1.0. The improved future benefit-cost ratio (relative to 1965) would be attributed to success in fish preservation techniques and increased value productivity of the fishery.

It should be noted that future benefit-cost ratios are based on costs amortized over a period of 100 years while increases in benefits are considered only until the year 2000. However, future investment is probably only poorly planned at present. Investment in additional supplemental facilities and future changes in supply and demand prevent more than tentative comparisons based on existing estimates.

CHAPTER VII

CONCLUSIONS

It is often popular to stress the theme that the Columbia River anadromous fishery will be lost in the next few years. This contention is not supported by available data.

As a whole, preservation efforts, particularly since 1960, have apparently been very successful. Although historical runs of all species may not have been maintained equally, or the runs to all areas not protected with equivalent success, changes in the overall productivity of the Columbia River over time does not support any dire claims of impending doom.

New problems must be expected that will require new answers, but if funds are forthcoming for this purpose, there is ample reason to believe that technically it will be possible to maintain a major fishery in the Columbia River in spite of additional demands imposed on available water resources. The purpose of the present study, however, is not to determine if it is technically possible to preserve these fish runs, but rather if it is economically advisable to continue to do so. To do this, it is necessary to determine the appropriate amount of resources, justified by economic criteria of consumer welfare, that should be committed to preserving or improving Columbia River anadromous fish runs. This requires that cost of maintaining these fish runs be compared with potential benefits. Meaningful comparisons can be made simply by converting all data to an annual basis although the economic interpretation of past expenditures relative to present and future decisions must be first established. Future costs, to the extent that future expenditure policies have been planned, must also be taken into account. Future physical productivity depends heavily on investment in new technology and supplemental facilities in order to neutralize new demands by products competing with anadromous fish for available water supplies.

Progress in Maintaining Productivity of Fishery

The maximum physical productivity of the Columbia River anadromous fishery apparently occurred when 49, 480, 000 pounds of salmon and steelhead were marketed in 1911 (76, p. 11). An average of 29.8 million pounds were produced from 1928 to 1932, the five years prior to beginning construction of Bonneville Dam, but commercial production fell to 23.5 million in 1936 (76, p. 11.) The average annual commercial, sport, and Indian catch for the period 1938 to 1947 has been estimated at almost 32 million pounds (76, p. 11). The commercial production of salmon-steelhead from 1948 to 1965 is presented in Table 9 with a harvest of 20, 788, 000 pounds estimated for the 1965 commercial catch (does not include shad).

The following factors affecting commercial catch records need to be kept in mind in the above comparisons:

(1) Fish taken in earlier years probably were larger on the average since a greater percentage of the harvest occurred as fish returned at maturity to fresh water spawning streams. In this case, increased production would be a theoretical possibility at present from this source if ocean sport and commercial harvest were curtailed.

(2) Earlier catch data in some cases may refer to Columbia River landings which is not equivalent to Columbia River production.

In spite of these limitations, these comparisons give a general indication of changes over time in the level of physical productivity of the fishery. The 1965 commercial production apparently exceeds that for 1925 (Table 9 and Table 13) and total production of the Columbia River in 1965 is nearly equal to the harvests of other years listed in the above example except for the record 1911 catch. In 1965, an estimated 30 percent of the Columbia River harvest was taken on sport gear (Figure 10) which means an additional production estimated at 9,606,663 pounds based on the average weights explained in earlier sections. When this is added to the commercial catch of 20, 788, 000 pounds and the Indian catch of 1, 324, 700 pounds, an estimated total production of 32, 070, 363 pounds results (including the minor shad run (351, 000). If shad is excluded for purpose of comparison to historical data, the total production was 31, 719, 363.

Production of the Columbia River anadromous fishery for selected years relating to periods when dam construction was absent, minor or proceeding at a rapid pace is shown in Figure 17. It is important to remember the limitations that have been pointed out in connection with the data demonstrated in Figure 17. Of particular importance for historical data is the possibility of confusion between records relating to Columbia River landings and Columbia River production. Landings in the Columbia River area probably were more nearly equivalent to production during earlier fishing seasons when more of the production was taken in the Columbia River (Appendix Table 24 indicates this change). Current estimated catch and value data is especially limited by lack of knowledge of Columbia River contribution to various West Coast fishing areas. Some duplication is also likely between commercial and Indian data. The information presented in Figure 17 probably provides more comparable value than production data. Benefit-cost comparisons have been converted to 1965 basis as explained in the following section.

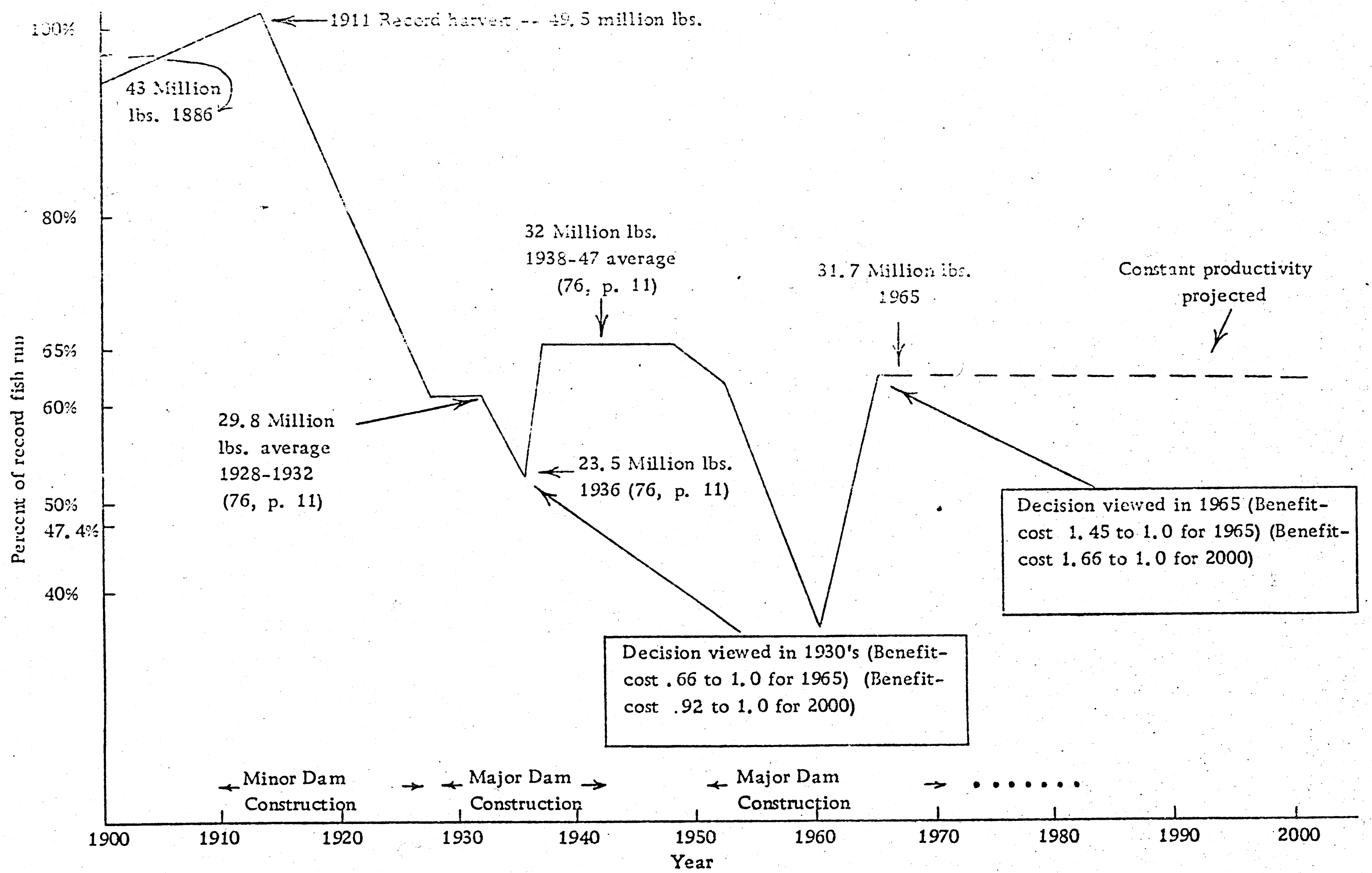


Figure 17. Approximate physical production of the Columbia River anadromous fishery in relation to dam construction, limitations on decision making, and benefit-cost ratios.

A few dams affecting anadromous fish were constructed as early as 1910. Serious development began in the 1930's, picked up steam following the post-war reconversion period through the 1950's and continues at a fast pace (see Appendix Table 25). Too often, however, the wisdom of preserving Columbia River anadromous fish runs is posed at present in the form in which this problem might have appeared in the 1930's. Decisions concerning resources committed in the past to fish preservation directly influence present investment decisions only to the extent of the greater of either salvage or alternative use value. Funds committed in the past to the construction of fish ladders, for example, have no direct influence on current preservation decisions. Past decisions based on noneconomic criteria should be included in current analysis only to the extent that expenditures are subject to change at present or in the future.

Decision-Making Limitations

The interpretation of alternative benefit-cost ratios can also be clarified with respect to Figure 17. An economic analysis in the 1930's (had available knowledge led to predictions equivalent to the estimates of this study using 1965 benefit estimates) would have indicated that a benefit-cost ratio of .66 to 1.0 could have been expected by 1965. This is based on annual amortization of $11, 262, 900 (Table 5) plus annual operation and maintenance, and alternative use value resulting in annual costs of $20, 771, 220. This is compared to 1965 benefits totaling $13, 805, 098.

Had the problem in the 1930's been viewed even further in the future to the year 2000 (using 1965 results), total costs of $26, 262, 900 ($15, 000, 000 plus $11, 263, 900 annual amortization of past investments) would have been compared to total benefits of $24, 158, 922 (175 percent of the 1965 level). This yields a benefit-cost ratio of .92 and 1.00. If analyzed on this basis in the 1930's preserving the over-all productivity of the Columbia River anadromous fishery would not have been justified by economic criteria alone (unless projected beyond 2000). This does not mean that preservation would not have proceeded justified by extra-market values. Nor does this imply that an error results from this procedure. Throughout this study, benefits have been limited to those represented by e stimated market prices. This does not suggest that total welfare considerations based on extra-market values are not an appropriate justification for efforts to maintain productivity of these fish resources.

However, from the standpoint of present decision making costs remaining subject to control at present or in the future amount to $15, 000, 000 compared to benefits of $24, 158, 922. This benefit-cost ratio for the future is expected to be 1.61 to 1.0. The 1965 costs subject to control ($9, 508, 320) yields a benefit-cost ratio of 1.45 to 1.00.

Based on 1965 and expected future benefit-cost ratios, it would be unwise to discontinue efforts to maintain the productivity of these fish resources based on economic criteria, in addition to any justification based on extra-market criteria. A benefit-cost ratio of 1.45 to 1.0 estimated for 1965 and 1.66 to 1.0 for 2000 justify the continuation of preservation effort based on traditional capital costs and where no alternative public investments are considered. Investment already made, therefore, limits the range of choice in decisions concerning maintaining the productivity of these fish resources.

The question as it might have been posed in the 1930's was "should we attempt to preserve Columbia River anadromous fish resources?" The problem in the 1960's however, is "should we continue this effort to maintain the productivity of these resources?" Based on economic welfare criteria, as indicated by estimated market prices, (but considering this project in isolation from other alternatives), data developed in this study indicates the answer to the first question would have been no, while the answer to the second is clearly yes. The point often confused is that only the latter question remains subject to present decision making. As the result of past investments, the share of this task that appears to remain indicates that we are committed at present on an economic basis (in addition to any former commitments based on noneconomic criteria) to continued effort to maintain production of a composite product from the water resources of the Columbia River Basin.

Improving Benefit-Cost Ratios

Having made this decision, the need to improve existing benefit-cost ratios should be given further consideration. Economic analysis normally is based on the assumption that the most efficient technology is used in production methods. This is not the case for the Columbia River anadromous fishery. Regulated inefficiency wastes benefits made possible primarily by the natural trait of salmon to return to fresh water at maturity. This waste has been rationalized and taken into account in estimating techniques used in this study. The fishery has a value to society as reflected in estimated market prices regardless of the decision to waste this value through the process of regulated inefficiency.

Fishery management policies that give inadequate weight to economic principles has not been taken into account in the benefit-cost ratios determined in this study. This includes lack of consideration for economic principles in production as well as in the need to guide future investment into activities with greatest expected return.

There is also a potential to alter future management policies to provide more favorable benefit-cost ratios by including economic criteria as an important factor in policy formulation. This can be done by reducing operating and maintenance costs on existing facilities, by making past investment more productive, by increasing the efficiency of future investment and by using past data as the basis for improving future actions. These topics are beyond the scope of this study, but some examples of improving over-all benefit-cost ratios will briefly be pointed out.

One possible means of reducing operation and maintenance costs of existing facilities is to make fish ladders subject to closing during the three winter months of December, January and February or other periods when fish counts may be extremely low. Few fish apparently use the ladders during this winter period although counting is discontinued at this time and definite data is not available. Furthermore, the ladders are often closed during a portion of this winter period for necessary repairs.

Since power is sold on the basis of assured minimum supplies, maintaining fish ladders subject to close could mean that water could be available to fishways at any time spillage was taking place. At present, this is estimated to be about 40 percent of the time on the average. It is possible that a very small fish loss may result if operation of fish ladders were discontinued during these winter months.

It has been estimated that the inclusion of fishway water for three months of the year would have a value in power production of $276, 000 (3-month closure).[31/] Since spillage is estimated to occur 40 percent of the time, theoretically this water would not have an opportunity cost. On this basis, 60 percent of the above figure, or $165, 600 could possibly be saved from annual operation and maintenance costs on existing facilities. This is suggested only as a possibility and obviously would require further study before being proposed for implementation. Based on economic criteria, however, the marginal value productivity of fishway water should be equal in production of power or fish preservation. This fact would determine the period of the year when ladders should be subject to closing due to insufficient fish to justify water use in the ladders. A decision to make ladders available beyond this period would have to be justified by noneconomic criteria and should not become a part of any future economic analysis.

This argument can be extended to many cases where preservation efforts aim at maintaining the entire run. It may be far more practical to sacrifice some marginal proportion in the interest of

---

31/ Bonneville Power Administration, Branch of Power Resources, Portland, Oregon. July 1967. Based on Federal and nonfederal projects existing and under construction.

economic feasibility. While it may be technically possible to preserve virtually the entire run from a threatened loss, it will be far more practical from an economic point of view to evaluate marginal gains with costs.

Research expenditures also might effectively gain from economic analysis. The hatchery evaluation study outlined in the previous chapter involved a cost of approximately $2, 250, 000 and required stationing of personnel along the Pacific Coast for the necessary number of years to record marked fish data available from normal fishing operations. Only about 10 percent of this amount was involved in marking costs. From an economic standpoint, the cost necessary to adequately recover all marks from this study was fixed regardless of number of fish marked. Additional marking of production from all hatcheries and all streams was considered. This variable cost would have potential to spread the heavy fixed costs of recovering marked fish and tabulating data over increased numbers of fish. These additional markings were omitted due to the high death loss from the marking process and lack of facilities for capturing wild fish and estimating proportion marked. However, the level of fixed costs required for this research study suggests that evaluation perhaps should have been postponed until additional research could be undertaken to solve these problems, In the first place, it is questionable that a study costing approximately $2, 250, 000 to evaluate hatcheries involving an investment of $7, 099, 000 (see p. 185) can be justified on an economic basis. Of more importance to economic analysis is the need to determine the relative productivity of alternative preservation and improvement projects. If economic criteria are to be included as a basis for fishery management policies in the future, eventually a study similar to the hatchery evaluation project will be needed. A basis for establishing the productivity of alternative projects will become essential as the basis for applying economic production theory to problems relating to fish resources. It may prove unfortunate that the hatchery evaluation study was not postponed until techniques could be developed to provide this data and thereby achieve greater efficiency from the fixed cost involved in recovering data from fish marking studies.

There seems to be a strong tendency to justify efforts to preserve historical runs or species distribution regardless of economic justification while demanding a much more stringent set of rules for supplemental facilities such as hatcheries or improved productivity from remaining natural habitat. The Columbia River and Pacific Ocean provide a gigantic laboratory and in some cases new knowledge may be much more costly than maximizing known production techniques. For example, a fish barrier constructed at Brownlee Dam at a cost of $3, 424, 688 was abandoned in 1963. It has been pointed out that $2, 250, 000 was spent to evaluate the productivity of 12 hatcheries that cost less than three times this amount to construct. Although the variable operating costs in the two cases are far different, it is of interest to note that a careful evaluation of hatchery operation was demanded; it would be interesting to have an accurate comparison of funds expended in evaluating the feasibility of the fish barrier at Brownlee prior to its construction. This example appears to be somewhat typical of the justification required for different types of investment. This difference probably results from the method of formulating fishery management policies.

Framework for Policy Decisions

It has recently been charged that "more money is spent to save the salmon in the Columbia River than to conserve and develop all of the rest of the food fishery resources on the Pacific Coast" (57, p. 17b). If this is true, it may provide preliminary evidence that insufficient funds have been committed to the development of other Pacific Coast fisheries, or possibly that an inappropriate balance exists between areas where funds are committed. But this provides no economic evidence that excess resources have been committed to maintaining or improving anadromous fish runs in the Columbia River.

The framework for this study has been evaluation of a single public program. The study assumes that the goal of this program is consistent with consumer welfare. This is necessary since the program is evaluated from a central point with past effort taken as given data.

Several important limitations should be noted in using this approach. Past investment decisions, present management policies and future plans do not have to be based on economic criteria. This can be summarized simply--benefits and associated costs are evaluated according to economic criteria, but the underlying expenditure decisions and resulting benefits are not the result of economic decision making.

Evaluating resulting benefits has been limited by lack of adequate information to determine the Columbia River contribution to Pacific Coast fishing areas and by inadequate catch statistics for sport fishing.

Potential benefits from sport-caught fish were estimated, based on techniques that substitute transfer cost as a proxy for market prices which are not available. In this case, a demand curve is predicted with the resource "owner" assumed to maximize returns based on existing supply and demand conditions, through imposition of a daily charge for fishing rights.

Only sport fishing demand in Oregon has been estimated by this method, and only for 1962. Assuming that tastes and preferences of sport fishermen remained constant, this demand situation was used as the basis to generate a new function based on population and income changes from 1962 to 1965. This is the last year with all necessary sport data tabulated at the time of this study. The 1965 Oregon demand for sport fishing was then extrapolated to other sport fishing areas where Columbia River spawned salmon and steelhead make an important contribution.

It is important to appreciate the potential error that may result from inadequate catch status where this method of evaluating benefits is employed. Therefore, the method used will be briefly reviewed. The value of sport fishing in Oregon was estimated first, but this was independent of fishing success. Sport catch was then determined from available statistics and a value per fish determined for Oregon sport fishing. The lower the Oregon catch, the greater will be the value per fish. Any error established at this point was magnified later since the Oregon value per fish was extrapolated to the entire Columbia River catch in all areas.

Official sport catch data was based on conservative estimates according to officials interviewed in this study. Thus, it was necessary to use an estimated Oregon catch that was believed to be more representative of actual results. This was accepted in this study based on the belief that if an error resulted, it should be toward the conservative end of possible value estimates.

Had the Oregon catch been accepted at low harvest figures (which may be completely correct) and coupled with an estimation technique that evaluates fish independent of fish harvest, an inflated value bias could have resulted. Extrapolation to other areas made this possibility sufficiently serious that a conservative bias seemed the more palatable of available choices. Additional research to estimate a current demand curve for sport fish for all areas where the Columbia River makes an important contribution is needed.

Evaluating the effect of variations in fishing success on sport fishing demand is another problem that needs to be attacked in order to avoid restricting estimation to past events. Fishing success needs to be related to demand for fishing to avoid this limitation. Present estimating techniques take fishing success as given data.

Additional research to determine the most efficient method of harvesting commercially-caught fish is another pressing need if the evaluation method used in this study is to be made more accurate. Estimating techniques need to be improved to eliminate limitation of this method to established market prices and a given fish supply. This requires determining a demand function for these fish products and relating investment to market values. However, it is necessary to develop more accurate data on Columbia River contributions to various fishing areas. Until this is done, studies encompassing additional effort to reduce present estimating restrictions may not be warranted.

Summary

In spite of certain limitations, it is believed that the estimates obtained in this study provide a good indication of existing potential benefits. An effort has been made to avoid over-evaluating benefits whenever this appeared to be a problem. Reliable cost data, except for future costs, was available.

Using the most reliable data available indicates that technically we can continue to maintain the productivity of the Columbia River anadromous fishery. Economic analysis of present and projected future conditions provide justification for continuing this effort. However, a serious error will result if we do not challenge current management policies with the goal of eliminating regulated inefficiency and improving the productivity of investment in maintaining these fish resources. It should also be kept in mind that most, if not all, of the investment in the Columbia River anadromous fishery has been to maintain existing productivity or supplement productive capabilities lost in one area of the river basin with increased output in another. Maintenance of historical production patterns has also been an important factor in investment decisions.

A decision-making system primarily guided by social values and limited primarily only by technical knowledge, due to the inability to quantify, of necessity resolves to a system of value judgments. Major decisions and policies in this case are obtained by political means through the influence of social organization. Resource allocation and consumer welfare can be improved by including economic principles as an integral part of future management and investment decisions for the anadromous fish resources of the Columbia River Basin.

BIBLIOGRAPHY

1. Angstrom, Richard L. Informational report of fishery benefits attainable by enhancing the Klaskanine salmon hatchery water supply through development of an upstream storage reservoir on the north fork of the Klaskanine River. Portland, Oregon Fish Commission, Water Resources Section, June, 1965. 9 p.

2. Bator, Francis M. The anatomy of market failure. Quarterly Journal of Economics 72:351-359. Aug. 1958.

3. Bell, F. W. and J. E. Hazeltine (eds.) Recent developments and research in fisheries. Dobbs Ferry, N. Y., Oceana Publications, 1967. 233 p.

4. Benefit-cost analysis: papers presented at the meeting of the American Association for Advancement of Science (Sections K and M), Berkeley, California, Dec. 27, 1954. (Western Agricultural Economics Research Council. Committee on the Economics of Water Resources Development. Report no. 3).

5. Brett, J. R. Salmon research and hydroelectric power development. Ottawa, Canada, 1957. 96 p. (Canada, Ottawa Fisheries Research Board. Bulletin no. 114).

6. Brown, William G. et al. An economic evaluation of the Oregon salmon and steelhead sport fishery. Corvallis, 1964. 47 p. (Oregon. Agricultural Experiment Station. Technical Bulletin 78).

7. Buchanan, D. R. and B. A. Campbell. The incomes of salmon fishermen in British Columbia, 1953-1954. Ottawa, Canada, Dept. of Fisheries, 1957. 48 p.

8. Canada. Dept. of Fisheries. British Columbia catch statistics. Vancouver, British Columbia, 1948-1965.

9. Clawson, Marion. Methods of measuring the demand for and value of outdoor recreation. Washington, D. C., Resources for the Future, Inc., 1959. 36 p. (Reprint no. 10).

10. Cleaver, Frederic C. The effects of ocean fishing upon Columbia River hatchery stock of fall chinook salmon. Ph. D. thesis. Seattle, University of Washington, 1967. 159 numb. leaves.

11. Cristy, Francis T., Jr. and Anthony Scott. The commonwealth in ocean fisheries. Baltimore, Johns Hopkins Press, 1965. 281 p.

12. Crutchfield, James A. (ed.) Biological and economic aspects of fisheries management. Seattle, University of Washington, 1959. 160 p.

13. Crutchfield, James A. Common property resources and factor allocation. The Canadian Journal of Economics and Political Science 22:292-300. Aug. 1956.

14. Crutchfield, James A. An economic evaluation of alternative methods of fishery regulation. Journal of Law and Economics 4:31-143.

15. Crutchfield, James A. Economic evaluation of sport fisheries: A progress report. A review of current economic literature on valuation of sport fishing. Seattle, Washington, University of Washington, Dept. of Economics. 17 p. (Mimeographed).

16. Crutchfield, James A. Economic value of Washington state fisheries, 1955. Pacific Northwest Business 31:5-15. July 1957.

17. Crutchfield, James A. (ed.) The fisheries: Problems in resource management. Seattle, University of Washington Press, 1965. 134 p.

18. Crutchfield, James A. Valuation of fisheries resources. Land Economics 38:145-154. 1962.

19. Crutchfield, James A. and Arnold Zeller. Economic aspects of the Pacific halibut fishery. Washington, D. C., U. S. Government Printing Office, 1963. 173 p. (U. S. Bureau of Commercial Fisheries. Fishery Industrial Research, vol. 1, No. 1).

20. Davidsen, F. A. Population trends in the blueback and Upper Columbia River fall chinook salmon. Ephrata, Washington, Public Utility District of Grant County, 1966. 36 p.

21. Donaldson, Ivan. Fish wheels of the Columbia. Portland, Oregon, 1967. (Submitted for publication to Binford-Marts)

22. Dorfman, Robert (ed.) Measuring benefits of government investments. Washington, D. C., The Brookings Institution, 1963. 429 p.

23. Fiekowsky, S. and W. Ballaine. Economic values of salmon and steelhead trout in Oregon rivers. Eugene, University of Oregon, Bureau of Business and Economic Research, 1952. 32 p.

24. Fiscus, Hugh and Warren Knispel. 1965 Columbia River (ocean) sport fishery. Portland, U. S. Bureau of Commercial Fisheries, 1966. 8 p.

25. Fry, Donald H., Jr. Potential profits in the California salmon fishery. California Fish and Game 48:256-267. Oct. 1962.

26. Galbreath, James L. Timing of tributary races of chinook salmon through the Lower Columbia River, based on analysis of tag recoveries. Research Briefs of the Fish Commission of Oregon 12:1-23. April, 1966.

27. Galbreath, James L. Timing of Willamette River spring chinook salmon through the Lower Columbia River. Research Briefs of the Fish Commission of Oregon 11:29-41. June, 1965.

28. Gerhardsen, G. M. Production economics in fisheries. Revista de Economia Estudos de Economia 5:1-12. 1952.

29. Greenhood, Edward C. et al. The California marine fish catch for 1965. Sacramento, California Department of Fish and Game, 1967. 57 p.

30. Gordon, H. Scott. Economic factors in catch fluctuations. Journal of Fisheries Research (Canada) 12:1. 1953.

31. Gordon, H. Scott. Economic theory of a common property resource. Journal of Political Economy 62:124-142. 1964.

32. Hicks, Ronald H. and Lyle D. Calvin. An evaluation of the punch card method of estimating salmon and steelhead sport catch. Corvallis, 1964. 75 p. (Oregon. Agricultural Experiment Station. Technical Bulletin 81).

33. Hutchings, Harvey M. Assessment of our capability for management of common property fish resources. Washington,

D. C., 1965. 6 p. (U. S. Bureau of Commercial Fisheries. Program Planning Staff. Issue Paper no. 4)

34. Idaho. Fish and Game Department. Annual Report. Boise, Idaho. 1962-1965.

35. Ingalls, Donald. The Pacific Northwest region of the Bureau of Commercial Fisheries. Washington, D. C., U. S. Dept. of Interior, 1965. 24 p.

36. Knetsch, Jack L. Outdoor recreation demands and benefit. Land Economics 39:388-396. 1963.

37. Knispel, Warren and Hugh Fiscus. The 1966 Columbia River (ocean) sport fishery. Portland, U. S. Bureau of Commercial Fisheries, 1967. 6 p.

38. Krutilla, John V. The Columbia River treaty: an international evaluation. Washington, D. C., Resources for the Future, Inc., 1963. 22 p. (Reprint no. 42)

39. Krutilla, John V. and Otto Eckstein. Multiple purpose river development. Baltimore, Johns Hopkins Press, 1958. 301 p.

40. McKean, Roland N. Efficiency in government through systems analysis. New York, John Wiley and Sons, 1958. 336 p. (Operations Research Society of America. Publications in operations research, No. 3)

41. Maltzeff, Eugene M. Summary report: Indian fishery on the Columbia River. Portland, U. S. Bureau of Commercial Fisheries, 1965. 18 p. (Mimeographed)

42. Marts, Marion E. and W. R. D. Sewell. The application of benefit-cost analysis to fish preservation expenditures. Land Economics 35:38-55. 1959.

43. Milne, P. J. The chinook and coho salmon fisheries of British Columbia. Ottawa, Fisheries Research Board of Canada, 1964. 46 p.

44. Mishan, E. H. Rent as a measure of welfare change. The American Economic Review 49:386-394. 1959.

45. Netboy, Anthony. Salmon of the Pacific Northwest. Portland, Metropolitan Press, 1958. 122 p.

46. Nye, Gene D. and Dale Ward. Washington salmon sport catch report. Seattle, Washington Dept. of Fisheries, 1967. 36 p.

47. Oregon. Fish Commission. A report on the 1964 coho salmon fishery in Young Bay. Portland, Oregon, 1965. 6 p. (Mimeographed)

48. Oregon. Fish Commission. Take or catch of commercial food fish--Columbia River and major coastal fisheries during January through December, 1965. Portland, Oregon, 1966. 23 p.

49. Oregon. Fish Commission and Washington Dept. of Fisheries. The status report of the Columbia River commercial fisheries. Portland, Oregon, 1965-1967.

50. Oregon. State Game Commission. Fishery Division. Annual Report. Portland, Oregon, 1957-1965.

51. Oregon. State Planning Board. A study of commercial fishing operations on the Columbia River. Portland, Oregon, Aug. 22, 1938. 73 p.

52. President's Water Resources Council. Policies, standards and procedures in the formulation, evaluation and review of plans for use and development of water and related land resources. Washington, D. C., 1962. 13 p.

53. President's Water Resources Policy Commission. Ten rivers in America's future. Washington, D. C., 1950. 193 p. (Report of the Commission, vol. 2)

54. Rassmussen, Jewel J. Book review of the commonwealth in ocean fisheries. American Economic Review 61:1341-3. 1966.

55. Ricker, W. E. Some principles involved in regulation of fisheries by quota. The Canadian Fish Culturist 22:1-6. May, 1958.

56. Robison, Robertson, Dale Ward and Gene Nye. 1965 fisheries statistical report. Seattle, Washington Dept. of Fisheries, 1955. 96 p.

57. Royce, William F. ...And also problems. National Fisherman 46:17b. April, 1967.

58. Royce, William F. et al. Salmon gear limitations in Northern Washington waters. Seattle, University of Washington Press, 1963. 123 p.

59. Schoeneman, Dale E., Richard T. Pressey and Charles O. Junge, Jr. Mortalities of downstream migrant salmon at McNary Dam. Transactions of the American Fisheries Society 90:58-72. Jan. 1961.

60. Schultz, Charles L. Statement of the Director of the Bureau of the Budget. In: Fiscal policy issues of the coming decade: Hearings before the Subcommittee on Fiscal Policy of the Joint Economic Committee, Congress of the United States, 89th Congress, 1st Session, July 20, 21, and 22, 1965. Washington, D. C., 1965. p. 59-96.

61. Scott, Anthony. The fishery; the objectives of sole ownership. Journal of Political Economy 63:116-124. 1955.

62. Scott, A. D. Notes on user cost. The Economic Journal 63:368-384. June, 1953.

63. Sewell, W. R. D. and M. E. Marts. The Nez Perce Dam and the value of a fishery. Land Economics 37:257-260. Aug. 1961.

64. Sewell, W. R. D. et al. Resources for tomorrow: guide to benefit-cost analysis. Ottawa, Queen's Press, 1965. 49 p.

65. Silliman, Ralph P. Estimation of the troll catch of Columbia River chinook salmon, oncorhynchus tshawytsha. U. S. Fish and Wildlife Service, 1948. 15 p. (Special Scientific Report no. 50)

66. Smith, Stephen C. and Emery N. Castle (eds.) Economic and public policy in water resource development. Ames, Iowa State University Press, 1964. 463 p.

67. Stansby, Maurice E. (ed.) Industrial fishery technology. New York, Reinhold Publishing Corp., 1963. 393 p.

68. Stevens, Joe B. Angler success as a quality determinant of sport fishery recreational values. Transactions of the American Fishery Society 95:357-363. 1966.

69. Stevens, Joe B. Recreation benefits from water pollution control. Water Resources Research 2:167-182. 1966.

70. Stevens, Joe B. and Frank Bollman. Paper presented at the meeting of the Committee on the Economics of Range Use and Development of the Western Agricultural Economics Research Council, San Francisco, August 2, 1966.

71. Turvey, Ralph. Optimization and suboptimization in fisheries regulation. Agricultural Economics Research 16:64-76. Mar. 1964.

72. U. S. Army. Corps of Engineers. Annual fish passage report, Bonneville, The Dalles, and McNary dams. Portland, 1958-1961.

73. U. S. Army. Corps of Engineers. Annual fish passage report, North Pacific division, Bonneville, The Dalles, McNary and Ice Harbor dams. Portland, 1962-1966.

74. U. S. Army. Corps of Engineers. Annual report, passage of fish over Bonneville, and McNary dams, Columbia River, Oregon and Washington. Portland, 1954-1956.

75. U. S. Army. Corps of Engineers. Columbia River and tributaries, northwestern United States. Vol. 1. Washington, D. C., 1962. 396 p. (81st Congress, 2nd session, House Document no. 531)

76. U. S. Army. Corps of Engineers. Information bulletin--fish passage facilities--Bonneville dam. Portland, April, 1958. 85 p. (Report 66-1)

77. U. S. Army. Corps of Engineers. Water resources development. Anchorage, Alaska, 1967. 52 p.

78. U. S. Bureau of Commercial Fisheries. Columbia River fisheries program. Washington, D. C., Nov. 1964. 45 p. (Circular 192)

79. U. S. Bureau of Commercial Fisheries. An economic evaluation of Columbia River anadromous fish programs: a preliminary study. Washington, D. C., Aug. 1965. 45 p. (Mimeographed)

80. U. S. Bureau of Commercial Fisheries. Economic values of anadromous fishes in Oregon rivers. Portland, 1952. 28 p. (Mimeographed)

81. U. S. Bureau of Commercial Fisheries. Fishery statistics of the United States. Washington, D. C., 1948-1965.

82. U. S. Bureau of Commercial Fisheries. General comments on harvest and production of Columbia River salmonids. Portland. Nov. 1966. 16 numb. leaves. (Unpublished)

83. U. S. Bureau of Commercial Fisheries. Economic Research Branch. Projected needs for fish products. Washington, D. C., May 9, 1967. (Issue Paper no. 1)

84. U. S. Bureau of the Census. Statistical Abstract of the United States. Washington, D. C., 1966. 1039 p.

85. U. S. Office of Business Economics. Per capita income by states and regions. Survey of Current Business 47:15. April, 1966.

86. U. S. Dept. of the Interior. Departmental manual; Water and related land resources. Various paging.

87. U. S. Fish and Wildlife Service. Columbia River fishery program. Washington, D. C., 1964. 20 p. (Circular 192)

88. Van Hyning, Jack M. Factors affecting the abundance of all chinook salmon in the Columbia River. Corvallis, Oregon State University, 1967. (Unpublished and incomplete Ph. D. Thesis)

89. Washington. Dept. of Fisheries. Annual report. Seattle, 1958-65.

90. Wendler, Henry O. Regulation of commercial fishing gear and seasons on the Columbia River from 1859 to 1963. Washington Dept. of Fisheries, Fisheries Research Papers 2:19-31. Dec. 1966.

91. Young, L. L. Patterson Ridge pumped storage site, Washington. Tacoma, U. S. Dept. of the Interior, 1967. 35 p.

APPENDIX A

Appendix Table 1. Estimated costs of fish facilities for U. S. Corps of Engineers projects in the Columbia River Basin[1/]

Project	Total est. proj. cost	Fisheries engineering research costs: Const.	Fisheries engineering research costs: O & M	Total direct costs fish facilities	E & D Chargeable to fish facilities	S & A chargeable to fish facilities	Total cost of fish facilities	Average annual: Operation & maintenance	Average annual: Replacements
				Completed projects (dollars)					
Chief Joseph Dam, Wash.	144, 400, 000	320, 000			300, 000	20, 000	320, 000		
Columbia River at Bonneville, Oregon and Washington	83, 200, 000		67, 100	7, 003, 900	300, 000	361, 000	7, 732, 000	231, 000	1, 500
McNary L&D, Oregon and Washington	294, 800, 000	550, 000	39, 500	24, 176, 900	976, 300	1, 536, 000	26, 728, 700	100, 000	120, 000
The Dalles L&D, Oregon and Washington	248, 000, 000	1, 000, 000	43, 500	13, 879, 100	668, 900	717, 900	15, 309, 400	68, 000	3, 000
Ice Harbor L&D, Washington	130, 000, 000	263, 500	28, 800	10, 376, 000	683, 400	666, 800	11, 755, 000	73, 000	68, 000
Cougar Reservoir, Oregon	54, 700, 000	166, 000	9, 500	627, 700	63, 400	54, 300	754, 900	10, 000	1, 000
Detroit Reservoir, Oregon	53, 546, 800		38, 300	1, 337, 200	109, 600	96, 900	1, 582, 000	122, 100	2, 000
Dorena Reservoir, Oregon	13, 529, 500			20, 000	5, 800	400	26, 200	1, 000	500
Fall Creek Reservoir, Ore.	21, 200, 000	25, 000	9, 900	1, 219, 800	156, 200	75, 000	1, 460, 900	11, 600	5, 200
Hills Creek Reservoir, Ore.	45, 800, 000	25, 000	5, 800	121, 400	9, 300	9, 800	146, 300	15, 100	1, 000
Lookout Point Reservoir, Ore.	77, 950, 800	35, 000	61, 200	1, 557, 300	111, 800	144, 200	1, 874, 500	164, 000	2, 000
Total	1, 167, 127, 100	2, 384, 500	303, 600	60, 319, 300	3, 384. 700	3, 682, 300	67, 689, 900	795, 800	204, 200
Leaburg Hatchery (Trout)							-1, 102, 000	-116, 000[2/]	
	1, 167, 127, 100	2, 384, 500	303, 600	60, 319, 300	3,384, 700	3, 682, 300	66, 587, 900	679, 800	204, 200

(continued)

Appendix Table 1. (Continued)

Project	Total est. proj. cost	Fisheries engineering research costs: Const.	Fisheries engineering research costs: O & M	Total direct costs fish facilities	E & D chargeable to fish facilities	S & A chargeable to fish facilities	Total cost of fish facilities	Average annual: Operation & maintenance	Average annual: Replacements
				Projects Under Construction (dollars)					
John Day L & D, Oregon and Washington	448,000,000	772,500	43,500	19,880,000	1,900,000	1,200,000	23,023,500	540,000	13,000
The Dalles L & D, Oregon and Washington	57,200,000			300,000	30,000	15,000	345,000		
Dworshak Reservoir Idaho	248,000,000	388,000		14,218,000	1,400,000	853,000	16,417,000	666,500	7,500
Little Goose, L & D, Wash.	148,000,000	230,000		6,600,000	660,000	429,000	7,689,000	105,900	5,300
Lower Granite L & D, Wash.	190,000,000	210,000		7,445,000	740,000	491,000	8,676,000	102,100	4,600
Lower Monumental L & D Washington	181,000,000	203,000		8,090,000	465,000	536,000	9,091,000	73,000	29,000
Blue River Reservoir, Oregon	30,100,000	25,000	5,100	59,000	22,000	3,000	89,100	13,000	750
Green Peter-Foster Reservoir, Oregon	82,300,000	94,000	40,300	2,757,000	463,400	179,200	3,439,900	57,100	1,000
Total	1,384,600,000	1,922,500	88,900	59,349,000	5,680,400	3,706,200	68,770,500	1,557,600	61,150

(Continued)

Appendix Table 1. (Continued)

Project	Total est. proj. cost	Fisheries engineering research costs: Const.	Fisheries engineering research costs: O&M	Total direct costs fish facilities	E&D chargeable to fish facilities	S&A chargeable to fish facilities	Total cost of fish facilities	Average annual: Operation & maintenance	Average annual: Replacements
Projects Authorized for Construction (dollars)									
Asotin Dam, Idaho & Wash.	102,000,000			11,070,000	617,700	645,000	12,332,700	64,000	4,600
Catherine Creek Reservoir, Oregon	14,000,000			580,000	59,000	56,000	695,000	15,400	2,400
Lower Grande Ronde Reservoir, Oregon	14,000,000			642,500	57,400	54,200	754,100	15,400	2,400
Strube Reregulating Reservoir, Oregon	9,890,000			294,000	35,000	16,200	345,200	8,000	1,000
Total	1,384,600,000			12,586,500	769,100	771,400	14,127,000	102,800	10,400
Projects in Planning Status (dollars)									
Bonneville L&D and powerhouse, Oregon and Washington	128,000,000			6,050,000	600,000	302,000	6,952,000		
Cascadia Reservoir, Oregon	41,800,000			1,082,000	108,000	54,000	1,244,000	5,000	1,000
Gate Creek Reservoir, Oregon	24,300,000			428,000	43,000	21,000	492,400	5,000	1,000
Total	194,100,000			7,560,000	751,000	377,000	8,688,400	10,000	2,000

1/ Source: Corps of Engineers Office, Custom House, Portland, Oregon.

2/ Fiscal year 1967, including annual replacement expense.

Appendix Table 2. Funds obligated for expenditure through the Columbia River Fishery Development Program by purpose and agency, June 30, 1966 1/

Agency	Purpose			
	Construction	Management techniques	Operation and maintenance	Total by agency
	Thousand dollars			
Bureau of Commercial Fisheries	6,027	1,100	8,262	15,389
Idaho Department of Fish and Game	2,626	334	251	3,211
Oregon Fish Commission	5,033	384	4,933	10,250
Oregon Game Commission	1,184	149	955	2,288
Washington State Department of Fisheries	7,402	454	5,907	13,763
Washington State Department of Game	1,231	128	1,326	2,685
Total by purpose	23,503	2,549	21,634	
Total funds				47,686

1/Source: Columbia River Fisheries Development Program Office, Portland, Oregon.

Appendix Table 3. State operating and maintenance costs not reimbursed by other funds, by activity and by agency (fiscal year 1966 or calendar year 1965) 1/

Activity	Washington Dept. of Fisheries 2/	Washington Dept. of Game 2/	Idaho Dept. of Fish and Game 3/	Oregon Fish Comm. 4/	Oregon Game Comm. 2/	Total
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Hatcheries and fish culture	85,000	27,500	25,115	146,446	21,290	305,981
Stream improvement and fish screens 5/	75,000	17,500			217,530	310,030
Research and education	50,000		4,000	96,850	73,350	224,200
Administration	51,000	15,000	14,000	145,025	32,950	257,975
Engineering				20,522		20,522
Miscellaneous					74,890	74,890
Subtotal	261,000	60,000	43,115	408,843	420,640	1,193,598
Law enforcement	36,000	15,000	35,000		143,490	229,490
Total	297,000	75,000	78,115	408,843	564,130	1,423,088

1/ Source: State fish and game agencies.
2/ Calendar year 1965.
3/ Fiscal year 1965.
4/ Fiscal year 1966.
5/ Includes some items that might normally be classified as capital investment.

Appendix Table 4. Annual operation, maintenance and law enforcement expenditures of funds provided by the states, 1962-1965 1/

Agency	Expenditure category	Fiscal or calendar year			
		1962	1963	1964	1965
Oregon Game Commission 2/	Oper. and maint.	327,230	358,320	389,410	420,500
	Law enforcement	123,700	130,297	136,893	143,490
	Total	450,930	488,617	526,303	563,990
Oregon Fish Commission 3/	Oper. and maint.	392,906	392,906	359,361	359,361
	Law enforcement	---	---	---	---
	Total	392,906	392,906	359,361	359,361
Idaho Department of Fish and Game	Oper. and maint.	24,925	20,750	28,975	43,115
	Law enforcement	26,000	46,700	45,000	35,000
	Total	50,925	67,450	73,975	78,115
Washington Department of Game	Oper. and maint.	60,000	60,000	60,000	60,000
	Law enforcement	15,000	15,000	15,000	15,000
	Total	75,000	75,000	75,000	75,000
Washington Department of Fisheries 2/	Oper. and maint.	201,000	221,000	241,000	261,000
	Law enforcement	29,000	31,333	33,666	36,000
	Total	230,000	252,333	274,666	297,000
Total all state fish and game agencies	Oper. and maint.	1,006,061	1,052,976	1,078,746	1,143,976
	Law enforcement	193,700	223,330	230,559	229,490
Total state expenditures		1,199,761	1,276,306	1,309,305	1,373,466

1/ Data provided by state fish and game agencies. Includes stream improvement expenditures.
2/ Data for 1963 and 1964 estimated from a straight line projection of 1962 and 1965 figures.
4/ Based on estimated expenditures and Governor's budget request.

Appendix Table 5. Estimated gain in energy from use of fishway water 1/

Project	Approx. fishway use (c.f.s.)	August H/K	MW mo.
Federal			
Bonneville	1,600	4.32	82.8
The Dalles	1,050	6.40	80.4
John Day	1,000	7.88	94.8
McNary	1,000	5.51	66.0
Ice Harbor	216	7.21	19.2
Lower Monumental	200	7.59	18.0
Little Goose	200	7.10	16.8
Lower Granite	200	7.24	16.8
Subtotal			394.8
Nonfederal			
Priest Rapids	500	6.05	36.0
Wanapum	500	6.29	37.2
Rock Island	250	2.12	6.0
Rocky Reach	700	7.34	61.2
Wells	1,100	5.23	69.6
Subtotal			210.0
Future projects			
Asotin	200	8.00	19.2
China Gardens	200	4.94	12.0
Ben Franklin	500	3.00	10.4
Subtotal			41.6

1/ Source: Bonneville Power Administration, Branch of Power Resources, Portland, Oregon.

Appendix Table 6. Comparison of Nez Perce and High Mountain Sheep-Lower Canyon Projects (63, p. 258-259)

Comparison of features and costs of Nez Perce and High Mountain Sheep-Lower Canyon Projects 1/

Item	Unit	Nez Perce	Two-dam plan: High Mountain Sheep	Two-dam plan: Lower Canyon	Two-dam plan: Total
Usable storage	Mil. ac. ft.	4.5	2.1	2.5	4.6
Initial power cap.	KW	1.5	0.6	0.6	1.2
Costs:					
Construction	Mil. dol.	284.8	226.3	194.5	420.9
Annual	Mil. dol.	13.7	10.5	9.3	19.9
Benefits:					
Flood control	Mil. dol.	5.9	1.8	3.4	5.2
Power	Mil. dol.	38.1	22.7	16.4	39.1
Recreation	Mil. dol.	.1	-- 2/	.1	.1
Total	Mil. dol.	44.1	24.5	19.9	44.4
B-C ratio		3.21	2.33	2.14	2.24

1/ Source: United States Corps of Engineers, Water Resource Development, Columbia River Basin, Portland, Oregon, June 1958, vols. I and V.

2/ Estimated at $16,000 per annum.

Continued

Appendix Table 6. Comparison of Nez Perce and High Mountain Sheep-Lower Cannyon Projects (63, p. 258-259 (cont'd.)

Costs of fish and wildlife preservation at Nez Perce High Mountain Sheep and Lower Canyon Projects 1/

Item	Nez Perce	High Mountain Sheep	Lower Canyon	Total two-dam plan
		Million dollars		
Fish collection, handling and passage facilities	8,000	4,000	8,000	12,000
Contingencies	4,000	600	4,000	4,600
Investigations	120	130	120	250
Land requirements, range restoration, supplemental spawning, etc.	420	430	320	750
Total cost--fish and wildlife	12,540	5,160	12,440	17,600
Total project costs	284,820	226,380	194,550	420,930

1/ Source: United States Corps of Engineers, Water Resource Development, Columbia River Basin, vol. 5, Portland, Oregon, June 1958. No detailed breakdown is available of costs associated with fish preservation as distinct from wildlife preservation. However, the largest expenditures are associated with fish.

Appendix Table 7. Commercial catch of salmon and steelhead attributable to the Columbia River, by gear, 1948-1965 1/

	Catch (round weight)			Value		
Year	Troll	Gill-net	Total	Troll	Gill-net	Total
	Thousand pounds			Thousand dollars		
1948	9,844	20,326	30,170	2,281	4,090	6,371
1949	9,293	13,057	22,350	1,947	2,083	4,030
1950	7,797	13,348	21,145	2,010	2,837	4,847
1951	14,179	12,907	27,086	3,277	3,144	6,421
1952	16,083	11,001	27,084	3,514	2,448	5,962
1953	14,959	9,721	24,680	3,178	2,068	5,246
1954	12,055	7,705	19,760	2,851	1,698	4,549
1955	12,894	10,873	23,767	3,422	2,634	6,056
1956	12,920	9,848	22,768	3,754	2,812	6,566
1957	12,966	7,478	20,444	3,336	2,216	5,552
1958	9,775	8,129	17,904	3,316	2,401	5,717
1959	8,739	6,251	14,990	2,719	1,881	4,600
1960	6,851	5,300	12,151	2,654	1,754	4,399
1961	7,016	5,533	12,569	2,790	1,909	4,699
1962	7,400	6,980	14,380	3,113	2,504	5,617
1963	9,650	5,940	15,590	3,724	1,829	5,553
1964	11,325	7,068	18,393	4,316	2,064	6,380
1965	12,142	8,646	20,788	4,281	2,435	6,716

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Department of Fisheries of Canada, and percentages summarized from Table 8.

Appendix Table 8. Columbia River commercial fishing seasons below Bonneville Dam, and number of gill-net licenses issued, 1938-1966 (49, p. 67-68, 1966)

Year	Days open to fishing	Number of licenses issued
1938	272.00	1,191
1939	272.00	1,153
1940	273.00	1,108
1941	274.00	1,018
1942	272.00	939
1943	199.75	931
1944	220.50	878
1945	219.50	916
1946	207.50	992
1947	207.50	998
1948	208.25	1,102
1949	180.85	1,119
1950	174.25	1,060
1951	174.25	1,006
1952	157.25	966
1953	153.25	919
1954	153.00	890
1955	158.50	812
1956	140.00	792
1957	124.75	818
1958	115.25	873
1959	97.75	869
1960	101.00	806
1961	101.25	791
1962	101.50	754
1963	98.00	740
1964	83.00	689
1965	76.75	683
1966	80.25	636

Appendix Table 9. Percentage of chinook salmon tagged at sea and recovered in a stream area and in the Columbia River from various experiments 1/

Area	Year tagged	No. stream recoveries	No. Columbia River recoveries	Percent Columbia River recoveries of stream recoveries
Newport, Oregon	1948-55	17	8	47
Columbia River	1948-55	50	40	80
	1958 & 1962	5	3	60
	1959	55	49	89
	1960	53	47	89
	1961	29	27	93
Grays Harbor	1951	8	5	63
Umatilla Reef	1948-49	12	6	50
Swiftsure	1948-49	15	7	47
S. Vancouver Island	1925-30	274	182	66
	1949-50	52	25	48
N. Vancouver Island	1925-30	83	55	66
	1949-51	14	5	36
Queen Charlotte Sound	1930	15	2	13
Queen Charlotte Islands and Hecata Str.	1925-30	245	73	30

Continued

Appendix Table 9. Percentage of chinook salmon tagged at sea and recovered in a stream area and in the Columbia River from various experiments -- Continued

Area	Year tagged	No. stream recoveries	No. Columbia River recoveries	Percent Columbia River recoveries of stream recoveries
Mid. and S. SE.				
Alaska	1927	38	22	58
	1950-51	70	24	34
N. SE.				
Alaska	1950-51	29	21	73

Summary

Mid-Oregon coast	47	Vancouver Island	45
Off Columbia River	80	North British Columbia	25
Washington coast	65		
Neah Bay	50	Southeast Alaska	45

1/ Based on: Pacific Marine Fisheries Commission Bulletin No. 2 (1951), papers by Fry and Hughes, Kauffman, Neave, and Hyning; Milne (1957), Recent British Columbia Spring and Coho Salmon Tagging Experiments, and a Comparison with Those Conducted from 1925 to 1930, Fisheries Research Board of Canada, Bulletin No. 113 and early papers referred in this bulletin; Parker and Kirkness (1956), King Salmon and the Ocean Troll Fishery of South-Eastern Alaska, Alaska Department of Fisheries Research Report No. 1; and Van Hyning (1967), Factors Affecting the Abundance of Fall Chinook in the Columbia River, Ph. D. thesis, Oregon State University.

Appendix Table 10. Commercial catch of chinook salmon attribu-to the Columbia River, by states, 1948-1965 1/

Year	Oregon	Washington	Alaska	British Columbia	Total
			Thousand pounds		
1948	12,929	7,349	4,132	n.a.	24,410
1949	8,507	5,811	4,249	n.a.	18,567
1950	7,801	5,473	3,178	n.a.	16,452
1951	7,866	6,913	4,061	2,966	21,806
1952	6,283	6,793	4,021	3,574	20,671
1953	5,483	6,304	4,164	3,583	19,534
1954	4,536	5,211	3,097	2,849	15,693
1955	7,390	6,220	2,934	2,969	19,513
1956	7,681	5,151	1,777	3,622	18,231
1957	5,266	4,959	2,424	3,444	16,093
1958	5,043	4,160	2,574	2,830	14,607
1959	3,368	3,140	2,866	2,651	12,025
1960	3,517	2,241	2,066	2,049	9,873
1961	3,588	2,908	1,133	1,845	9,474
1962	4,168	3,127	1,473	1,834	10,602
1963	3,970	2,979	1,940	2,118	11,007
1964	3,644	2,571	2,826	2,747	11,783
1965	4,835	2,536	2,200	2,943	12,514

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and the Department of Fisheries of Canada, and percentages summarized in Table 8.

Appendix Table 11. Commercial catch of coho salmon attributable to the Columbia River by states, 1948-1965 1/

Year	Oregon	Washington	California	British Columbia	Total
		Thousand pounds			
1948	1, 590	1, 636	n. a.	n. a.	3, 226
1949	1, 285	1, 115	n. a.	n. a.	2, 400
1950	1, 331	1, 513	n. a.	n. a.	2, 844
1951	1, 740	1, 555	n. a.	77	3, 372
1952	2, 088	1, 481	282	83	3, 934
1953	1, 413	1, 156	216	64	2, 849
1954	1, 011	830	160	52	2, 053
1955	1, 307	1, 119	129	52	2, 607
1956	1, 813	1, 235	276	54	3, 378
1957	2, 063	1, 039	177	48	3, 327
1958	756	833	113	77	1, 779
1959	580	733	230	60	1, 630
1960	543	480	85	32	1, 140
1961	733	1, 180	202	88	2, 203
1962	1, 499	1, 230	140	88	2, 957
1963	1, 858	1, 229	384	74	3, 545
1964	3, 596	1, 675	723	101	6, 095
1965	3, 914	2, 804	881	158	7, 756

1/ Calbulated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Department of Fisheries of Canada, and percentages summarized in Table 8.

Appendix Table 12. Value of commercial catch of chinook salmon attributable to the Columbia River by states, 1948-1965 1/

Year	Oregon	Washington	Alaska	British Columbia	Total
			Thousand dollars		
1948	2, 757	1, 782	759	n. a.	5, 298
1949	1, 465	1, 266	791	n. a.	3, 522
1950	1, 765	1, 394	763	n. a.	3, 922
1951	2, 100	1, 946	781	550	5, 377
1952	1, 520	1, 775	916	612	4, 823
1953	1, 268	1, 567	893	644	4, 372
1954	1, 119	1, 468	663	547	3, 797
1955	1, 974	1, 849	655	692	5, 170
1956	2, 351	1, 706	397	1, 002	5, 456
1957	1, 604	1, 602	568	853	4, 627
1958	1, 621	1, 490	862	825	4, 799
1959	1, 095	1, 082	843	769	3, 789
1960	1, 318	907	724	692	3, 641
1961	1, 406	1, 237	532	613	3, 788
1962	1, 602	1, 454	738	715	4, 509
1963	1, 376	1, 257	970	776	4, 379
1964	1, 222	984	1, 195	1, 055	4, 456
1965	1, 566	875	831	1, 143	4, 415

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Department of Fisheries of Canada, and percentages summarized in Table 8.

Appendix Table 13. Value of commercial catch of coho salmon attributable to the Columbia River by states, 1948-1965 1/

Year	Oregon	Washington	California	British Columbia	Total
			Thousand dollars		
1948	320	371	n. a.	n. a.	691
1949	171	174	n. a.	n. a.	345
1950	281	360	n. a.	n. a.	641
1951	340	326	n. a.	14	680
1952	325	271	51	13	660
1953	213	205	47	9	474
1954	170	164	41	9	384
1955	258	262	32	10	562
1956	430	330	74	13	847
1957	392	230	48	8	678
1958	198	250	50	29	518
1959	152	199	87	15	453
1960	207	189	37	11	444
1961	214	353	71	23	661
1962	426	364	51	22	863
1963	423	321	127	19	890
1964	981	511	257	29	1, 778
1965	1, 008	780	322	44	2, 154

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Department of Fisheries of Canada, and percentages summarized in Table 8.

Appendix Table 14. Commercial catch of anadromous fish attributable to the Columbia River, by species and gear, 1948-1965 1/

Year	Chinook			Coho			Other salmon and steelhead	Shad	Total
	Troll	Gill-net	Total	Troll	Gill-net	Total	Gill-net	Gill-net	
	Thousand pounds								
1948	7, 793	16, 617	24, 410	2, 052	1, 174	3, 226	2, 534	395	30, 565
1949	7, 792	10, 775	18, 567	1, 500	900	2, 400	1, 383	437	22, 787
1950	6, 002	10, 450	16, 452	1, 796	1, 048	2, 844	1, 849	687	21, 832
1951	11, 775	10, 031	21, 806	2, 404	968	3, 372	1, 908	426	27, 512
1952	13, 224	7, 447	20, 671	2, 860	1, 074	3, 934	2, 479	378	27, 462
1953	12, 568	6, 966	19, 534	2, 391	458	2, 849	2, 297	277	24, 957
1954	10, 307	5, 386	15, 693	1, 748	305	2, 053	2, 014	246	20, 006
1955	10, 889	8, 624	19, 513	2, 004	603	2, 607	1, 647	285	24, 052
1956	10, 011	8, 220	18, 231	2, 909	469	3, 378	1, 159	245	23, 013
1957	10, 032	6, 061	16, 093	2, 934	393	3, 327	1, 024	150	20, 594
1958	8, 167	6, 440	14, 607	1, 608	171	1, 779	1, 518	194	18, 098
1959	7, 258	4, 767	12, 025	1, 482	121	1, 603	1, 362	132	15, 122
1960	5, 870	4, 003	9, 873	980	160	1, 140	1, 138	170	12, 321
1961	5, 201	4, 273	9, 474	1, 815	388	2, 203	892	406	12, 975
1962	5, 509	5, 543	10, 602	2, 341	616	2, 957	821	895	15, 275
1963	6, 607	4, 400	11, 007	3, 043	502	3, 545	1, 038	859	16, 449
1964	7, 202	4, 581	11, 783	4, 123	1, 972	6, 095	515	305	18, 698
1965	6, 307	6, 207	12, 514	5, 835	1, 921	7, 756	518	351	21, 139

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Department of Fisheries of Canada, and percentages summarized in Table 8.

Appendix Table 15. Value of commercial catch of anadromous fish attributable to the Columbia River, by species and gear, 1948-1965 1/

Year	Chinook			Coho			Other salmon and steelhead	Shad	Total
	Troll	Gill-net	Total	Troll	Gill-net	Total	Gill-net	Gill-net	
	Thousand dollars								
1948	1, 825	3, 473	5, 298	456	235	691	382	25	6, 396
1949	1, 723	1, 799	3, 522	224	121	345	163	29	4, 059
1950	1, 592	2, 330	3, 922	418	223	641	284	45	4, 892
1951	2, 769	2, 608	5, 377	507	173	680	364	34	6, 455
1952	3, 026	1, 797	4, 823	488	172	660	479	38	6, 000
1953	2, 771	1, 601	4, 372	407	67	474	400	30	5, 276
1954	2, 515	1, 282	3, 797	336	48	384	368	22	4, 571
1955	2, 971	2, 199	5, 170	450	112	562	324	26	6, 082
1956	3, 006	2, 450	5, 456	748	99	847	263	27	6, 593
1957	2, 730	1, 897	4, 627	606	72	678	247	12	5, 564
1958	2, 837	1, 962	4, 799	479	39	518	400	19	5, 736
1959	2, 295	1, 494	3, 789	424	29	453	358	11	4, 611
1960	2, 261	1, 380	3, 641	393	51	444	314	14	4, 413
1961	2, 234	1, 554	3, 788	556	105	661	250	39	4, 738
1962	2, 409	2, 100	4, 509	705	158	863	245	109	5, 726
1963	2, 947	1, 432	4, 379	777	113	890	284	39	5, 592
1964	3, 005	1, 451	4, 456	1, 312	466	1, 778	146	15	6, 395
1965	2, 516	1, 899	4, 415	1, 765	389	2, 154	147	16	6, 732

1/ Calculated from catch statistics from the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Department of Fisheries of Canada, and percentages summarized in Table 8.

Appendix Table 16. 1965 Indian Columbia River salmon-steelhead fishery value (ex-vessel values, f. o. b. point of delivery) 1/

Species	Commercial sale	Subsistence 2/, 3/	Comm. and subsistence value per pound 4/	Total comm. and subsistence	Tourist sale 5/	Total price per lb. 6/	Total value tourist	Total value Indian fishery
	Pounds	Pounds	Dollars	Dollars	Pounds	Dollars	Dollars	Dollars
Spring chinook	280, 660	59, 540	0. 41	139, 480	25, 050	0. 50	12, 530	152, 010
Summer chinook	110, 810	11, 080	0. 37	45, 100	4, 430	0. 45	1, 990	47, 090
Sockeye	22, 630	3, 820	0. 37	9, 790	1, 050	0. 45	470	10, 260
Summer steelhead	107, 140	12, 460	0. 20	23, 920	4, 980	0. 30	1, 970	25, 890
Fall chinook	526, 810	61, 260	0. 15	88, 210	24, 500	0. 25	6, 130	94, 340
Coho	58, 890	6, 850	0. 21	13, 810	2, 740	0. 30	820	14, 630
Total	1, 106, 940	155, 010	--	320, 310	62, 750	--	23, 910	344, 220

1/ Source: Denny Miller, Bureau of Commercial Fisheries, Columbia River Fisheries Development Program Office, Portland, Oregon, August 1967. All data are preliminary estimates from continuing study of the Columbia River Indian fishery.

2/ Includes catch from Klickitat, Yakima, Okanogan and Deschutes Rivers.

3/ Estimated at 10% of total catch plus known tributary catches.

4/ Based upon weighted average price data from Portland Fish Company at The Dalles, Oregon, and Cowlitz Fish Company, Lyle, Washington. Value of subsistence fish assumed the same as commercial.

5/ Estimated at 4% of total catch, plus known restaurant sales.

6/ Price per pound rounded to closest 5¢ at 10¢ greater than commercial value.

Appendix Table 17. Chinook salmon sport catch for various Pacific Coast fisheries, 1949-1966 1/

Year	Columbia River mouth (ocean)	Washington (ocean) 2/	Washington upriver of Columbia 3/	Oregon (ocean) 2/	Oregon upriver of Columbia 3/	Idaho
			No. of fish			
1949	11,200	13,100	--	--	--	1,500
1950	16,600	24,100	--	--	--	2,000
1951	7,200	39,600	--	--	--	3,000
1952	11,000	92,700	--	--	--	4,000
1953	14,700	44,800	--	--	--	4,000
1954	12,500	72,915	--	--	--	15,000
1955	12,500	86,200	--	--	18,095	19,000
1956	34,000	109,550	--	1,612	25,792	21,000
1957	18,500	104,400	--	1,033	19,244	39,000
1958	25,600	85,400	--	575	36,135	25,000
1959	23,400	91,800	--	1,330	60,936	20,000
1960	37,700	69,500	--	1,022	37,063	22,000
1961	20,500	89,100	--	2,951	36,401	13,000
1962	29,600	71,000	15,000	4,256	45,510	12,000
1963	32,600	77,900	15,000	6,772	45,868	12,000
1964	28,100	109,500	28,988	7,800	58,894	8,000
1965	53,200	112,900 5/	54,509	9,495	52,267	Closed
1966	71,400	167,649 6/	28,577	4/	51,319	4/

1/ Sources: Washington State Department of Fisheries, Washington State Department of Game, Oregon State Game Commission, California Department of Fish and Game, and Idaho Fish and Game Department.

Continued

Appendix Table 17. Chinook salmon sport catch for various Pacific Coast fisheries 1949-1966--Continued

2/ For Neah Bay and Straits, La Push, Westport, and Tokeland.
3/ Includes coho catch as well as chinook salmon.
4/ Not available.
5/ Neah Bay and Straits, La Push, and Westport.
6/ Neah Bay and Straits, La Push, Westport, Sekiu and Ilwaco.

Appendix Table 18. Coho salmon sport catch for various Pacific Coast fisheries, 1949-1966 1/

Year	Columbia River mouth (ocean) 2/	Washington (ocean) 3/	Washington, Columbia River 4/	Oregon (ocean) 5/	California (ocean)
			No. of fish		
1949	2,800	3,800		---	2,500
1950	2,300	15,400		---	6,200
1951	1,900	18,600		---	11,100
1952	4,000	48,400		---	13,300
1953	8,000	55,700		---	15,200
1954	16,000	50,850		---	18,500
1955	15,200	65,150		---	19,900
1956	50,000	124,450		32,689	17,600
1957	38,700	193,850		20,948	6,900
1958	39,600	141,800		11,654	8,000
1959	50,500	157,700		26,965	8,400
1960	34,600	54,800		20,713	5,600
1961	85,500	136,200		59,845	3,542
1962	118,900	187,100		85,538	12,986
1963	116,200	191,000		140,079	32,759
1964	134,100	132,000		122,935	39,384
1965	251,800	303,200		330,998	20,509
1966	5/	351,230	4,236	6/	6/

1/ Source: Washington State Department of Fisheries, Oregon State Game Commission, and California Department of Fish and Game.
2/ Includes both Oregon and Washington catch.
3/ For Neah Bay and Straits, La Push, Westport, and Tokeland.

Continued

Appendix Table 18. Coho salmon sport catch for various Pacific Coast fisheries, 1949-1966 1/ -- Continued

4/Coho not separated prior to 1966.
5/Apportioned between Chinook and Coho on basis of 1962-1964 catch.
6/Not available.

Appendix Table 19. Steelhead sport catch on Columbia River and tributaries, 1936-1966 1/

Year	Washington	Oregon	Idaho
		No. of fish	
1956	--	23,748	--
1957	--	22,479	--
1958	--	31,835	--
1959	--	48,585	--
1960	--	33,891	--
1961	--	37,122	--
1962	100,593	48,819	19,600
1963	83,118	34,022	27,400
1964	66,890	38,583	18,000
1965	87,640	41,129	19,000
1966	2/	41,500	2/

1/ Sources: Washington State Department of Game, Oregon State Game Commission, and Idaho Department of Fish and Game.

2/ Not available.

Appendix Table 20. 1965 Sport catch by area and by species 1/

Area and specie	Oregon	Washington	Idaho	California	Total coho	Total chinook	Total steelhead	Total area
Columbia River and tributaries:								245,545
Coho	10,000 2/	4,200 3/			14,200			
Chinook	42,267 2/	50,309 3/				92,576		
Steelhead	41,129	87,640	19,000				147,769	
Columbia River mouth (ocean): 4/								305,000
Coho	73,022	178,778			251,800			
Chinook	15,428	37,772				53,200		
Ocean:								
Coho	384,801	221,300 5/		20,509	626,610			
Chinook	9,495	38,500 5/				122,395		
		74,400 6/						
Total	576,142 7/	692,899	19,000	20,509	892,610	268,171	147,769	1,308,550

1/ Source: Washington State Department of Fisheries, Washington State Department of Game, Oregon State Game Commission, Idaho Department of Fish and Game.

2/ Chinook and coho catch not separated for Oregon. Coho catch is estimated at 10,000.

3/ Chinook and coho catch not separated. Coho catch estimated from 1966 data (see Appendix Table 18.

4/ Divided between Washington and Oregon (71% Washington - 29% Oregon) according to 1966 catch

Continued

data. See The 1966 Columbia River (Ocean) Sport Fishery, Warren Knispel, Oregon State Game Commission, and Hugh Fiscus, Washington State Department of Fisheries, May, 1967, p. 3. Note: Apparently many Oregon residents use Washington shore ports due to more favorable ocean conditions for small pleasure craft.)

5/ Westport and La Push.

6/ Neah Bay and Straits

7/ Estimated (see p. 143 "Data Limitations for Estimating Sport Values).

Appendix Table 21. Computation of benefits from the salmon-steelhead fishery in Oregon and Columbia River, using consumer surplus.

(1) Estimated consumer surplus 1965, Ore.	(2) Proposed changes per day	(3) Predicted days of salmon-steelhead Fishing	(4) Revenue to non-discriminating monopolist	(5) Days less of fishing taken	(6) 1/ No. of fish transferred to commercial harvest	(7) 2/ Possible added value commercial catch	(8) 3/ Sum of consumer surplus, estimated revenue from sportsmen, and added commercial value	(9) 4/ Extrapolation to entire Columbia River production
$9,722,751	0	1,248,456	$ 0	0		$ 0	$9,722,751 5/	$15,670,735 5/
8,557,186	1.00	1,099,679	1,099,679	148,831	68,627	209,964	9,866,829	15,902,954
8,267,257	1.27	1,055,646	1,340,670	185,852	85,697	262,190	9,870,117 6/	15,908,254 6/
7,531,436	2.00	967,855	1,935,710	279,809	129,022	394,743	9,861,619	15,894,557
6,628,679	3.00	851,835	2,555,505	395,082	182,175	557,364	9,741,548	15,701,032
5,834,028	4.00	749,722	2,988,888	496,551	228,963	700,512	9,523,428	15,349,475
5,134,686	5.00	659,850	3,299,250	585,850	270,139	826,490	9,260,426	14,925,579
4,519,172	6.00	580,751	3,484,506	664,445	306,379	937,367	8,941,045	14,410,813
3,977,438	7.00	511,135	3,577,945	733,619	338,276	1,034,955	8,590,338	13,845,558
3,500,650	8.00	449,863	3,598,904	794,500	366,349	1,120,845	8,220,399 7/	13,249,305 7/
3,081,009	9.00	395,936	3,563,424	848,084	391,056	1,196,436	7,840,869	12,637,594
2,711,677	10.00	348,474	3,484,740	895,244	412,802	1,262,968	7,459,385	12,022,734
2,100,525	12.00	268,216	3,218,592	973,282	448,786	1,373,061	6,692,178	10.786,181
756,285	20.00	96,570	1,931,400	1,144,928	527,933	1,615,211	4,302,896	6,935,233

1/ $\frac{(5)}{2.1687}$ 2/ (6) x $3.0595   3/ (1) + (4) + (7)   4/ $\frac{(8)}{.62044}$ 5/ present position

6/ Max. to society   7/ Max. to a non-discriminating monopolist (charging sportsmen).

Appendix Table 22. Preliminary estimate of contribution of 1961 brood fall chinook from 11 Columbia River hatcheries to the Pacific Coast and Columbia River fisheries 1/

Fishery	1963 Age 2	1964 Age 3	1965 Age 4	1966 2/ Age 5	Total	Percent
Washington sport	5,625	18,766	5,122	525	30,038	14.17
Oregon sport	0	1,627		33	2,074	.98
California sport	3/	0	0	0	0	0
Southeast Alaska commercial	3/	20	266	33	319	.15
British Columbia commercial	3/	45,885	21,849	2,693	70,427	33.21
Washington commercial	30	35,789	4,935	558	41,312	19.48
Oregon troll	0	3,634	218	0	3,852	1.82
California troll	3/	227	39	33	299	.14
Columbia River gill-net	1,457	22,656	35,750	2,102	61,965	29.23
Columbia River sport	0	207	0	0	207	.10
Klickitat River dip-net	3/	1,457	69	0	1,526	.72
Total all fisheries	7,112	130,268	68,662	5,997	212,019	
Percentages	3.4	61.4	32.4	2.8		100.00

1/ Source: Roy J. Wahle, Bureau of Commercial Fisheries, Columbia River Fisheries Development Program Office, Portland, Oregon, August 1967 (percentages added).

2/ Preliminary. (catch data not available; therefore, it was assumed that 30% of the catch was examined.

3/ Not sampled.

Appendix Table 23. Components of simple linear regression over time for fish counts at Rock Island Dam and Ice Harbor Dam relative to Bonneville count

	Rock Island Dam 1/				Ice Harbor Dam 2/			
	Constant	Coefficient	Std. error	t-value	Constant	Coefficient	Std. error	t-value
Chinook	.000538	.0045718	.0004308	10.611	.27554	-.030806	.021308	-1.4457
Spring	.05134 3/	.003708	.0006747	5.4956	.3385	-.016874	.035672	- .4730
Summer	.14948 3/	.01121	.001779	6.2982	.38185	-.045172	.012286	-3.6764
Fall					.18525	-.033496	.02063	-1.6232
Sockeye	.22207	.02927	.003311	8.8410				
Steelhead	.14360	.001077	.000289	3.728	.66276	-.069414	.021496	-3.2291
Total salmon-steelhead	.01835	.0099147	.0009544	10.387	.37368	-.058339	.020068	-2.9070

1/ Data from 1938 to 1966, inclusive.
2/ Data from 1962 to 1966, inclusive.
3/ Data from 1959 to 1966, inclusive.

Appendix Table 24. Columbia River canned salmon pack[1/]

Year	Number of canneries	Cases	Value
1888	28	372, 477	$2, 234, 862
1900	16	358, 772	2, 282, 296
1910	15	391, 415	2, 544, 198
1920	22	481, 545	6, 198, 617
1930	21	429, 505	5, 658, 177
1940	11	386, 999	5, 379, 826
1950	11	192, 990	6, 645, 471
1960	8	72, 770	3, 400, 598
1961	8	96, 051	4, 575, 386
1962	8	92, 044	4, 114, 306
1963	8	82, 374	3, 643, 016
1964	8	88, 226	3, 754, 866
1965	8	127, 471	5, 484, 795
1966	7	103, 868	4, 834, 498

1/ Pacific Fisherman Yearbook, 1967, p. 41.

Appendix Table 25. Actual or projected completion dates for selected dams affecting anadromous fish 1/

Project	Year of initial service
Columbia River	
Rock Island	1933
Bonneville	1938
Grand Coulee	1941
McNary	1953
Chief Joseph	1955
The Dalles	1957
Priest Rapids	1959
Rocky Reach	1961
Wanapum	1963
John Day	1968
The Dalles (Units 15-22)	1971
Bonneville (second powerhouse)	1975
Snake River	
Swan Falls	1910
Brownlee	1958
Ice Harbor	1961
Cxbow	1962
Lower Monumental	1969
Little Goose	1970
Dworshak	1972
Lower Granite	1972
Lower Grand Ronde	1974
Catherine Creek	1974
Asotin	1975

1/ U. S. Army Corps of Engineers, Portland, Oregon, and 1966 Status Report of the Columbia River (49, p. 66).

APPENDIX B

COST ESTIMATE FOR TRAPPING FACILITIES FOR COMMERCIAL FISHING AT BONNEVILLE DAM 1/

Costs were based on trapping facilities on both the Washington shore and Bradford Island fish ladders. It is assumed that the existing fishway system will adequately handle any increase in fish runs that can be reasonably anticipated. No consideration was given to what effect a future power house on the Washington shore might have on the division of use in fish ladders. Both trapping facilities, although sized for each fishway on present division of fish use, are adequate in size for the purpose. Later adjustment in size should not affect the cost in any appreciable amount.

The peak day considered is 100, 000 fish handled in one day. This includes 14, 000 summer chinook; 36, 000 blueback, and 50, 000 shad and miscellaneous species. A division at this time of year between the two fishways was assumed to be 70 percent for the Bradford Island fishway and 30 percent for the Washington shore fishway. The trapping facilities design had to include consideration of escapement with no interference to fish entering and surmounting the fishways.

1/ Prepared by Bureau of Commercial Fisheries, Columbia River Fisheries Development Program Office, Engineering Section, Portland, Oregon.

These cost estimates do not include cost of truck parking and loading site nor any possible upgrading of new road access to trapping facilities nor possible cost in restoration of public visitor facilities, particularly on Bradford Island.

COST ESTIMATE FOR TRAPPING FACILITIES FOR COMMERCIAL FISHING AT BONNEVILLE DAM

Excavation:

35 X 80 X 12 = 33,600
40 X 180 X 10 = 72,000
25 X 80 X 24 = 48,000

153,600 cubic feet = 5,680 yards.

5,680 yards @ $3.00 per yard	$ 17,040
Care of water	40,000

Concrete:

Ladder - 2 9.5 X 1.5 X 80 = 2,280
80 X 30 X 1.5 = 3,600

Holding Pool -
2 150 X 9 X 1.0 = 2,700
150 X 36 = 5,400
13 X 3 X 36X2 = 2,800
25 X 3 X 20X2 = 3,000
20 X 3 X 39 = 2,340

Pump - 46 X 25 X 2 = 2,300

24,420 cubic feet = 900 yards

900 yards @ $100 per yard		90,000
Fish sorter (false weir and push-button operators)		
1 required	Sorter control center	8,500
4	Sorters and false weir @ $8,000 each (Wells)	32,000
Conveyor		20,000
(Cowlitz conveyor and sorting table - $22,000)		

Pumps -

Total capacity - 150 cfs or 67,320 gpm
Variable head - 4 ft. to 16 ft. or 4 - 17,000 gpm

Total carried forward $207,540

COST ESTIMATE FOR TRAPPING FACILITIES
FOR COMMERCIAL FISHING AT BONNEVILLE DAM -- Cont'd.

Balance brought forward	$207,540
4 @ $25,000 each (includes controls)	100,000
Valves - 4 36-inch butterfly gates @ $4,500 each	18,000
Electrical	6,000
Spray system	2,000
Fishladder and bulkhead gates - Rebuild for back pressure 2 - 15 ft. X 15 ft. for 12 ft. head required Approx. 8,000 lbs. @ 50¢ per lb.	8,000
Crowder - Brail	25,000
Miscellaneous	30,000
Total	$396,540
20% Engineering and inspection	79,308
15% Contingencies	71,377
TOTAL	$550,000

Operating and Maintenance:

4 Operators at one time required for 16-hour day, 7 days a week, during peak of runs - say 3 shifts per week for 5 months -

3 X 4 X $600/month X 5	$ 45,000
1 Maintenance man	10,000
Electricity - based on 3¢ per kw hr.	15,000
Total carried forward	$ 70,000

COST ESTIMATE FOR TRAPPING FACILITIES
FOR COMMERCIAL FISHING AT BONNEVILLE DAM -- Cont'd.

Balance brought forward			$ 70,000
Replacement of equipment - 20-year basis:			
Pumps	$100,000		
Sorters	32,000		
Conveyors	20,000		
Crowders - Brail	25,000		
	20/$117,000 =		9,000
TOTAL			$ 79,000

Washington Shore Installation

Forty percent in size because of smaller number of fish; however, cost must allow for approximately same water care cost, et. Assume, therefore, cost approximately 50 percent of Bradford Island installation. This also assumes no additional access roads will be required on the Washington fishway installation $270,000

Operation and Maintenance

2 Operators required at one time - 3 shifts per week for 5 months - Total operators required - 6	$ 22,500
Same maintenance man as for Bradford Island	
Electricity	7,500
Equipment	5,000
TOTAL	$ 35,000

Bonneville trapping cost	$820,000
Operation and maintenance	$114,000

APPENDIX C

COMPUTATION OF THE NET VALUE OF THE 1962 OREGON SALMON-STEELHEAD FISHERY

Nondiscriminating Monopolist

The computation of the Oregon salmon-steelhead sport fishery was based upon demand functions that were statistically estimated from cross-sectional data obtained from Oregon anglers. (6) The demand function which gave the best over-all results, judged by criteria such as goodness of fit and economic logic, was the following algebraic form:

$$Y_{3j} + b_o e^{(b_1 X_{2j} + b_2 X_{3k} + b_3 \ Y_{2j})} \qquad (6, \text{p. } 41\text{-}42) \qquad (1)$$

The least squares fit in logarithms was:

$$\ln Y_{3j} + 0.95061 + 0.00727 X_{2j} - 0.00201 X_{3k}$$
$$-0.12769 Y_{2j} \qquad (2)$$

where

Y_{3j} was S-S (salmon-steelhead) days taken per unit population subzone J;

X_{2j} was average family income of subzone j;

X_{3k} was average miles traveled per salmon-steelhead trip for the main distance zone in which the jth subzone falls.

Y_{2j} was average salmon-steelhead variable cost per day for subzone j.

Based upon the above demand function, total revenue to a monopolist able to charge for fishing rights to this fishery would have been maximized by an $8 charge per day. A predicted total of 390, 300 salmon-steelhead days of fishing would be taken by Oregon anglers with an assumed increase in salmon-steelhead fishing costs per day of $8. Thus, assuming that the salmon-steelhead anglers would have reacted to a daily charge in the same way as to their other variable costs of fishing, Oregon anglers would have been willing to pay $8 X 390, 300 or about $3, 122, 000 for the privilege of fishing for salmon and steelhead at $8 per day. Therefore, the estimated net economic value of the Oregon salmon-steelhead sport fishery in 1962 was $3, 122, 000.

<u>Discriminating Monopolist</u> (6)

Conceptually, the consumer's surplus would be estimated separately for each of the subzones which are listed in the Oregon study. (6) The demand function for each subzone would be integrated between two limits, the lower limit being the actual level of variable fishing costs incurred with the upper limit tending to positive infinity.

Since total salmon-steelhead days taken under 1962 salmon-steelhead variable costs and income conditions have already been computed, a much easier way to compute the sum of the definite integrals is to merely multiply the predicted 1962 salmon-steelhead fishing days by the constant, $1/.12769 = 7.831466$. (79) The validity of this procedure can easily be seen. For any specific subzone under 1962 conditions, we can express the quantity of salmon-steelhead days taken as a function of salmon-steelhead variable costs per day (denoted by P). That is,

$$Y_{3j} = ke^{-.12769P}$$

where k is a constant determined by the values of the income and distance variables for the jth subzone. For integration, denote the actual 1962 salmon-steelhead variable cost level by P_o. Then, the definite integral is given by

$$\int_{P_o}^{\infty} ke^{-.12769P}\, dP = \frac{-1}{.12769} \int_{P_o}^{\infty} ke^{-.12769P} (.12769)dP.$$

Upon evaluation, this definite integral is easily seen to be

$$\frac{k}{.12769} e^{-.12769P_o} = 7.831466 \, ke^{-.12769P_o}$$

However, except for 7.831466 the right side of the above equation is Y_{3j}, the 1962 quantity of salmon-steelhead fishing days for the jth subzone which has already been calculated. (6) Therefore, the total area under the demand curve for Oregon is simply 7.831466 X 1.084,000 which is approximately \$8,489,000.

(continued from inside front cover)

14. A Price Incentive Plan for Distressed Fisheries by A. A. Sokoloski and E. W. Carlson.

15. Demand and Prices for Shrimp by D. Cleary.

16. Industry Analysis of Gulf Area Frozen Processed Shrimp and an Estimation of Its Economic Adaptability to Radiation Processing by D. Nash and M. Miller.

17. An Economic Evaluation of Columbia River Anadromous Fish Programs by J. A. Richards.

18. Economic Projections of the World Demand and Supply of Tuna, 1970 - 90 by F. Bell.

19. Economic Feasibility of a Seafood Processing Operation in the Inner City of Milwaukee by D. Cleary.

20. The 1969 Fishing Fleet Improvement Act: Some Advantages of its Passage by the Division of Economic Research.

21. An Economic Analysis of Policy Alternatives for Managing the Georges Bank Haddock Fishery by L. W. Van Meir.

22. Some Analyses of Fish Prices by F. Waugh and V. Norton.

23. Some Economic Characteristics of Pond-Raised Catfish Enterprises by J. E. Greenfield

24. Elements Crucial to the Future of Alaska Commercial Fisheries by D. Nash, A. Sokoloski, and D. Cleary.

25. Effects on the Shrimp Processing Industry of Meeting the Requirements of Wholesome Fishery Products Legislation by D. Nash and M. Miller.

The goal of the Division of Economic Research is to engage in economic studies which will provide industry and government with costs, production and earnings analyses; furnish projections and forecasts of food fish and industrial fish needs for the U. S.; develop an overall plan to develop each U. S. fishery to its maximum economic potential and serve as an advisory service in evaluating alternative programs within the Bureau of Commercial Fisheries.

In the process of working towards these goals an array of written materials have been generated representing items ranging from iterim discussion papers to contract reports. These items are available to interested professionals in limited quantities of offset reproduction. These "Working Papers" are not to be construed as official BCF publications and the analytical techniques used and conclusions reached in no way represent a final policy determination endorsed by the U. S. Bureau of Commercial Fisheries.