INTRODUCTION

Economic considerations in the management of anadromous fish habitat fall into two major categories: economic efficiency and economic equity. Assessing economic efficiency in resource management focuses on the costs and benefits obtained from alternative patterns of use. "Efficiency" implies maximizing overall benefits, minus costs. Techniques of cost-benefit analysis developed over the past few decades allow us to estimate monetary values of a wide range of resource-based activities. Commercial fishing, mineral extraction, logging, and livestock grazing are commodities that have a clear economic value. Economists are also interested in estimating values for noncommodity activities, such as recreational fishing, camping and back-packing, and preservation of natural sites. Because of both data and conceptual limitations, cost-benefit analysis does not always accurately estimate net economic benefits. Nevertheless, cost-benefit analysis is the best means of assessing the overall economic efficiency of alternative resource-management policies.

Economic efficiency, broadly defined, is the essence of the Water Resources Council (WRC) (1982) Guidelines, which require agencies to develop as one alternative a plan that reasonably ". . . maximizes net national economic development benefits . . . ." The guidelines further state that the recommended plan ". . . is to be the alternative with the greatest net economic benefit, unless the Secretary of a department or head of an independent agency grants an exception to this rule" (Water Resources Council 1982). Economic efficiency is also the essence of the USDA National Forest System land- and resource-management planning regulation stating, "The primary goal in formulating alternatives, besides complying with NEPA procedures, is to provide an adequate basis for identifying the alternative that comes nearest to maximizing net public benefits . . ." (U.S. Department of Agriculture 1982).

Economic theory provides no clear guidance on the "equity" of management alternatives; however, some generally recognized principles help define the fairness of any distribution of benefits. For example, arbitrarily impoverishing particular groups or denying access to long-standing resource users without compensating them are actions normally considered inequitable. They are examples of what economists call redistributions of income or wealth. Economic methods can be used to anticipate and measure the probable effects of redistributions by identifying specific groups or individuals bearing significant portions of the costs or receiving significant portions of the benefits of management choices.

This paper explores the effects of forest and rangeland management on the economics of commercial and sport harvest of anadromous fish. The overall effect that forest and rangeland management has on the net benefits to producers and consumers of anadromous fish, as well as the cost incurred by resource managers and owners, is included.

ECONOMIC DIMENSIONS OF ANADROMOUS FISHERIES IN THE PACIFIC

Commercial salmon harvests by all nations bordering the north Pacific Ocean have recently averaged over 221 million fish per year (table 1). The United States catches slightly more salmon than do Japan and the Soviet Union. Canada takes less than one-third as many fish per year as do the other three. The five major commercial species of salmon are sockeye (or red), chum (or dog), pink (or humpback), coho (or silver), and chinook (or king). Three additional anadromous salmonids occur in western North America—steelhead and cutthroat trout, and Dolly Varden.

Salmon fisheries are classified according to geographical separation, political boundaries, fishing gear used, and motivation for fishing (recreation, subsistence, or commercial livelihood). Table 2 shows the breakdown of catches by some of the more significant divisions. Commercial purse-seine and gill-net fishing occur in protected waters such as Puget Sound, the Columbia River, and the inside waters of Southeast Alaska. Commercial trolling dominates the ocean fishery in California, Oregon, and Washington. Trolling is significant in southeastern Alaska as well. Historically, some species of salmon (especially chinook, coho, and sockeye) were caught primarily by traps, "fish wheels," and dip nets during spawning runs (Netboy 1980). These fishing techniques were more effective and less expensive than ocean fishing, but they are now generally prohibited.

Table 1--Average annual north Pacific commercial salmon catches, 1976-80

	Sockeye	Chum	Pink	Coho	Chinook	Total
			- Thousands of fish -			
U.S.S.R.	910	4,744	55,730	1,116	171	62,671
Japan	3,787	29,838	24,885	2,228	401	61,139
Canada	5,534	1,958	8,620	3,309	1,458	20,879
United States:	22,460	8,058	38,469	5,495	2,194	76,676
Alaska	21,097	7,340	37,106	2,478	676	68,697
Washington	1,363	712	1,337	1,883	633	5,928
Oregon	0	6	25	896	333	1,260
California	0	0	1	238	552	791
Total	32,691	44,598	127,704	12,148	4,225	221,365

Sources: Fredin (1980), Food and Agricultural Organization (1981).

Table 2--Annual average catches by United States user groups, 1975-79

State	Commercial salmon				Recreational		
	Purse seine	Gill net	Troll	Other gear	Salmon	Steelhead	Subsistence
			- Thousands of fish -				
Alaska	33,487	23,067	1,332	625	329	3	679
Washington	2,388	1,738	1,258	889	1,314	108	--
Oregon	--	229	1,110	--	425	155	--
California	--	--	840	--	137	NA	23
Idaho	--	--	--	--	3	6	--
Total	35,875	26,034	4,540	1,514	2,208	272	901

-- = These fisheries do not exist in these States.

NA = not available.

Sources: U.S. Department of Commerce, National Marine Fisheries Service (1976, 1977, 1981); International North Pacific Fisheries Commission (1982).

Commercial salmon fisheries consist of many independent operations with no more than a few crew members (Petry 1979). Many trollers and gillnetters are operated by only one or two persons. Nevertheless, about 33,000 workers fish commercially at least part time in United States salmon fisheries, using 20,000 vessels (table 3). At least 727 party-boat or charter-boat operators derive a substantial portion of their business from salmon anglers. Most salmon vessels fish other marine species as well. In 1976, for example, 8,169 of the 12,558 vessels reported landing salmon in Washington, Oregon, or California also sold some groundfish, crab, or albacore.[1] Many are

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[1] Huppert, D.D.; Thompson, C.; Edwards, B. Annual summary files from the 1974 thru 1976 coastwide summary data base: contents and summary statistics. Unpublished Admin. Rep. LJ-82-29. La Jolla, CA: U.S. Department of Commerce, National Marine Fisheries Service, Southwest Fisheries Center; 1982. 46 p.

fully employed in commercial fishing for only a portion of the year, however. In comparison, the average monthly employment in logging in Oregon, Washington, and California was about 28,000 in 1978. Logging is also seasonal; the number of people employed in logging at some time during the year is substantially more than the average monthly figure. The average monthly employment in the timber industries of these three States, including logging, sawmills, veneer and plywood mills, and pulp and paper mills, was about 129,000 in 1978.

Table 3--Estimated number of fishing units and employment in salmon fisheries

| | Commercial fishing fleet | | | | |
| | Vessels by gear type used | | | | |
State	Troll	Gill net	Purse seine	Crew	Party/charter boats
	- - - - - - - - - - - - - - - Number - - - - - - - - - - - - - - -				
Alaska	872	3,500	1,244	11,032	--
Washington	2,601	3,169	396	7,889	414
Oregon	3,259	718	--	5,852	253
California	4,158	--	--	8,316	60
Total	10,890	7,387	1,640	33,089	727

-- = These fisheries do not exist in these States.

Sources: Pacific Fishery Management Council ("Third Draft Framework Plan for Managing Ocean Salmon Fisheries Off Washington, Oregon, and California," Portland, OR, 1983. 133 p.; "Proposed Plan for Managing the 1983 Ocean Salmon Fisheries Off of Washington, Oregon, and California," Portland, OR, 1983; Alaska Commercial Fisheries Entry Commission (1982); U.S. Department of Commerce, National Marine Fisheries Service (1981).

In recent years, commercial salmon fishing has grossed around $300 million to $400 million (table 4). The finished products (mostly canned pack, cured, and fresh or frozen fillets and steaks) have a market value of around $1 billion wholesale (table 5). Of this $1 billion in wholesale value, about $20 million to $40 million is produced in Oregon, Washington, and California. In comparison, the estimated wholesale value of timber products produced in Oregon and Washington was about $8.5 billion in 1978.

Table 4--U.S. commercial landings of Pacific salmon by species and total ex-vessel values, 1950-82

	Landings						Ex-vessel value
Year(s)	Sockeye	Pink	Chum	Coho	Chinook	Total	
	- - - - - - - - - - Millions of pounds - - - - - - - - - -						$ Millions
1950-54	89.6	101.9	73.8	38.5	39.2	343.0	43.4
1955-59	68.1	93.9	51.6	24.4	32.9	270.9	41.7
1960-64	71.5	124.7	52.6	26.2	26.4	301.4	51.6
1965-69	90.3	111.0	41.7	34.9	27.3	305.2	63.3
1970-74	82.4	69.0	52.4	36.0	29.9	269.7	97.2
1975-79	103.0	140.5	48.0	33.6	32.3	357.4	240.4
1980	207.6	253.5	84.9	39.3	28.5	613.8	352.4
1981	226.2	257.1	98.9	35.2	31.1	648.5	436.2
1982	200.2	221.5	92.0	59.2	34.6	607.5	392.0

Sources: U.S. Department of Commerce, National Marine Fisheries Service (1973); U.S. Department of Commerce, National Marine Fisheries Service (1971-82).

The salmon fishery--along with tuna and shrimp fisheries--is one of the three most valuable marine commercial fisheries in the United States, based on gross market value. Much of the increase in salmon market values since the early 1950's was caused by increased prices. The average ex-vessel price rose from $0.126/lb in 1950 to 1954, to $0.669/lb in 1975 to 1980. In recent years, huge runs of Alaska sockeye and pink salmon have caused a moderate drop in ex-vessel prices.

Recreational fishing expanded during the past two decades to become a major user of the salmon resource in certain areas--particularly in Puget Sound, the southern part of the Washington coast and Columbia River mouth, and the northern Oregon coast. According to State records, annual sport salmon harvests nearly doubled from an average of 546,000 fish per year in 1950 to 1954, to 1,018,000 fish in 1976 to 1980. Although the sport harvest does not rival the commercial harvest, major portions of the coho and chinook salmon catches are taken by recreational hook-and-line, and almost all of the steelhead are taken by recreational anglers.

Table 5--Quantity and value of processed fishery products from the United States' north Pacific salmon fisheries

	1976	1977	1978	1979	1980	1981
Pacific coast:						
Fresh and frozen--[1]/						
Quantity (thousand of pounds)	4,129	3,153	4,111	3,042	1,582	2,826
Value (thousands of dollars)	8,281	7,015	9,885	6,282	4,263	7,863
Canned--[2]/						
Quantity (thousands of cases)	156	243	16	53	18	167
Value (thousands of dollars)	17,121	25,824	1,798	5,825	4,169	17,336
Cured--[3]/						
Quantity (thousands of pounds)	5,055	4,504	5,602	3,677	3,465	4,046
Value (thousands of dollars)	14,523	16,825	21,817	14,298	12,737	16,119
Alaska:						
Frozen--[1]/						
Quantity (thousands of pounds)	50,578	76,674	121,419	149,211	195,404	283,265
Value (thousands of dollars)	101,438	170,589	291,955	308,134	526,553	788,150
Canned--[2]/						
Quantity (thousands of cases)	2,512	2,651	3,409	3,109	4,175	4,445
Value (thousands of dollars)	190,745	180,753	242,260	286,422	400,060	440,911
Cured--[3]/						
Quantity (thousands of pounds)	3,783	NA	NA	NA	NA	NA
Value (thousands of dollars)[4]/	11,880	NA	NA	NA	NA	NA
Total Value	343,988	401,006	567,715	620,961	947,782	1,270,379

NA = not available

[1]/Includes steaks and fillets.
[2]/Standardized to 48 1-lb cans.
[3]/Includes smoked fish, caviar, bait eggs, and salted fish.
[4]/Actual values not available. These values estimated using average price for frozen products on the Pacific coast.

Sources: U.S. Department of Commerce, National Marine Fisheries Service (1975-81); The Fishermen's News (1983).

The economic importance of recreational fishing is more difficult to measure than that of commercial fishing because of the lack of market prices. Special fishing surveys in Washington, California, and Oregon estimate total recreational expenditures to be around $186 million per year for salmon and steelhead fishing trips (table 6). This figure includes travel, on-site, and gear expenditures. Another measure of economic value is the net amount the recreationists would be willing to pay for fishing over and above costs.

This net economic value for salmon angling is estimated to be about $83 million in Washington, Oregon, and California (table 6). Equivalent values are not available for Alaska because the necessary studies have not been performed.

Table 6--Estimated economic measures for recreational salmon and steelhead fishing

	Expenditures	Net value
	- - - - Millions of dollars - - - -	
Washington	126.3	42.5
Oregon	53.2	31.5
California	6.3	9.0

Sources and procedures:

1. Washington and Oregon expenditures from Sorhus and others (1981).
2. California expenditures estimated from 1976-80 average annual ocean salmon angler-days (179,820) and average expenditure per day for San Francisco area partyboat salmon anglers ($38.88) from 1979 National Marine Fisheries Service survey reported by Center for Natural Areas ("Survey of Partyboat Passengers to Summarize and Analyze Recreational Demand for Partyboat Fishing in California," Southwest Fisheries Center Administrative Report No. LJ-80-14C, La Jolla, CA, 1980. 75 p.).
3. Net-value estimates for Washington and Oregon are from Brown and others (1980). California net value is estimated by multiplying number of trips by $50, about midway between the estimated day-values for Oregon and Washington ocean salmon-fishing trips.

Subsistence fishing is important for residents of Alaska and for Native Americans in certain areas of Washington, the Columbia River, and the Klamath River. Native Americans constitute a growing portion of those fishing commercially. In Washington and Columbia River fisheries, they are increasingly using their historical fishing rights, which were established in Federal Courts. These rights allocate harvestable portions of the fish stocks that return to the "usual and accustomed" fishing places as specified by treaty. During 1976 to 1981, harvests by Native Americans increased from about 1 million to 3 million fish per year in Washington and the Columbia River. Because total annual harvests (treaty and non-treaty commercial plus recreational) remained between seven and eight million fish, treaty fisheries have taken an increasing share of the harvest in the region.

The north Pacific salmon and steelhead fisheries are extremely widespread, diverse, and economically significant. These fisheries provide employment to thousands fishing commercially and also shoreside workers. Often the fishery is one of the few livelihoods available in isolated coastal communities. Large numbers of salmon contribute to the subsistence of many people. Among recreational anglers in Alaska and the Pacific Northwest, salmon and steelhead fishing are extremely popular. Anadromous fish are thus a resource worthy of substantial consideration in resource-management decisions.

CONCEPTS OF ECONOMIC VALUATION FOR FISHERIES

To understand and properly use estimates of economic value, several related concepts must be distinguished. An economic value given to a particular resource or industry can be divided into those values accruing to consumers, producers, taxpayers, and resource owners. The economic value may be positive to one group, but negative to another. For any given target group, the value may be calculated as an "all-or-nothing" value or as a "marginal" value. An all-or-nothing value is the value of having resources or commodities, rather than not having them; the marginal value is the value of a small change in the quantity of the resource or commodity. Estimates of value can apply to one or more potential uses for a resource; for example, commodity value pertains to the increase in value when basic materials or resources are made into consumable goods, and amenity values often come from natural environments and in situ resources.

In practice, the economic value of some commodity or activity is measured as the dollar amount that consumers or business firms are willing to pay for the commodity. This "willingness to pay" can be expressed as an all-or-nothing value, representing the total amount consumers would pay to avoid going without the existing amount of the commodity. The marginal value--an increase or decrease in willingness to pay associated with a small increment or decrement to existing quantities supplied--is often more useful to know. Most forest- and rangeland-management decisions are concerned with marginal effects on commodity markets.

COMMODITY VALUES

Values of commodities are related to the market-demand curve (fig. 1). If consumers allocate their expenditures among commodities to maximize their well-being, they will purchase more of virtually any product when the price is low, and less when the price is high. This theory explains why the demand curve depicted in figure 1 slopes downward to the right. For any given consumption rate, there is a maximum price consumers will pay for an additional unit. This price is a useful measure of the marginal value of the product to consumers. Multiplying the price times the quantity demanded yields the gross market value.

Gross market value of harvests is commonly available for whole fish at dockside, processed fish at wholesale, and retail fish in final goods markets. Similar values can be computed for stumpage or forage, wholesale primary wood products or beef, or for finished wood products or meat in consumer markets. Although gross market value can be a useful indicator of industry size, it is of limited use in assessing economic benefits from an industry because it represents neither the value of the total supply to consumers, nor the net economic value accruing to producers.
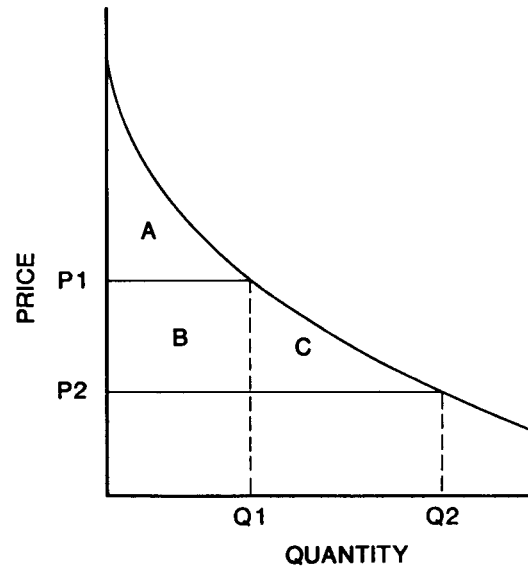

QUANTITY

Figure 1.--Market-demand curve. If quantity increases from Q_1 to Q_2, market price would fall from P_1 to P_2. Total willingness to pay, for quantity Q_1, equals the area labeled A, plus the gross market value P_1 x Q_1. Consumer surplus--the amount consumers are willing to pay above the amount they actually pay--for Q_1 is equal to area A.

When large changes occur in quantity supplied, the market price and underlying marginal value to consumers will change. If quantity supplied increases from Q1 to Q2 (fig. 1), the market price would fall from P1 to P2. Gross market value could rise or fall depending on whether the percentage change in price is less than or greater than the percentage change in quantity. Neither the change in gross market value, nor the change in quantity times the original price is a valid measure of the change in economic benefits. Consumers are better off with the lower price because they can still buy the original quantity and have money left over.

Economists use willingness to pay to measure the amount by which consumers are better off. For any given quantity consumed, the demand price represents the amount consumers are willing to pay for a marginal increase in consumption. If we value each unit--from the first one up to the actual quantity consumed--at its marginal value, the total willingness to pay would be measured by the area under the demand curve. For quantity Q1, for example, this total would equal the area labeled A plus the gross market value P1 x Q1. The consumer surplus--the additional amount consumers are willing to pay above the amount they actually pay--for quantity Q1 is equal to the area A. By similar reasoning, the increase in consumer surplus associated with an increase in quantity from Q1 to Q2, accompanied by a price decrease from P1 to P2, is represented by the sum of areas B and C. The change in consumer surplus is the most relevant measure of the change in benefits to consumers.

Producers, like consumers, may enjoy a surplus. The producer surplus is the excess of market value over the costs of production, where costs must include reasonable payments to labor, management, and capital, as well as payments for other raw materials. This surplus may be represented by profits earned by firms in the industry. The change in producer surplus is the most relevant measure of the change in benefits to producers.

Producers of natural-resource commodities usually draw on some resource stock such as a fish population, forest, or mineral deposit. When producers find that production of commodities from a particular resource is profitable, they should be willing to pay fees to the resource owner. In a private-enterprise economy with private-property rights established for natural resources, the fees actually paid contain two distinct components: an economic rent, and compensation for maintenance and other costs incurred by the resource owner. The rent is an economic surplus similar to a profit.

Economic rent reflects the scarcity of a fixed, productive asset, whereas profit reflects the success of firms at generating revenues in excess of operating costs. When commodity producers also own the resource, or when publicly owned resources are provided free to producers, reporting of profits versus rents is muddied; the rental value of resources may be hidden in the reported profits of producing firms. Regardless of how the rental value of a scarce resource is reported in the industry's accounts, two distinct economic surpluses are to be included as benefits to the producer side of the market--profits and rents. Consequently, the total net economic value accruing to the economy through production of natural-resource commodities consists of consumer surplus, producer profits, and resource rents.

Market prices and monetary costs recorded by business firms provide information on economic values and costs. This is especially true if prices and costs are determined in a perfectly competitive market. A competitive market is one with sufficient numbers of buyers and sellers to prevent any one of them from establishing the going price, where all buyers and sellers are free to buy or sell as much as they want at the going price, and where property rights to the commodities being sold are well defined and exclusive. Exclusive means the rights to use, to exclude others from use, and to sell a unit of the commodity are vested in its owner. Under these conditions, market prices are a good measure of the marginal value to society, and the marginal costs of producers are a good measure of the marginal cost to society.

The same conclusions apply in other markets. If labor and capital markets are perfectly competitive, the wage rates and rates of return on capital observed represent valid measures of the full social costs of using these factors of production. Where competitive markets establish rents for natural resources, the rents represent the marginal value of the resource to commodity producers. In the United States, however, many resources are not sold competitively. Some markets are dominated by large firms that dictate prices, and--more importantly--for many resource commodities (especially those associated with the public good, such as air and water quality, natural fish runs, and environmental amenities), clear private-property rights have not been established. When property rights are insufficient to define the various rights and responsibilities of all resource users, free use of or competition for the resource often results in what economists call an externality. When logging operations damage salmon spawning gravels, an external cost is imposed on the salmon-fishing industry. Similarly, when salmon fishing is competitive for a common pool of fish, each person in effect imposes an external cost on others because fish are harder and more costly to catch when the available stock is smaller. Finally, competitive market allocation of land and of associated renewable and nonrenewable resources is uncommon on public lands administered by Government agencies. When competitive markets do not function or external costs are imposed by one firm on others, private market prices do not provide an adequate basis for measuring economic value.

The market for public forage does involve a payment by the rancher to the agency, but the price is determined administratively, not by a competitive market. The actual price paid may be higher or lower than the market price that would prevail if forage were allocated through competitive bidding. The market for publicly owned timber also involves a payment based on the amount harvested. In general, the payment is based upon an oral or sealed-bid auction. In those areas with sufficient competition for timber harvesting rights, the price is reasonably close to a competitive-market price. The conditions of sale are not necessarily typical of what would normally be found in an open and competitive market, however.

Because salmon fisheries are common property, administered through public agencies, no fees are paid to private owners. Traditionally, the responsible agencies charge no direct fees for capture of fish. States do charge annual license fees, and sometimes they collect a flat-rate poundage fee for fish landed. Thus, economic value of the anadromous fish resource cannot be calculated based on fees paid, but must be estimated, based on potential or actual net revenues. The potential rent from a fish stock can be roughly calculated as the ex-vessel value of harvested fish minus the minimum necessary harvesting costs. The quantity of harvest used in this calculation would be based on knowledge of the potential yield of the fish population, and the cost estimate would depend on knowledge of the best capture technology and associated costs. Expecting actual fisheries to generate a net economic value equal to this potential rent is unrealistic because of the common property status of the fish population and traditional fishery-management methods--which seek to conserve the fish stocks but do not encourage economically efficient harvesting. Actual net revenues from commercial fisheries are generally a small (if not vanishing) proportion of potential rent.

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RECREATIONAL VALUES

Although recreational fishing values are expressed as value per fishing day or fishing trip—not value per fish—the demand curve still can be used for analysis. Using figure 1 as reference, suppose that price is replaced by cost of getting to a particular site and fishing there. Quantity is the number of times per season or year that the angler goes fishing. When costs per trip are lower, anglers go fishing more often; thus, the demand curve slopes down to the right. The main problem is that recreational fishing is not sold in private markets. Estimation of the recreational demand curve requires indirect information, such as expenditures, fishing participation patterns, and possibly other socioeconomic data on anglers. Furthermore, it requires application of complex sets of assumptions and models. For full explanations of the alternative procedures available, see Desvousges and others (1983), Dwyer and others (1977), Freeman (1979), or Huppert (1983).

Once a demand curve for recreational fishing is estimated, a consumer surplus value can be given to fishing. As in commercial fishery evaluation, a net economic value for a change in total quantity consists of the marginal value of the increment to consumers, minus the marginal cost of producing the increment. Recreational commodities differ from commercial ones, however, in that commercial goods are generally distributed widely, making market prices nearly uniform, except for differences in transportation costs. Recreation, however, cannot be shipped to consumers; consumers have to go to the fishing site and produce their own recreation. Consequently, the costs of recreational fishing will be higher for anglers more distant from fishing sites. The value of recreational fishing to an angler will be lower for more distant sites, because the costs to use them are higher.

Fishing values are often expressed as an average per fishing trip or fishing day. If used carefully, these unit-day values are good approximations of the value of recreational fishing. Table 7 is a summary of salmon- and steelhead-fishing value estimates compiled by Meyer (1982). The wide range of values is partly from variations in research methodologies and partly from variations in the quality of recreational fishing being studied. Some of the factors that make salmon and steelhead fishing a heterogeneous activity are accessibility, scenery, congestion, and catch rate at different fishing sites.

To evaluate fishery management properly, the marginal value of salmon added by management and enhancement should be known. Unfortunately, estimates of fishing-day values are not easily translated into estimated values of fish caught because the satisfaction of anglers depends on various attributes of the fishing trip. Relaxation, the challenge of dealing with natural hazards, the excitement of the hunt, communion with nature, and the provision of food are all valued by recreational anglers. The prevailing recreational catch rate represents just one quality variable. Greater catch per fishing day would mean higher quality fishing. Similarly, more tranquil and natural surroundings would represent an improvement in recreational quality to many anglers. Recent advances in assigning recreational values have made value estimates for increased catch rate more accurate.

Interactions between fishing and the fish population need to be examined in any comprehensive assessment of recreational fishing. Because salmon are available to recreational anglers as common property, any increase in catch rate caused by stock enhancement will attract additional fishing effort. This would shift the demand curve to the right in figure 1. More fishing, however, will cause some reduction in fish population, which will in the long run result in a lower catch rate than originally expected.

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Table 7--Estimates of Pacific Northwest salmon and steelhead fishing values based on sport-fishing demand

Author	Recreational product	Year data collected	Estimated value per day	Value in 1980 dollars
			Dollars	
Brown, Singh, and Castle	Oregon salmon and steelhead	1962	13.70	39.02
Gordon	Idaho salmon	1968	8.00	19.81
	Idaho steelhead	1968	15.00	37.14
Brown, Charbonneau, and Hay	U.S. fishing (nonriver)	1975	22.00	35.20
	River salmon and steelhead	1975	51.00	81.60
Tuttle, Richards, and Wahle	Columbia River salmon and steelhead	1975	28.00	44.60
Brown, Sorhus, and Gibbs	Pacific Northwest salmon and steelhead	1977	45.00	63.94
Crutchfield and Schelle	Washington ocean salmon	1978	18.19	24.01

Source: Meyer (1982).

In specific circumstances, fishing-day values may be used in estimating the value of improved anadromous fish stocks. For example, recreational and commercial fishing seasons for coho salmon off the coasts of Oregon and Washington have been strictly limited in recent years to achieve desired spawning escapement. An increase in fish-run size would result in increased season length. If lengthened seasons would create additional fishing days with uniform quality, the increased value of recreation could be estimated by the product of average fishing-day value and the increment in number of days fished.
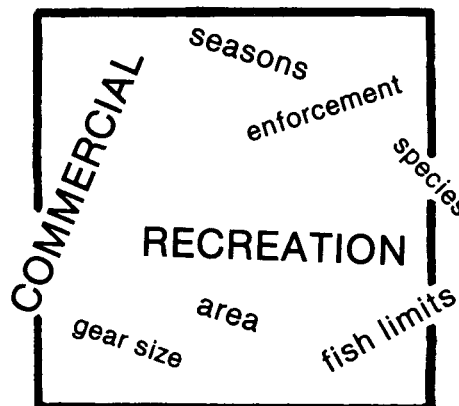
MANAGEMENT OF ANADROMOUS FISHERIES

A proper evaluation of how forest and rangeland management affects anadromous fish stocks requires estimates of economic and other benefits originating from the fisheries, and estimated costs of the forest and range industries, and of the Government agencies responsible for the management. Economic performance of salmon fisheries, however, largely depends on the management procedures of the responsible agencies.

BIOLOGICAL CHARACTERISTICS AND OBJECTIVES

Each salmon population spawning in a specific river or stream is treated as a separate stock. Fish populations are sometimes further subdivided according to the spawning season (for example, Columbia River "fall" chinook salmon). The sustainable yield of each stock depends on such factors as extent and quality of spawning gravel, and extent and quality of rearing habitat (including streamflow, cover, dissolved nutrients, and food supply). Additional factors include mortality during upstream and downstream migrations, and ocean survival. Because fishery managers control the quantity and timing of harvests only during the ocean-feeding stage and during the spawning migration of the fish, population models developed for fishery management assume a given size and quality of freshwater habitat.

One such model, a "spawner-recruit" curve (fig. 2), pertains to a group of coho salmon stocks spawning in Oregon coastal streams (Oregon Department of Fish and Wildlife 1982); however, curves for other species and stocks are similar. On the horizontal axis is an estimate of adult coho salmon reaching spawning sites in Oregon streams. Spawning stock size is plotted versus number of adult fish recruited to the fishery 3 years later (the typical time between generations). The fitted curve predicts the run size resulting from any given spawning stock, and the diagonal line is the replacement line. If the recruitment of spawning stock falls above the 45-degree line, the progeny more than replaces the spawning stock. The excess of recruitment over spawning-stock size can be harvested without causing a reduction in original stock size.

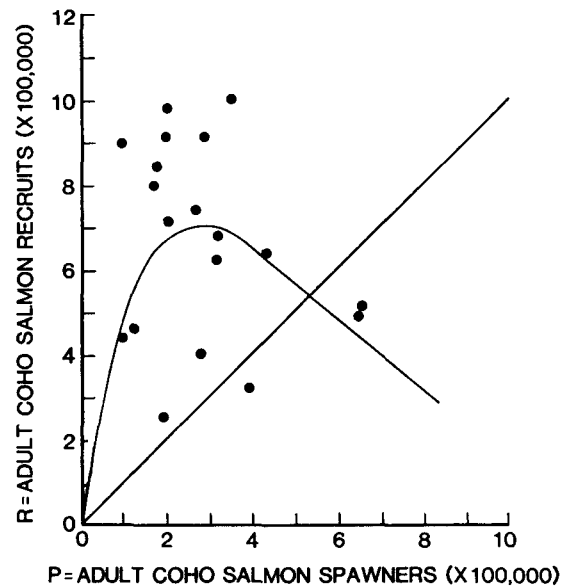P=ADULT COHO SALMON SPAWNERS (X100,000)

Figure 2.--Spawner-recruit curve for Oregon coastal coho salmon (adapted from Oregon Department of Fish and Wildlife 1982).

Maximum recruitment is achieved at some spawning-stock size intermediate between zero and the maximum observed (fig. 2). One biological basis for fishery management is maintenance of the spawning population to achieve maximum recruitment. Because spawning fish have survived the ocean-feeding migration and escaped the fishery to return to spawning sites, spawning-stock size and escapement are often used interchangeably. The great variability of the run sizes about their expected values is caused both by natural fluctuations in reproduction and survival of fish, and by errors in measuring the numbers of spawners and recruits. Because of the inherent variability, maintaining a maximum run size is impossible. Even if the escapement is successfully maintained to achieve the maximum run-size every year, the annual harvest would fluctuate widely.

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Achievement of escapement objectives is complicated by the tendency of many salmon stocks to mix in the ocean. Variations in timing and location of oceanic migrations make it difficult to predict what proportions of each stock will be caught in a particular area. Consequently, some less-productive stocks tend to be overfished and some highly productive stocks may be under-fished by a mixed-stock fishery. This problem is particularly evident when hatchery stocks mingle with natural-spawning stocks, and are then jointly harvested. Because hatchery stocks tend to have high upstream-migration survival and very high smolt production per spawner, they can sustain a higher exploitation than naturally spawning salmon stocks.

ECONOMIC CHARACTERISTICS AND MANAGEMENT OBJECTIVES

Because of the common-property status of anadromous fish populations, competitive fishing by commercial fleets in the face of high prices would rapidly deplete stocks and severely reduce long-run economic returns. To prevent this, management agencies have historically controlled annual harvests by increasing costs of harvest rather than by reducing fleet capacity. Consequently, very little net economic return from publicly managed salmon fisheries can be expected.

The revenue and cost curves in figure 3 rely on concepts from population biology and economics. When recruitment exceeds replacement, the fishery can take the surplus without reducing subsequent run size. This surplus is equivalent to a sustainable annual yield. To construct the sustained-revenue curve, we further assume that any catch corresponds to a given fishing effort, here represented as vessel-days and measured along the horizontal axis. The total-revenue curve represents this sustained yield times market price. Total cost is equal to fishing effort times cost per unit of effort. For simplicity, both the fish price and the cost per unit effort are assumed to be independent of harvest. See Anderson (1977) for less simplistic versions of the model.
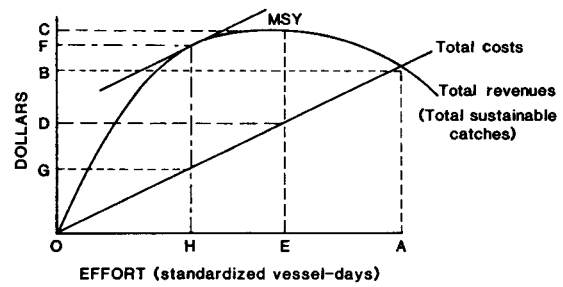

EFFORT (standardized vessel-days)

Figure 3.—Bioeconomic model of the fishery. Economic efficiency corresponds to the effort represented by point H. Economic equilibrium with open access occurs where revenues just cover all private costs of fishing, with effort at point A and revenue at point B. Because point A is to the right of the maximum sustainable yield (MSY), overharvest (in the biological sense) would be expected—but it would depend on how high the price is relative to the cost of effort.

With open access and no regulations, the competitive fishing fleet can be expected to grow until prospective profits of a new vessel are zero. Economic equilibrium occurs where revenues just cover all private costs of fishing. From a strict economic-efficiency perspective, such a resource has no value because the revenue produced is consumed in paying for the capital and labor used to harvest the fish. In fact, it would have a negative value because no surplus is left to pay for costs of managing the resource. In figure 3, this point occurs with effort at point A and revenue at point B. Because point A falls to the right of the maximum sustainable yield, this open-access fishery is expected to overharvest the stock in the usual biological sense. The extent to which this overfishing occurs in any particular case depends on how high the price is relative to the cost of effort. With a higher price or lower cost per effort, the fleet would be expected to stabilize with higher effort. With lower prices or higher costs, the fleet would stabilize with a lower effort.

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Economic efficiency, which requires that the difference between revenues and costs be at a maximum, corresponds to the effort represented by point H. At this point, the slope of the revenue curve is equal to the slope of the total cost curve. At any effort greater than H, cost is increasing faster than revenue, which means that each additional unit of effort adds more to costs than to revenues. In other words, the marginal cost exceeds the marginal revenue. At any point below H, where marginal revenue is greater than marginal costs, increasing the amount of effort in the fishery makes sense. Thus, point H and the corresponding harvest are economically efficient; they give a maximum economic yield. This maximum economic yield represents the potential amount of economic rent that could be earned by a sole owner of the fish stock, if such an owner existed.

Traditional techniques of fisheries management, such as gear regulation, season closure, and quotas, all reduce catches to achieve escapement objectives; however, they tend to raise costs of fishing. To obtain a stable open-access fleet size with effort level E, cost of effort must increase until the cost curve intersects the yield curve at the MSY point. This solution is little better than the solution with open access; the total value of the resource is consumed in paying for the capital and labor used to harvest the fish, and no surplus remains to cover the cost of managing the resource. Once this point has been achieved, a price increase that raises the revenue curve further will have to be followed by more restrictions on the fishing fleet to raise costs again. Fishing costs increase through a variety of mechanisms. A reduced fishing season, for example, results in higher fixed costs per fishing day. Limiting the use of the most effective fishing gear reduces the catch per fishing day and raises costs per unit harvest. Rising salmon prices over the past two decades, coupled with traditional management tools for achieving escapement objectives, have led to repeated increases in fleet investments and decreases in fishing opportunities for each vessel operator.

To maintain low costs while controlling the fishing fleet's harvest, fishing effort must be managed in specific ways. In recent years, management methods--such as effort control, economic rationalization, and limited entry--have been discussed and evaluated by several national and international conferences (Fisheries Research Board of Canada 1979, Rettig and Ginter 1978, Sturgess and Meany 1982). Economically efficient management requires one of two approaches: creating financial disincentives to excessive fishing effort, or establishing a private property-like right to fish. The first approach could include landings taxes or royalties, and the second could include annual individual quotas. Both represent radical departures from previous management of North American fisheries, and are not being widely accepted. These ideas are not without precedent in public-resource management, however. Royalties are collected from most mineral extraction firms on public lands, and allocation of annual forest harvests (by auction or other methods) is analogous to the individual fisherman quota.

A first step toward economic rationalization in fisheries was license limitation. Limiting licenses prevents expansion of the fishing fleet during periods of rising fish prices, and thus works toward reducing overall harvest costs. License limitation was initiated in British Columbia in 1968; Alaska began its limited entry program in 1974; and Washington, Oregon, and California began a joint, cooperative license-limitation program for salmon in 1978. The details and restrictiveness of these programs differ widely among States, and the economic consequences depend on the progress made in reducing fleet sizes and in preventing compensating increases in fishing capacity per vessel.

Much of the effectiveness of license limitation is nullified, however, because such limitation does not prevent increased investment in fishing capacity within the existing fleet size. Most license-limitation programs eventually add some form of capacity limitation to each license. In British Columbia, replacement vessels are limited to the tonnage of the previously licensed vessel. California requires replacement vessels to be declared equivalent in fishing capacity by an expert review board. These provisions make license limitation more effective, but they may not prevent operators from increasing the capacity of existing vessels. Thus, even among fisheries economists, license limitation remains a controversial subject, and license limitation has resulted in little economic efficiency among fishing fleets on the Pacific coast.

OTHER FISHERY-MANAGEMENT OBJECTIVES AND CONSIDERATIONS

As with most public resources, a variety of special considerations and objectives guide fishery-management decisions. Most important objectives are stated in the Magnuson Fisheries Conservation and Management Act (MFCMA), the broadest piece of fisheries legislation to date. The MFCMA establishes Regional Fishery Management Councils to develop marine fishery-management plans for use by the U.S. Department of Commerce. The MFCMA sets out national standards for fishery management, which include: preventing overfishing, achieving "optimum" yields, promoting efficiency in the use of resources, and minimizing costs "where practicable." Optimum yield is defined broadly enough to include adjustments to escapement in anadromous fisheries for economic, social, or ecological reasons.

Current policies in fishery management attempt to maintain high fish populations and annual yields, while addressing socioeconomic factors such as maintenance of jobs and incomes in the many coastal communities that depend on the fishery. Another objective is the equitable division of available fish among competing user groups. The Pacific Fishery Management Council's Salmon Plan (1983), for example, provides for a 30-percent share of coho salmon for recreational fishing off the Oregon coast and the Columbia River. Also, allowable annual catches of salmon in the ocean-troll fishery are set with the intention of permitting the escapement of salmon to "inside" (protected water) net fisheries.

IMPLICATIONS FOR ECONOMIC EVALUATION OF ANADROMOUS FISH HABITAT

Given the economic problems of open-access fisheries under their existing management, how should we evaluate a prospective increase in salmon stocks contributing to the fisheries? In the commercial fishery, no net economic yield will occur when harvests are increased if more fishing vessels enter the fishery. Resource management authorities have consistently failed to generate a rental value for fisheries. This failure suggests that other objectives, such as fisheries employment or freedom of choice in fishing occupations, were considered more important. One could then argue that these other objectives must have been worth at least what was "paid" for them. Maintenance of additional employment in coastal communities, for example, could be counted as a benefit, but this argument assumes too much about the knowledge and intentions of public decisionmakers. If other social or cultural objectives are achieved at the expense of economic efficiency, they need to be evaluated and justified on their own merits.

Prospects for generating net economic yields from commercial fisheries are not so bleak as the simple bioeconomic model suggests, however, if recently established license-limitation programs prevent some of the potential new investment in the fishing industry. For marginal growth in anadromous stocks, one could assume that additional harvests involve no additional costs, because sufficient capacity is already available. Some increase in fishing effort would probably be necessary to take additional catch, however, and this effort involves some incremental cost. Thus, for increments taken by fishing fleets whose capacity is rigidly controlled, only the incremental costs of increased capital depreciation, consumable supplies, and labor hired away from alternative employment need be subtracted from market value to determine net economic value accruing to producers. Both Meyer (1982) and Crutchfield and others (1982) suggest that about 90 percent of gross ex-vessel value of marginal harvest is net value. This figure applies only so long as the fishing industry is prevented from expanding its capacity in response to the increased catch.

In addition to this net value in commercial fishing, consumer surplus is generated in both the commercial and recreational fishing sectors. Neither of these values has been sufficiently documented to be used for practical assessments, but both could be important in preserving and improving salmon habitat. Finally, nonmonetary factors, such as maintenance of fishing communities, cultural traditions, and a sometimes attractive lifestyle, must be counted as benefits of anadromous fish stock management. More comprehensive studies of these factors may allow us to assign a monetary equivalent to these benefits.

MANAGEMENT OF FRESHWATER HABITAT

DEPENDENCE OF ANADROMOUS FISH PRODUCTIVITY ON HABITAT

Anadromous salmonids of western North America have an extensive geographic range extending from the McKenzie River on Alaska's north slope to southern California. Habitats within this range are used by eight species of anadromous salmonids. Certain geographic areas are dominated by one species, but several species almost always cohabit within the range. Habitats within much of the range of anadromous salmonids are found in coniferous forests.

Anadromous salmonids use freshwater, estuarine, and marine environments to complete their life cycles. Habitat requirements are exacting for all species. All accessible freshwater environments, and an extensive variety of microhabitats, are used by anadromous salmonids at some stage in their life history. Most reproduction occurs in fresh water, although some species occasionally reproduce in brackish intertidal areas. Juveniles of most species rear in fresh water for some time before migrating to the

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sea where they mature. For optimum production all species require: water between 5.6 and 14.6 °C; free migratory access to and from the sea; clean gravel substrate, with less than 10 percent sediment smaller than 1-mm diameter, for reproduction; water with turbidity of less than 50 NTU (nephelometric turbidity units) during the growing season, for sight feeding; dissolved oxygen greater than 6 mg/liter in streams, lakes, and the intergravel environment; and invertebrate organisms for food (Everest and Harr 1982). Species preferences for these habitat variables differ slightly and are presented in detail by Reiser and Bjornn (1979).

Natural habitats are important in maintaining viable populations of wild anadromous salmonids. Because most waters support several species of anadromous salmonids, natural habitats must contain a diverse and complex set of depths, velocities, substrates, and cover, in addition to having adequate water quality, to meet the needs of several life stages of cohabiting species. Any environmental manipulations that simplify habitat will have a direct, negative effect on fish population structure and abundance. Because the ranges of anadromous salmonids and coniferous forests are largely coincident, forest management rather than range management will likely have the greater influence on salmonid habitat in the long run.

EFFECTS OF FOREST AND RANGELAND MANAGEMENT ON ANADROMOUS FISH RUNS

Links between forest management and fish production are complex and depend on many environmental variables. A physical disturbance created by forest management, interacting with the physical and biological features of the environment, can have either minor, major, or neutral effects on fish habitat. The general effects of forest management on habitat of anadromous

salmonids have been documented by several studies. Effects range from drastic changes in physical habitat and fish populations to no apparent change in either habitat or fish numbers, depending on prescribed treatment.

Timber-management activities and logging-road construction have three primary effects on salmonid habitat. These activities tend to increase sediment and temperature in streams while reducing the source of large woody debris—the primary structural component of habitat in small streams. Other effects include changes in water chemistry resulting from timber cutting, burning, or use of forest chemicals, and an increased biochemical oxygen demand (BOD) caused by addition of fine organic debris to streams. Minor changes in streamflow also occur. A few studies have shown that these effects, singly or in combination, have decreased the standing crop of salmonids. Most studies, however, have only assessed the effects of timber management on habitat, rather than on salmonids, because assessing fish populations is a long-term, expensive operation. Consequently, the relation of habitat changes caused by logging to populations of juvenile salmonids needs further documentation (Everest and others, in press).

Salmonids are able to tolerate some short-term habitat disturbances because of their natural compensatory mechanisms, such as high reproductive rates and a fairly broad scope of physiological and behavioral responses. Salmonid populations have always had to cope with short-term natural habitat disturbances, such as floods, sedimentation from landslides, scouring of stream substrates, and deposition of organic debris in streams. These disturbances occur with varying frequencies and magnitudes, and may depress fish production in the short run.

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The frequency of these events, however, is often accelerated by timber-management activities, and the construction and use of forest roads. Frequent occurrences sustained in intensively managed watersheds can produce cumulative effects that can cause long-term decreases in salmonid productivity.

These accelerated events, by themselves, probably would not completely eliminate salmonids from forested watersheds, even in a worst-case situation (Salo and Cederholm 1981). When the cumulative effects of logging activities on freshwater life-history stages are combined with an intensive harvest of fish stocks in both fresh and saltwater, however, and imposed over natural mortality rates of salmonids, fish production can drop below the level needed for desired seeding.

Removal of the forest canopy adjacent to and within the riparian area has the greatest effect on salmonid habitat. This removal raises summmer water temperatures (Moring and Lantz 1975), lowers winter water temperatures (Chapman 1962), and reduces the amount of terrestrial insect drop and litterfall into streams (Toews and Brownlee 1981). Canopy removal may also reduce bank stability, thereby increasing the amount of sediment entering the stream (Sedell and others 1982). In time, it will also reduce or eliminate the addition of large organic debris, which in turn will result in less structural complexity within the stream. Not all of the effects are detrimental, however; increased light reaching the stream can temporarily increase the production of algae and sustain greater densities of drifting invertebrates, which form the basic diet of fish.

Fauna and flora are often more abundant in sections of streams with open canopies than in forested sections (Aho 1976, Albrecht 1968, Erman and others 1977, Gregory 1980, Hughes 1966, LeCren 1969, Lyford and Gregory 1975, Murphy and Hall 1980, Newbold and others 1980, Thorup 1966). Removing streamside vegetation increases aquatic production at the lower end of the food chain. This production is a result of increased light, which stimulates growth of algae and periphyton (Gregory 1980, Murphy and Hall 1980). Many reports on logging effects, however, emphasize the destructive potential of accumulated sediment that adversely affects stream habitat (Cordone and Kelly 1961, Gibbons and Salo 1973, Iwamoto and others 1978). The long-term loss of large woody debris is equally detrimental. Thus, logging may have two opposing localized effects: canopy removal, tending to increase basic stream productivity; and sedimentation and loss of large woody debris, tending to decrease productivity.

Murphy and others (1981) found that small, open sections of streams passing through clearcuts had a greater density, biomass, or both of invertebrates and cutthroat trout than did shaded, forested reaches, regardless of sediment composition. They concluded that, for small streams in the Cascade Range, changes in fish-food status and increased production of algae resulting from shade removal masked or overrode effects of sedimentation. Their data indicate that strong links exist among amount of light reaching the stream, primary production, invertebrate production, and—ultimately—vertebrate production. Gregory (1980) found periphyton production in small streams in a western Oregon study area to be light limited. Chapman and Knudsen (1980) found that fish production in some Puget Sound streams was indirectly light limited.

Thus, canopy removal in small blocks can positively influence stream productivity, but cumulative effects of extensive cutting could cancel any potential benefits. Sedimentation and canopy removal both have adverse effects in the long run. Increases in sediment load can cause the stream to become wide, shallow, and unstable, often with a braided channel (Leopold and others 1964). Filling of pools with sedimentary material reduces suitable habitat for trout (Bjornn and others 1974) and damages spawning habitat. These effects of sediment are not usually observed in sites where large woody debris creates a stairstep channel profile, and forms plunge pools downstream of debris accumulations (Keller and Swanson 1979, Meehan and others 1977). Canopy removal and stream cleanup usually cause a substantial loss of the large woody debris that can mitigate the effects of sediment. Canopy removal rarely increases stream temperatures enough to kill trout (Martin and others 1981, Moring and Lantz 1975), but sublethal increases can indirectly affect survival, and cumulative effects can reduce the quantity and quality of rearing habitat in downstream waters.

Physical habitat for anadromous salmonids has been altered in the last two decades by a combination of increased sedimentation, channel sluiceouts, and excessive debris removal related to timber management. The cumulative result has been a loss of large, high-quality pools necessary for rearing juvenile salmonids and holding adult salmon before they spawn. Most high-quality pools in small streams are formed by large tree-sized debris.

Also, most high-quality cover in small streams is provided by large organic debris. Overzealous cleaning of the channel, or failure to provide a long-term supply of large organic debris after cutting, can turn a productive stream that is suitable for salmonids of a wide range of sizes and ages, into a marginal stream suitable primarily for underyearling fish (Bisson and Sedell, in press). Coho salmon and cutthroat trout habitat generally is reduced in this manner in exposed and cleaned streams. The loss of high-quality pools removes temperature refuges as well. Big pools, in both small streams and large rivers, tend to stratify thermally in summer, providing cool-water refuges in areas where cool surface water or ground water enters the stream and collects (Everest 1973).

ECONOMIC CHARACTERISTICS OF INSTITUTIONS

Like stocks of ocean and river fish, freshwater habitat also suffers from the common-property curse. Although a variety of legal and administrative institutions allocate and assign rights to riparian areas and access to surface water, rights to much anadromous fish freshwater habitat remain unassigned. As a consequence, when an activity such as logging or mining damages the habitat, the damage does not appear as a cost of production to the offending firm. Without public regulations in sensitive areas, logging or mining can cause excessive damage to the habitat. Imagine some economically efficient system in which property rights to freshwater habitat are owned by private citizens (this is close to the actual situation in parts of the United Kingdom). Then, the habitat owner would require compensation from a logging firm up to an amount equal to the value of fishing lost. The logging firm would have strong, economic incentives to avoid habitat damage and to log where fishing values are least affected.

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Under current laws, however, logging practices are publicly regulated. These regulations, in effect, are a substitute for the discipline of the private market that does not exist for habitat or fishery resources. Because regulations are formed in a public forum, various criteria for management of habitat need to be considered and agreed on.

ECONOMIC CRITERIA FOR MANAGEMENT

Each watershed, along with its anadromous fish stocks, forests, and rangelands, can be treated as a complex resource with multiple uses. Resource management should seek to raise the total net value of all resource uses. But some uses, such as fishing and logging, impinge on each other's potential value. Similarly, camping and backpacking may be incompatible with some forestry practices. Some different classes of recreational use, such as wilderness camping and developed motorhome camping, cannot use a given area simultaneously without conflict. Optimal use of forest lands requires balance among competing uses.

The broadest conclusion from economics is that each use should be adjusted until the marginal net value of one is equal to the marginal net value of all other uses. Thus, any increase in timber cutting should have a net economic value at least equal to the net economic value of fishing, camping, or other uses that is lost because of additional cutting. If the fishing or camping opportunities lost because of timber operations on a particular plot are worth more than the timber products, then the timber should not be cut. Where the timber value is greater than the fishery or recreational value, the timber should be cut. To achieve a balance in any case we need to know the marginal net values generated in fisheries, and the costs of efforts by management agencies and commercial enterprises to preserve or improve anadromous fish runs.

MARGINAL NET VALUES GENERATED IN FISHERIES

Improvements in freshwater habitat increase sustainable fishery yields for the major fisheries. Thus, marginal economic value in habitat management is expressed as the increase in harvest as a result of improved habitat times the marginal value of additional fish. Further, the value of additional sustainable harvest depends on how that harvest is allocated among commercial, recreational, and subsistence fisheries.

If fishery managers had exact control over the allocation of fish among users, they could achieve maximum value by allocating to highest valued uses first. Noncommercial uses having a higher value than the commercial harvest would probably be satisfied first, and the remainder allocated to the commercial harvest. This allocation would have little effect on the commercial price of salmon because of their large international market.

Placing values on net changes in fishery production would be simplified under the above allocation because marginal changes in production would primarily be changes in commercial harvest. The commercial value would therefore be the relevant value for that marginal change in production.

Fishery managers, however, have neither the capability (as long as the commercial catch from mixed stocks in the ocean is large) nor the desire to allocate fish in that manner. Thus, the actual change in value from marginal changes in fish production is an average of values for different uses that is weighted by the proportional allocation.

The net economic values from com-
mercial harvests may be quite low when
open access allows excessive numbers
of fishing firms to compete for limited
quotas. All ocean salmon fisheries on
the Pacific coast, however, are cur-
rently under license-limitation systems
and have sufficient capacity to harvest
additional fish. Thus, approximating
the marginal net economic value of im-
proved or restored fish runs as the
ex-vessel price of fish, minus the
marginal increase in operating costs
required to take the additional catch,
is becoming increasingly acceptable.
Under these conditions, the net value
of a small increase in fish may be
90 percent of the ex-vessel value.
This figure ignores possible increases
in consumer surplus in retail markets,
but most improvements in freshwater
habitat will be small enough to make
this an acceptable simplification.

Marginal values of anadromous fish
to recreational fisheries have not been
reliably estimated. The daily value
of recreational fishing is undoubtedly
greater when the daily catch is in-
creased, and the seasonal fishing value
for any fish run is greater when the
run is greater. But the contribution
of an increased run to either a daily
or seasonal catch depends on the nature
of the fishery and the fish run. Thus,
the incremental contributions of fish
runs to recreational values are hard
to estimate.

Subsistence and Indian-treaty fish-
eries have not been studied extensively
by economists to estimate net economic
values. From an economic perspective,
fish harvested by these groups would
be valued differently. The treaty
fishery is primarily an assignment of
property rights to harvest fish to a
particular segment of the commercial
sector. Special cultural considera-
tions may attribute a high value to a
portion of the harvest tied to
cultural-religious traditions. Beyond
that, the harvest going to commercial
markets would be valued much the same
as the remainder of the commercial
harvest, and this value would apply to

marginal changes in harvests. Because
under Indian treaties fish are gener-
ally harvested by less costly methods
than other commercial harvest, the net
economic value per fish may be somewhat
higher in the treaty fishery.

Subsistence fishing in Alaska is by
law for personal use or barter only.
Subsistence fishing was at one time
open to all residents; now it is lim-
ited to people residing in rural areas
and small towns. Because no qualifying
income test is used, some subsistence
fishing is done by people of above-
average means. The net economic value
of marginal changes in subsistence
harvest is probably somewhere between
the ex-vessel value of the commercial
harvest and the replacement cost of
the fish in the diets of subsistence
users. As with treaty fishing, some
portion of this fishery may have a
cultural-religious aspect.

COSTS INCURRED TO PRESERVE OR ENHANCE ANADROMOUS FISH RUNS

Current State and Federal forest-
practice guidelines in the Pacific
Northwest require protection of fish-
ery resources during all timber har-
vest operations. This protection can
cause out-of-pocket or opportunity
costs to responsible timber-management
agencies, private timber companies,
and contractors. Protection of fish
habitat results in increased cost to
timber managers in the following activ-
ities: constructing and maintaining
roads; protecting riparian vegetation;
and maintaining and protecting habitat
structure within streams.

Roads affect fish habitat primarily by accelerating sedimentation, infringing on stream channels and floodplains, and restricting fish passage. To alleviate sediment and infringement problems, roads in steep, unstable terrain should be avoided, or located on or near ridgetops, using varied grades to take advantage of favorable topography. Adequate drainage relief should be provided (Wenger 1984), and fish-bearing streams should be crossed on bridges or open-bottom culverts. Construction standards often require minimum road width and full-bench subgrade. Roads built to lesser standards often accelerate erosion and stream sedimentation (Fredriksen 1970, Megahan and Kidd 1972) and degrade habitat. The exact benefits of these activities to fish production, however, are hard to determine and each case must be examined individually. Most features of road location and design that benefit fisheries also provide long-term benefits to forest transportation systems. Although roads built to new, demanding standards are more costly, they are also less subject to cut-and-fill failures, and require less maintenance and reconstruction than roads built to lower standards. A complete analysis requires that all of the benefits from such roads—to timber management, fisheries, and other resources—be included in the benefit-cost equation whenever road construction or reconstruction is planned. At the planning stage, estimating the increased cost of construction is relatively easy, but determining the benefits of reduced maintenance costs and of less closure time because of road failures is much more difficult.

Protection of riparian vegetation and instream fish habitat also requires out-of-pocket and opportunity costs for timber managers. Timber managers must often use specialized timber felling and yarding practices to maintain riparian buffer strips. Directional felling of timber away from buffer strips by lining or jacking is a proven way to protect riparian vegetation. Directional (uphill) felling on steep, broken terrain is also safer for felling crews and reduces breakage of old-growth timber (Burwell 1971, McGreer 1975), resulting in increased recovery of wood fiber. The costs of directional felling are about three times greater than for conventional felling, but the benefits of directional felling in old-growth timber stands, based on increased fiber recovery alone, are often sufficient to pay the added costs. Several private timber companies use this technique to increase their timber production.

Large woody debris in streams is a critically important structural feature of fish habitat in forested watersheds. Fallen trees with attached rootwads and limbs provide the diversity and complexity of habitats required by the different species of salmonids residing in streams of the Pacific Northwest and Alaska. Because wood in aquatic systems has a finite lifespan, forest managers must provide a streamside source of large trees that will enter the stream channel, in the form of large organic debris, more or less evenly over time. Leaving commercial timber in buffer strips for this purpose may represent a substantial opportunity cost. The placement of artificial stream structures to compensate for the removal of riparian trees can also be costly, however. For example, a sound Douglas-fir, 36 inches in diameter, has an estimated volume of around 3,000 board feet. The stumpage value of such a tree could range from under $300 to over $1,200, depending on market conditions and location of the tree. The cost of installing a gabion structure to maintain a desirable stream habitat may range from $500 to $1,500, depending on its dimensions.

Because physical and economic characteristics differ among locations, both commercial and recreational values of a given stream habitat will differ also. Economic reasoning suggests giving greater attention to habitat protection and improvement in some areas than in others. Less productive streams, for example, may justify more aggressive forest practices, and more productive streams should be more strictly protected. Similarly, where timber inventories are less valuable, more timber should be left standing to protect stream habitat. Taking such variable factors into account, however, requires a high degree of knowledge and confidence about both physical and economic systems. Uniform rules of forest and range usage are easier to put into effect.

PROBLEMS OF IMPLEMENTATION

Economic considerations set forth in this paper should, ideally, improve management policies for freshwater anadromous fish habitat; however, economic criteria cannot, and should not, dominate policy formulation. Translating economics into specific rules is often difficult and fraught with uncertainty because of both a lack of well-developed economic models and a lack of data. The economic value of commercial fisheries depends on biological-yield potential, harvesting costs, and market demands. But uncertainties in biological assessments of potential yields leave most practical management decisions with order-of-magnitude estimates. Furthermore, harvesting costs depend on management strategies in the fishery, as well as market prices of fuel and equipment used in fishing. Finally, fish prices are subject to a wide variety of influences other than those from the fishery or river system. These factors, and the lack of useful economic studies for most anadromous fisheries, dictate that economic considerations be taken only as general guidelines for management.

Management plans for freshwater habitat are particularly complex and numerous because anadromous fish move from freshwater streams through sensitive estuarine habitats to oceanic feeding grounds, and back to the stream of origin. Individual States and Nations often control only one portion of a fish population's full habitat, which makes unified management of a fish population difficult. The United States' Regional Fishery Management Councils, for example, manage the 200-nautical-mile Fishery Conservation Zone. But many of the chinook salmon from the Columbia River system migrate to the ocean off British Columbia and southeastern Alaska. Inter-regional and international negotiations are necessary for overall management of these fish runs. Landward of the 3-mile territorial limit, States have more authority than the Fishery Councils. Moreover, responsibility for freshwater habitat is split among various State agencies and Federal departments. The interweaving of responsibilities and authorities makes it difficult to turn economically efficient propositions into management rules.

The real choice of policies for freshwater-habitat management is severely limited. Federal and State agencies are often restricted by necessary international compromises. Legislatures rarely allow management agencies to start some of the more economically attractive management methods, such as landings royalties or creation of private-property rights to instream habitat. Given the limited alternatives for managing anadromous fisheries, the economic objectives that can be adopted are limited also. Nevertheless, management must strive to use available natural habitats efficiently by balancing marginal net economic values among alternative uses, and by fairly distributing the economic gains from resource use among participants and citizens.

METRIC CONVERSIONS

1 inch = 2.54 centimeters
1 mile = 1.609 kilometers
1 nautical mile = 1.852 kilometers
1 pound (1b) = 0.45 kilogram
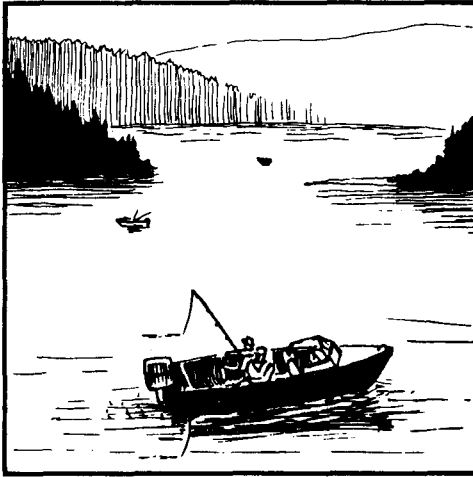
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