

Requesters

ENDANGERED

SPECIES

Deer Antlers Taken to
Assist Columbia River
Salmon



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United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-248261

July 13, 1992

The Honorable Bob Packwood
United States Senate

The Honorable Slade Gorton
United States Senate

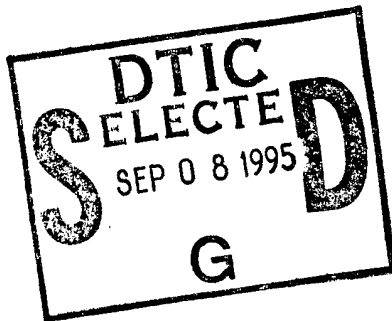
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Concerns about declining populations of certain wild salmon species led the Department of Commerce's National Marine Fisheries Service (NMFS) to list the Snake River sockeye salmon as an endangered species and certain types of Snake River chinook salmon as a threatened species under the Endangered Species Act. Your requests asked us to examine historical efforts to address declines in salmon runs. As agreed with your offices, we obtained from federal agencies and organizations in the Pacific Northwest the types of actions, and their costs, that have been taken to maintain and restore runs of salmon (both wild and hatchery-bred) on the Columbia and Snake Rivers. We also obtained the results of studies and research that have evaluated the effectiveness of the salmon recovery measures undertaken. On April 29, 1992, we briefed your offices on the results of our work. This briefing report presents the information provided at that briefing.

Separately, you also asked that we examine available assessments of the likely economic impacts of future actions being considered to protect the salmon species listed under the Endangered Species Act. We plan to report on the results of our work on this matter later this year.

In summary:

- Federal agencies and regional organizations have taken numerous actions and incurred substantial costs for more than 50 years to maintain and improve salmon runs in the Columbia River Basin.
- The cost of actions taken, as reported by federal and regional entities, is significant—since 1981 over \$1.3 billion (adjusted to 1991 dollars) has been spent. Substantial costs were also reported as being incurred prior to 1981, but because the cost data were generally not identified by the year incurred, we could not calculate total costs in 1991 dollars. (Apps. I and II provide a detailed breakdown of reported costs by organization for the post-1981 and pre-1981 time periods, respectively.)
- Actions taken have included the construction and operation of fish hatcheries; the construction of fish ladders and other facilities at



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Columbia and Snake River dams to assist salmon in their migration to and from the sea; improvements to salmon habitat; and research related to learning more about salmon or to assess and improve salmon runs.¹

- Regional efforts intensified following enactment of the Pacific Northwest Electric Power Planning and Conservation Act in 1980, which required that assistance be provided for fish and wildlife resources affected by power-generating facilities at Columbia River Basin dams.
- The effectiveness of actions taken to maintain and improve salmon runs, according to evaluations performed by a number of federal, state, and regional organizations, indicate that some actions taken have been effective in helping certain types of salmon at specific locations. But the evaluations either did not address or were inconclusive regarding the effectiveness of actions from a Columbia River Basin-wide perspective. For example:

- Hatchery operations have generally been viewed as successful by organizations in the Pacific Northwest. For example, about 250 million juvenile salmon were produced by hatcheries in 1988, compared with hatchery production of about 76 million in 1960. However, some studies have found that hatchery-produced salmon have had a negative impact on wild salmon runs. For example, in 1991 NMFS found that lower Columbia River wild coho salmon was no longer a distinct species because of interbreeding with hatchery-produced salmon.
- The effectiveness of facilities to assist salmon in their migrations has varied. For example, studies have found that the effectiveness of fish screens installed at dams to divert juvenile salmon away from electric power turbines differed by dam location and type of salmon.
- Efforts to transport juvenile salmon past dams in tank trucks or barges have worked well for some but not all salmon species. For example, transportation was more effective for steelhead trout than for spring chinook salmon.
- Similarly, studies of the effectiveness of improved salmon habitat showed varying results. For example, one study reported increased salmon density in a river basin where habitat improvements were made, while another study found that a similar habitat improvement in the same general area had not increased salmon density. (App. V lists the research studies we cite in this report.)

In conducting our review, we contacted 132 federal and state agencies, electric utilities, timber companies, Indian tribes and organizations, and

¹Appendix III presents statistics on historical salmon runs into the Columbia River from 1970 through 1990.

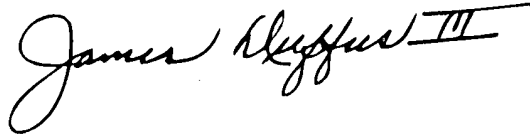
private organizations (see app. IV); we obtained costs allocated to salmon-related expenses by 22 of these entities.

As agreed with your offices, we did not obtain written comments on a draft of this briefing report from the organizations involved. We did, however, discuss the information contained in this briefing report with responsible officials of the major agencies involved, including representatives of the Office of Power Sales and the Fish and Wildlife Division of the Department of Energy's Bonneville Power Administration; U.S. Army Corps of Engineers headquarters officials, the North Pacific Division Commander and his staff, and representatives of the Portland District; the Acting Northwest Regional Director and the Division Chief, Environmental and Technical Services Division, NMFS; the Columbia River Coordinator, Department of the Interior's U.S. Fish and Wildlife Service; and the Executive Director and staff, Pacific Northwest Electric Power and Conservation Planning Council (an interstate planning agency). These officials generally agreed with the factual information presented; on the basis of their comments, we have made changes as appropriate.

Section 1 of this briefing report provides background and a discussion of the objectives, scope, and methodology of our work. Section 2 identifies actions taken to maintain and restore Columbia River Basin salmon runs, as well as the costs associated with the actions. Section 3 describes studies made and research performed to assess the effectiveness of actions taken.

Unless you publicly announce its contents earlier, we plan no distribution of this briefing report until 30 days from the date of this letter. At that time, we will make copies available to the Secretary of Commerce; the Secretary of the Interior; the Secretary of Defense; the Administrator, Bonneville Power Administration; the Chairman, Pacific Northwest Electric Power and Conservation Planning Council; and other interested parties. Copies will also be made available to others on request.

Please contact me on (202) 275-7756 if you or your staffs have any questions. Other major contributors to this briefing report are listed in appendix VI.

A handwritten signature in cursive script that reads "James Duffus III". The signature is written in black ink and is positioned above the typed name.

James Duffus III
Director, Natural Resources
Management Issues

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Abbreviations

GAO	General Accounting Office
NMFS	National Marine Fisheries Service
PUD	public utility district

Background

The Columbia River Basin, which encompasses parts of several northwestern states and southwest Canada, is habitat for four types of Pacific salmon—chinook, coho, sockeye, and chum—and for steelhead trout. The normal salmon¹ life cycle includes hatching at an upstream location within the river basin, migrating to the sea, and eventually returning as adults to the hatching location to spawn and die. Each tributary in the basin is a potential spawning location for a specific salmon “stock,” a species or subspecies affiliated with a particular spawning ground.

Pacific salmon are of significant economic and social importance to the Pacific Northwest region. Annually, large numbers of adult salmon are commercially harvested and others are caught by sport fishermen. The salmon runs are also important to various Indian tribes of the region that have traditionally depended on the salmon runs for sustenance and for economic, religious, and cultural reasons.

Historical Level of Salmon Runs Has Declined

The historical annual level of salmon runs has been estimated at 10 to 16 million salmon during the 1800s. Since that time, however, total salmon runs, including both adult salmon returning to the Columbia River Basin to spawn and those caught in the ocean, have significantly declined to an estimated 2.5 million annually. Furthermore, it is estimated that only about 500,000 of these returning adults are wild or naturally spawning fish. Wild fish are genetically unique populations of fish that have maintained reproduction successfully without supplementation from hatcheries. Natural fish are wild fish that have been genetically affected by hatchery fish.

According to representatives of regional organizations with salmon-related responsibilities, the decline in salmon runs before the 1930s resulted primarily from overfishing; subsequently, the construction of dams in the Columbia River Basin has been the primary factor in the decline in salmon runs.² Since 1933, 18 major dams have been constructed on the Columbia River and its major tributary, the Snake River.

¹In this report “salmon” includes all four types of Pacific salmon found in the Columbia River Basin, as well as steelhead trout.

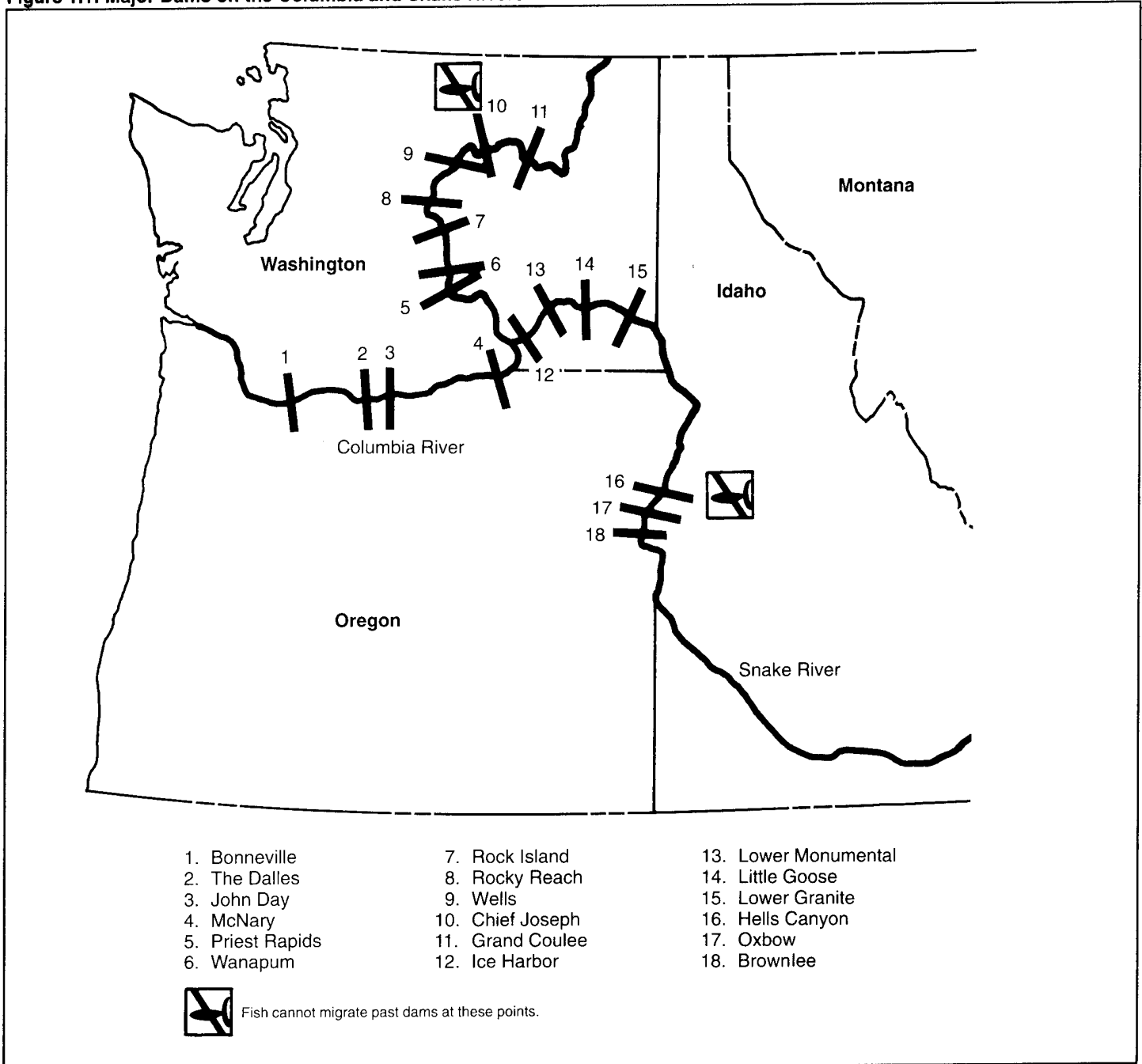
²Also contributing to diminished salmon runs are such other factors as irrigation; flood control; sea mammal predation; and poor logging, grazing, and farming practices affecting shoreline habitat and spawning beds.

Section 1
Background

The 18 major dams—constructed by the U.S. Army Corps of Engineers, the Department of the Interior's Bureau of Reclamation, and electric utilities on the Columbia and Snake Rivers—have been responsible for the majority of the salmon losses. Operational responsibility for 10 of these dams rests with the federal government; the Corps operates nine dams and Reclamation operates one. In addition, the Department of Energy's Bonneville Power Administration markets the electricity generated by the federally operated dams. The 18 dams provide a variety of benefits to the Pacific Northwest, including flood control, aids to navigation, hydroelectric power, and water for irrigation. Figure 1.1 shows the location of the major dams along the Columbia and Snake Rivers.

**Section 1
Background**

Figure 1.1: Major Dams on the Columbia and Snake Rivers



Section 1
Background

While the dams provide benefits to the Pacific Northwest, they also pose barriers to juvenile salmon as they migrate to the sea and to adult salmon as they attempt to return upstream to spawn. Recognizing the impact the dams have on annual salmon runs, agencies and organizations in the Pacific Northwest have undertaken a number of actions to reverse the declines in salmon runs. The initial construction of the dams included measures to aid the salmon, such as fish ladders to enable adult salmon to swim around the dams. Such efforts were intensified following enactment of the Pacific Northwest Electric Power Planning and Conservation Act in 1980. The act established the Pacific Northwest Electric Power and Conservation Planning Council, an interstate planning agency, and directed the Council, among other things, to develop a program for enhancing, mitigating, and protecting fish and wildlife affected by the Columbia River Basin power-generating facilities. The Council instituted its fish and wildlife program in 1982. Some salmon runs showed improvement through 1986, during good water years. However, salmon runs then declined during the remainder of the 1980s, a period when below-average rainfall in parts of the Pacific Northwest may have adversely affected salmon runs. In 1990 only 1.1 million adult salmon returned to the Columbia River Basin (excluding ocean harvest), of which about 300,000 were believed to be wild or naturally spawning salmon. (App. III presents statistics on historical salmon runs into the Columbia River from 1970 through 1990.)

The continuing decline of salmon runs has raised concern that certain stocks of wild salmon are reaching critically low levels, particularly those stocks whose spawning areas are far upstream on the Snake River.³ In response to a petition from Oregon Trout, a public interest group, and others, the Department of Commerce's National Marine Fisheries Service (NMFS) listed, in May 1992, the Snake River fall chinook and spring/summer chinook as threatened species under the Endangered Species Act. In addition, in November 1991, in response to a petition from the Shoshone-Bannock Indian tribe, NMFS listed the Snake River sockeye salmon as an endangered species.⁴

³Fisheries experts believe that wild salmon provide the genetic diversity necessary for maintaining salmon runs in the Columbia River Basin and that loss of genetic diversity may lead to a reduction in overall production and greater vulnerability of salmon to environmental change and disease.

⁴An endangered species is any species at risk of extinction in all or a significant portion of its range, whereas a threatened species is one that is likely to become endangered in the foreseeable future in all or a significant portion of its range.

As of June 1992 NMFS was in the process of designating habitat that is critical to the survival of these threatened and endangered Snake River species, and also developing recovery plans.

Objectives, Scope, and Methodology

In response to separate requests received from Senators Bob Packwood and Slade Gorton, this report presents information on (1) the costs and types of past actions taken in the Pacific Northwest to maintain and restore salmon runs on the Columbia and Snake Rivers and (2) the results of studies and research related to the effectiveness of actions taken. In a subsequent effort, also at the Senators' request, we plan to (1) identify what further actions are being considered to protect salmon listed as threatened or endangered under the Endangered Species Act and (2) assess any analyses that have been made to estimate the potential economic impact on the region of such further actions.

To determine the costs and types of past actions taken to maintain and restore salmon runs, we contacted 132 government agencies and other organizations, requesting annual expenditures for salmon-related activities. (See app. IV.) These agencies and organizations included the following:

- Federal agencies responsible for (1) managing salmon stocks, spawning areas, and migratory routes; (2) operating the dams on the Columbia and Snake Rivers; and (3) marketing electric power from the dams.
- State fish and wildlife agencies.
- Public and private electric utilities.
- Indian tribes and tribal organizations.
- Major timber companies.
- Environmental groups.

We selected these agencies and organizations because of their known or potential involvement in efforts to maintain or restore salmon runs.

As a result of our inquiry, we received information on actions taken by 22 agencies and organizations and estimates of the associated costs of these actions.⁵ The remaining agencies and organizations (1) reported that they had made no expenditures, (2) provided data not specific enough for our use, or (3) did not comply with our request. On the basis of the

⁵We originally asked for all salmon-related expenditures, by year, back to the year such expenditures started. However, as noted in appendixes I and II, several agencies' records limited the data that could be supplied.

Section 1
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information provided, we categorized the types of actions taken and their costs into the following four areas:

- Fish hatchery construction and operation.
- Actions taken to assist salmon in migrating upstream and downstream around the dams (fish passage).
- Improvements in salmon habitat.
- General research.

Cost information provided included costs directly associated with actions benefiting salmon; opportunity costs reflecting estimates of potential electric power revenues lost because specific amounts of water had been set aside to benefit salmon during their downstream migration rather than being used to generate electric power; and, in some instances, costs that were not exclusively for the benefit of salmon. We did not include the latter costs in our calculation of total costs incurred for the benefit of salmon.⁶ In addition, we did not independently verify agencies' reported costs for salmon-related activities.

We adjusted to 1991 dollars the cost information provided for the period from 1981 through 1991 because we were able to determine costs incurred by year. However, a significant amount of historical costs reported by the Corps of Engineers and several electric utilities were incurred prior to 1981. Because we could not readily determine the years in which such costs were incurred, we could not adjust these reported costs to 1991 dollars; thus, pre-1981 costs were not included in our overall cost calculations.

To obtain information on the results of studies and research related to the effectiveness of actions taken to aid the salmon, we contacted the same 132 organizations. These organizations identified hundreds of reports and studies. We obtained copies or summaries of most of these studies and analyzed each one to determine whether it

- was related to a specific action to benefit salmon and, if so, the specific action involved and
- reached conclusions or made recommendations for improving the actions.

⁶We did not count reported expenditures of about \$77 million by Public Utility District #2 of Grant County, Washington, and \$482,537 by the state of Idaho since they were not identifiable as related to specific salmon protection measures. In addition, the Pacific Northwest Electric Power and Conservation Planning Council reported no direct salmon protection costs. While the Council has fish and wildlife protection responsibilities, neither the Council nor Bonneville Power Administration, which funds the Council, were able to report what portion of the Council's budget was directly attributable to salmon protection.

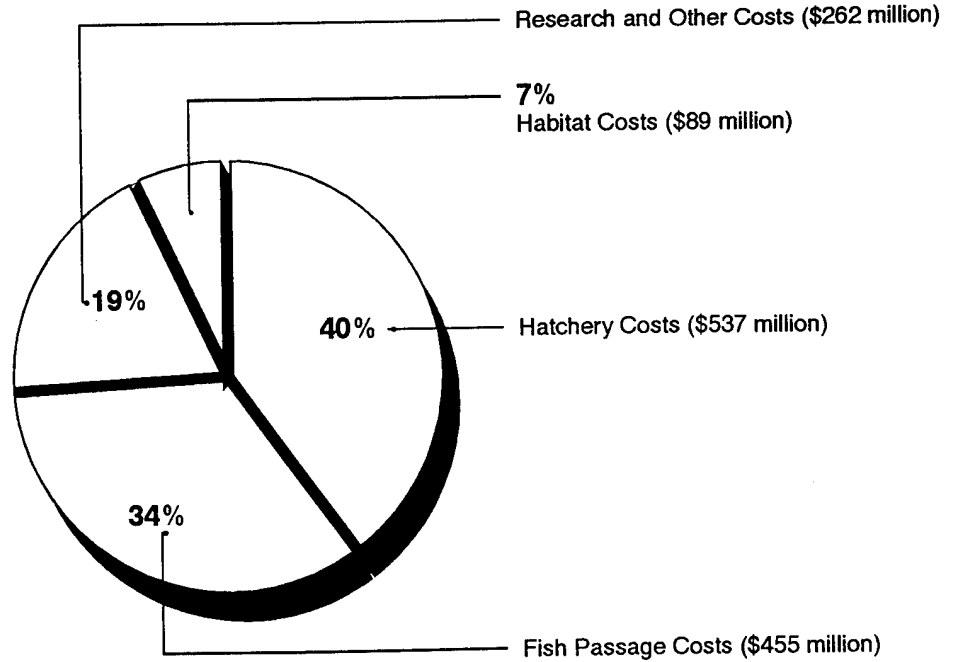
Section 1
Background

Our work was performed in accordance with generally accepted government auditing standards. As agreed with the requesters, we did not obtain written comments on a draft of this report from the agencies we contacted. However, we discussed the information in this briefing report with responsible officials from the major agencies involved, including representatives of the Office of Power Sales and the Fish and Wildlife Division, Bonneville Power Administration; U.S. Army Corps of Engineers headquarters officials, the North Pacific Division Commander and his staff, and representatives of the Portland District; the Acting Northwest Regional Director and the Division Chief, Environmental and Technical Services Division, NMFS; the Columbia River Coordinator, Department of the Interior's U.S. Fish and Wildlife Service; and the Executive Director and staff, Pacific Northwest Electric Power and Conservation Planning Council. These officials generally agreed with the factual information presented; on the basis of their comments, we have made changes as appropriate.

Types and Costs of Actions Taken to Benefit Salmon Runs

- Actions taken by federal agencies and other organizations to benefit salmon runs in the Pacific Northwest included the construction and operation of fish hatcheries; the installation of fish passage facilities and other measures, primarily at dam site locations, to assist salmon migration; improvement of fish habitat; and research.
- Figure 2.1 shows the costs incurred (in 1991 dollars) for actions taken since 1981 following enactment of the Pacific Northwest Electric Power Planning and Conservation Act. As shown, the largest costs are associated with fish passage measures and hatcheries, accounting for about 74 percent of the costs reported to us by 21 federal agencies and regional organizations.

Figure 2.1: Categories of Costs Incurred to Benefit Salmon Between 1981 and 1991

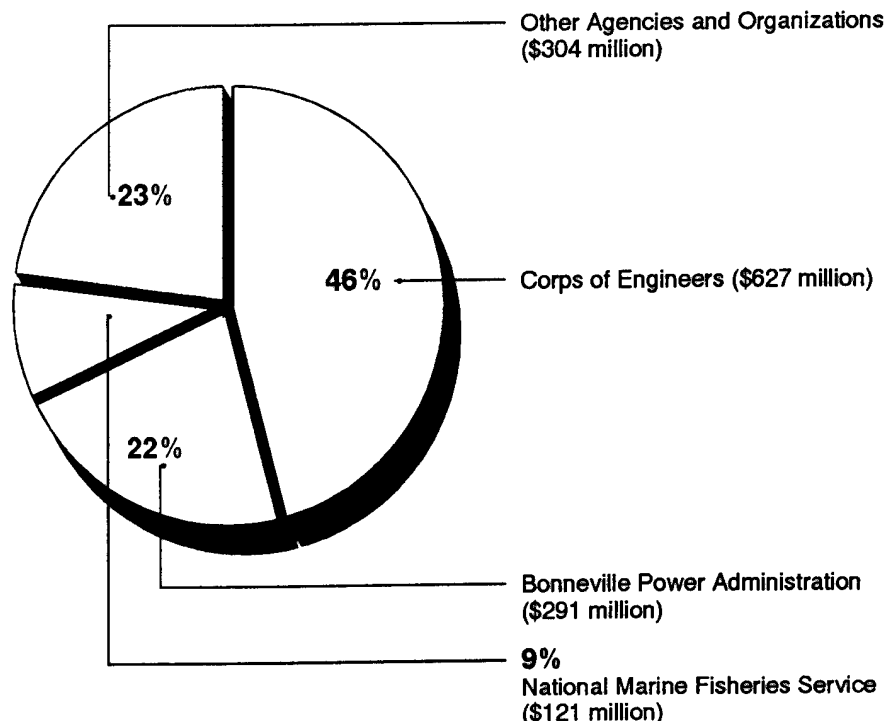


Note: Total, \$1,343 million.

- The Corps of Engineers and the Bonneville Power Administration reported the largest costs incurred since 1981. As shown in figure 2.2, these two agencies accounted for 68 percent of the reported costs. (App. I contains a more detailed breakdown of the reported costs by organization.)

Section 2
Types and Costs of Actions Taken to Benefit
Salmon Runs

Figure 2.2: Entities Incurring Costs to Benefit Salmon Between 1981 and 1991



Note: Total, \$1.343 million.

- In addition to the costs shown in Figure 2.2, Bonneville Power Administration and three public utilities reported estimates of electric power revenues not obtained totaling \$487 million between 1977 and 1991 because water from reservoirs behind dams was used to aid in salmon migration rather than produce electricity.¹ Bonneville reported an estimated \$423 million in electric power revenues foregone—almost 87 percent of the \$487 million reported. However, Bonneville also noted that these costs were derived annually using differing methodologies and that the estimates had a high degree of uncertainty associated with a large number of power-marketing assumptions.
- Agencies and organizations also reported a significant amount of pre-1981 expenditures for actions to benefit salmon. Pre-1981 costs reported primarily represented actions taken by the Corps of Engineers, NMFS, and several electric utilities to install fish passage facilities at dams to assist

¹These estimates of electric power revenue foregone have not been adjusted to constant dollars.

salmon in their migration from the sea, and to construct and operate fish hatcheries. (Pre-1981 actions to assist salmon and the reported costs of these actions are included in app. II.)

- The salmon protection costs reported by Bonneville as well as about 90 percent of those reported by the Corps, according to these agencies, are ultimately funded by regional electricity ratepayers through their electric bills. To date, these costs have resulted in a 1 percent to 2 percent increase in retail electric rates, according to Pacific Northwest Electric Power and Conservation Planning Council officials. Regional electric ratepayers also fund through their electric bills the salmon mitigation measures reported by nine public and private utilities.

Fish Hatcheries

Fourteen agencies and organizations reported about \$537 million in salmon hatchery-related costs since 1981. Salmon hatcheries are located throughout the Columbia River Basin and are designed to maintain or increase runs of returning adult salmon by replacing the juvenile salmon that initially migrate downstream. According to a University of Washington School of Fisheries draft report, hatcheries have released about 1.7 billion juvenile salmon since 1980.

The hatchery-produced salmon mitigate the loss of salmon during dam passage, help offset the loss of spawning areas which are upstream from dams that do not provide any type of salmon passage, and offset the loss of spawning areas flooded by the reservoirs created behind the dams. Hatchery-produced salmon also offset salmon losses that are estimated to occur at dams with salmon passage facilities. These losses occur because juvenile salmon traveling downstream can be killed as they pass through the turbines of hydroelectric generators or can become easy targets for predators in slow-moving reservoirs immediately behind the dams. Finally, hatchery-produced salmon serve to maintain the levels of commercial harvesting of adult salmon.

While hatcheries have served to offset salmon losses, concerns have been raised about their detrimental effects on wild salmon stocks. For example, the Pacific Northwest Electric Power and Conservation Planning Council found that young hatchery-produced fish may compete with naturally produced juveniles for food and habitat and that hatchery-bred adult salmon may interbreed with wild salmon, altering wild salmon gene pools. The Council has concluded that artificial production facility operations need to be improved through hatchery operating policies that not only

minimize the negative impacts of hatcheries on wild and naturally spawning stocks, but also improve the quality of the hatchery fish.

Fish Passage Activities

Thirteen agencies and organizations reported costs totaling about \$455 million since 1981 for actions taken to assist salmon migrating downstream and upstream. Specific actions taken to assist the downstream migration of juvenile salmon include the following:

- Bypass screens are installed at dam sites to divert juvenile salmon away from a dam's hydroelectric turbines and into special conduits that allow them to reenter the river below the dam. In some cases, the conduits are used to collect the juveniles for loading into trucks or special barges, which then proceed downriver and discharge the juveniles back into the Columbia River below Bonneville Dam, the last dam before the river enters the Pacific Ocean.
- Predator control entails reducing the number of predatory fish in the river that feed on juvenile salmon, most notably the squawfish, which congregates around dams and has been identified as a major predator of juvenile salmon.
- Irrigation screening uses screens or other devices to divert juvenile salmon from irrigation canals as part of withdrawals of water for irrigation.
- "Spill" and "water budget" are terms applied to water used to assist the migrating salmon. Spill represents water released through the spillway of a dam rather than through the turbines that generate electricity. The water budget represents an amount of water used annually in the Council's fish and wildlife program for release from upriver reservoirs to restore a portion of the natural Columbia and Snake River flows. This is done primarily to reduce the juveniles' travel time through the eight Lower Columbia and Snake River reservoirs to the ocean. The water budget also represents a loss of potential hydroelectric power revenue because the water is released downstream when the juveniles need it—usually in the spring—rather than being stored in an upriver reservoir until the power that it will produce is needed the most, such as during the winter to heat homes in the Pacific Northwest. Four organizations reported that they had foregone electric power revenue in order to provide water to aid in salmon migration. The organizations estimated the cumulative value of revenue foregone at about \$487 million since 1977, when they first reported spill costs.

Fish passage actions taken to assist adult salmon returning upstream to spawn include the construction of fish ladders at most Columbia River

dam sites. Fish ladders are ascending series of steps that allow returning adults to swim around dams that would otherwise block their migration upstream.

Habitat Protection and Restoration

Eleven agencies and organizations reported costs totaling about \$89 million since 1981 for actions taken to restore and protect the habitat in which salmon reside. The Department of Agriculture's U.S. Forest Service, with expenditures of about \$35 million, and the Bonneville Power Administration, with expenditures of about \$32 million, reported the largest costs for habitat-related actions. Some of these expenditures are required as part of other planned government actions, such as timber sales. Some environmental groups stated that they had made significant habitat improvements with nonmonetary contributions, such as volunteer labor.

The types of habitat improvement actions reported included efforts to (1) prevent streambank erosion by installing rocks and planting vegetation along streambanks, (2) enhance spawning areas by installing gravel needed for spawning beds, and (3) improve water quality.

Research and Studies

Nine organizations reported costs of about \$262 million since 1981 for research and other activities, such as monitoring and evaluating prior mitigation efforts involving Columbia River Basin salmon stocks. Research and studies performed were undertaken to learn more about the conditions and needs of salmon populations or to assess and improve mitigation efforts. Bonneville Power Administration and the Corps accounted for about 81 percent of these costs, or about \$213 million.

Effectiveness of Actions Taken to Assist Salmon Populations

- Agencies and organizations reported a wide range of studies that have evaluated the effectiveness of actions taken to protect and enhance salmon runs in the Columbia River Basin.
- Studies generally focused on the effectiveness of a specific action taken at a specific location (such as a dam site) and thus did not address the overall effectiveness of specific actions (such as fish screens) throughout the Columbia River Basin.
- Many of the studies made recommendations to enhance the effectiveness of specific actions at particular dams. For example, a 1990 study of fish screens at Bonneville Dam's second powerhouse found that previously recommended screen modifications increased by 55 percent the number of spring chinook being guided into the bypass. (App. V lists the research studies we have cited in the discussion that follows.)

Hatcheries

Hatcheries in the Columbia River Basin have provided mitigation for federal water projects by producing and introducing large numbers of juvenile fish. According to the Pacific Northwest Electric Power and Conservation Planning Council, high reliance has been placed on producing hatchery salmon stocks to maintain salmon runs in the basin. Until recently, hatchery operations have been considered successful in that overall hatchery production of salmon has increased from about 76 million juveniles released from hatcheries in 1960 to about 250 million salmon released in 1988.

While overall hatchery production has maintained some salmon runs, some evidence indicates that hatchery-produced salmon have had a negative impact on wild salmon runs. For example:

- Biologists have reported that increasing production of hatchery salmon has contributed to higher commercial and sport harvest levels, which have resulted in the overharvest of certain wild salmon runs.
- NMFS found in 1991 that it was unable to identify the lower Columbia River wild coho salmon as a genetically distinct species because hatchery-produced salmon were introduced into and spawned in the wild coho salmon spawning areas.
- A 1990 U.S. Fish and Wildlife Service study examined the use of hatchery-produced salmon to supplement wild salmon runs.¹ Based on a review of 316 projects to supplement wild salmon runs, the study found that many of the projects were successful in providing additional salmon

¹Supplementation involves placing hatchery fish in streams so that they return as adults to spawn in the natural environment rather than returning to the hatchery.

for commercial and sport harvest, but that only 25 projects were successful in increasing the numbers of fish in natural, existing runs.

In light of the results of studies assessing the impact of hatchery-produced salmon on wild salmon runs, the Pacific Northwest Electric Power and Conservation Planning Council amended its Fish and Wildlife Program in 1991 to include (1) the development of hatchery performance standards to maintain the genetic integrity of wild salmon and (2) ongoing audits of hatchery operations.

Fish Passage

Organizations reported a range of studies addressing the effectiveness of fish passage actions, including bypass screens, transporting salmon around dams, predator control, irrigation screening, spill and water budget, and upstream adult passage. Many of these studies were directed at evaluating actions to assist juvenile or adult fish at a particular dam location.

Bypass Screens

As we noted in an earlier report on fish bypass actions,² evaluations of bypass screens are inconclusive as to whether screens have a significant effect in raising the survival rate of juvenile fish migrating downstream and thus increasing the number of returning adults.

A number of specific studies examined the extent to which bypass screens guide juvenile salmon into bypass conduits at specific dams; others compared the effectiveness of bypass screens with alternative means for assisting salmon around dams. For example:

- A 1990 NMFS study of fish screens at the Bonneville Dam's second powerhouse found that structural modifications to screens, which were made on the basis of previous studies, increased from 19 percent to 74 percent the proportion of hatchery-produced juvenile spring chinook being guided by the screens into the bypass conduits. However, the study also found that the passage rate for hatchery-produced juvenile summer chinook was only 25 percent, far below the Council's fish screen effectiveness criterion of 50 percent for summer fish.
- NMFS studies at Lower Granite Dam and at Bonneville Dam's second powerhouse assessed alternative means for juvenile salmon to negotiate these dams. The study at Lower Granite Dam indicated a lower survival

²Hydroelectric Dams: Issues Surrounding Columbia River Basin Juvenile Fish Bypasses (GAO/RCED-90-180, Sept. 6, 1990).

rate for hatchery-raised spring chinook juveniles using the bypass screen and bypass conduit than for juveniles using other means to get by the dam, such as over the spillway or through the turbines.

- The study at Bonneville Dam showed that in 1987, 1988, and 1989, hatchery-raised upriver bright fall chinook passing through the turbines had a higher survival rate than those using the bypass screen and bypass conduit. The 1990 study detected no statistically significant differences in relative survival between juveniles using the bypass screen and bypass conduit and those going through the turbines. An assessment of the data for all 4 years showed a statistically significant higher survival rate for juveniles going through the turbines than for those using the bypass screens. The study speculated that predation by the northern squawfish in the locality of the bypass outlets may be causing this diminished survival.

Transporting Salmon by Trucks and Barges

Study results show that using the bypass screens to divert juvenile salmon into tank trucks or barges for transportation around the downstream dams works very well for some, but not all, salmon species. For example:

- A 1986 NMFS study concluded that, on the basis of returns of adult fall chinook salmon previously marked and transported from McNary Dam as juveniles, transporting fall chinook provided vastly enhanced survival. A 1985 Corps study showed similar success when steelhead were transported.
- A 1985 Corps comprehensive summary of previous studies assessing the transportation of hatchery-raised spring chinook was inconclusive regarding the success of transporting this type of salmon. According to the summary, transportation resulted in a statistically significant increase in adult spring chinook returns in only 8 of 18 tests. In eight other tests, the differences in success between transported and nontransported juveniles were not statistically significant. In one test, nontransported spring chinook juveniles returned at a statistically significant higher rate than did transported fish. In the remaining test, no adults returned from either the transported or nontransported groups.

Predator Control

Studies assessing predator control actions focused primarily on efforts to control the squawfish that feed on juvenile salmon. For example, a 1990 U.S. Fish and Wildlife Service study, covering 1983 to 1986 data, found that juvenile salmon losses to predator fish may account for the majority of previously unexplained losses in the reservoir behind the John Day Dam. A 1984 Fish and Wildlife Service study stated that predation might be

reduced by releasing juvenile salmon at night, since predator fish are more active during the day. The study also stated that netting and trapping predator fish are good control measures, although research needs to be conducted to determine whether these methods have any long-term effect on predator populations.

While most research has focused on juvenile salmon predation, sea lions may be an increasing threat to returning adult salmon. In 1990 NMFS noted an unusually high occurrence (an estimated 40 percent to 50 percent) at Lower Granite Dam of returning adult spring chinook salmon that had teeth marks caused by marine mammal attacks, probably sea lions. Where the attacks took place or how many fish were killed prior to arrival at Lower Granite Dam was not known. However, according to NMFS, continuation of this problem could further jeopardize this seriously depressed salmon population.

Irrigation Screening

Some studies assessed the effectiveness of irrigation screens, which are used to divert juvenile salmon from the irrigation canals. For example:

- A 1990 study, prepared for Interior's Bureau of Reclamation, of four screening facilities that had been installed along the Yakima River found that the screens were 89 percent to 95 percent effective in recovering juvenile salmon that had entered irrigation canals.
- A 1988 study, prepared for the Bureau of Reclamation showed that the effectiveness of irrigation screens varied by the type of salmon. Screens were 96 percent to 97 percent effective for spring chinook, 84 percent for fall chinook, and 76 percent for steelhead.

Spill

Some studies were completed to provide data for improving the effectiveness of spills at specific dams and also to identify ways to increase the survival rates for juveniles spilled over the dams. For example:

- A 1990 NMFS study collected data on the numbers and timing of juvenile salmon going past three dams on the Columbia River (Bonneville, The Dalles, and John Day). The data from the study were used in 1990 to decide when to spill water through the dams, and how much to spill, to facilitate juvenile salmon passage.
- A 1979 NMFS study examined ways to control nitrogen supersaturation, which can occur when water plunges over spillways at dams and results in

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Effectiveness of Actions Taken to Assist
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gas-bubble disease in salmon. The study concluded that spillway deflectors were the most effective means of controlling supersaturation and reducing fish mortality. According to Corps officials, five of the eight Lower Snake and Columbia River dams have deflectors on most of their spillways. However, the effectiveness of the deflectors is reduced at higher levels of spill. Current estimates of spillway survival rates range from 97 percent at Lower Monumental Dam to 87 percent at Bonneville Dam.

Water Budget

Regional agencies and organizations did not identify any completed studies on the effectiveness of water budgets in assisting juvenile salmon in their migration to the sea. Consequently, there has been considerable debate in the region over the effectiveness of this program. The U.S. Fish and Wildlife Service, however, reported an ongoing study that is evaluating the effect of the water budget on juvenile salmon with regard to the amount of time the water takes to travel down river. Results of this study are not yet available.

Upstream Passage by Adult
Fish

Studies have examined the effectiveness of adult upstream passage of dams as well as how existing passage conditions might be improved. For example:

- NMFS compared counts of spring/summer chinook from the dam farthest downstream to the dam farthest upstream and reported that the overall adult passage loss from 1979 to 1989 was 35 percent; thus, 65 percent of adults were successfully passing the dams.
- A Washington Department of Fisheries study examined the extent to which adult salmon successfully traversing McNary Dam were falling back to the other side of the dam through the turbines. The study found that a significant number of steelhead were falling back into the turbines after traversing the dam during the month that bypass screens were usually removed for maintenance. The study recommended that the screens be left in place until later in the year.
- A 1988 Corps study recommended improvements at the Little Goose, Lower Monumental, and McNary Dams to ensure that fish ladders were receiving adequate water to accomplish their purpose.

Habitat Improvement
Research

Habitat-related studies and research have identified the types of actions taken to improve salmon habitat and, in some cases, evaluated the effectiveness of a particular habitat improvement after it was

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implemented. Studies showed that the effectiveness of habitat improvements varied. For example, a Forest Service multiyear study published in 1991 evaluated a project designed to improve salmon habitat in the Clearwater River Basin in Idaho by, for example, removing barriers to upstream salmon passage. The study concluded that the improvements led to a statistically significant increase in salmon density in areas where habitat had been enhanced, compared to control habitats that had not been enhanced. On the other hand, a 1991 state of Idaho study found that other similar habitat improvement projects in the same general area had not increased salmon density. However, NMFS officials cautioned that the increased salmon density in the Forest Service study may have resulted from hatchery supplementation rather than the habitat improvements.

Other Research

A number of studies and research related to Columbia River Basin salmon have addressed a variety of subjects, most notably efforts to improve fish health. For example, a 1989 Oregon Department of Fish and Wildlife report, discussing the results of an 8-year study, led to the development of improved food for fish at hatcheries. The study showed that the improved food increased the survival rate for coho salmon.

Salmon Protection Costs Reported to GAO, 1981-91

Dollars in millions

Reporting entity	Categories of costs incurred (costs reported have been adjusted to 1991 dollars)				Total
	Hatcheries	Passage	Habitat	Research	
Corps of Engineers ^a	\$258.99	\$298.59	\$0.0	\$ 69.10	\$626.68
Bonneville Power Admin. ^{b,c}	79.00	36.41	31.62	144.29	291.32
National Marine Fisheries Service ^d	106.64	4.48	0.0	10.22	121.34
Bureau of Reclamation ^e	0.0	55.11	8.08	0.0	63.19
Fish and Wildlife Service ^f	35.77	1.30	1.67	10.00	48.74
Forest Service ^g	0.0	0.0	35.07	11.87	46.94
Bureau of Indian Affairs ^h	4.37	2.96	1.14	1.83	10.30
Bureau of Land Management ⁱ	0.0	0.01	0.15	0.0	0.16
Soil Conservation Service ^j	0.0	0.0	0.02	0.0	0.02
State of Washington	1.75	3.45	2.67	0.0	7.87
PUD #1 of Douglas Co., Washington ^{c,k}	4.95	28.92	0.0	0.0	33.87
PUD #1 of Chelan Co., Washington ^{c,l}	13.46	9.35	0.0	7.00	29.81
PUD of Grant Co., Washington ^{c,m}	7.56	13.88	0.0	6.66	28.10
Idaho Power ⁿ	9.79	0.0	0.0	0.0	9.79
Portland General Electric ^o	5.10	0.13	0.0	1.34	6.57
Tacoma City Light ^p	6.27	0.0	0.0	0.0	6.27
PACIFICORP ^q	3.10	0.0	0.0	0.0	3.10
Cowlitz PUD ^r	0.38	0.0	0.0	0.0	0.38
Clark Public Utilities	0.0	0.03	0.02	0.0	0.05
Boise Cascade Corp. ^s	0.0	0.0	8.80	0.0	8.80
Idaho Rivers United	0.0	0.0	0.01	0.0	0.01
Total	\$537.13	\$454.62	\$89.25	\$262.31	\$1,343.31

^aTotal costs reported by the Corps include estimated capital costs for salmon protection at Corps facilities in the Columbia River Basin, operation and maintenance costs for these facilities, and the costs of the Corps' Fish Passage Development and Evaluation Program.

^bTotal costs reported by Bonneville are based on obligations for those portions of its fish and wildlife program that are specifically directed at salmon protection, and funding for hatcheries in the Columbia River Basin that are operated by other agencies.

^cThese organizations also reported electric power revenue foregone in order to provide water to aid in salmon migration.

^dTotal costs reported by the National Marine Fisheries Service include costs incurred under its Columbia River Fisheries Development Program and costs for providing liaison and technical expertise on fish passage to other agencies.

^eCosts reported by the Bureau of Reclamation include construction, operation, and maintenance costs reported by the Bureau's Northwest Regional Office from 1985 through 1991.

Appendix I
Salmon Protection Costs Reported to GAO,
1981-91

¹Total costs reported by the Fish and Wildlife Service include resource management funding for the Service's Region 1, fish passage costs of the office of the Columbia River coordinator, and administrative costs incurred as a result of the Service's responsibilities under the Pacific Salmon Treaty.

²Costs reported by the Forest Service include anadromous fish habitat costs incurred between 1988 and 1991, including expenditures made from Knutson-Vandenberg funds; and estimates of expenditures for salmon research performed by the Service's Pacific Northwest and Intermountain Research Stations between 1985 and 1991. The Forest Service acknowledged that its land management and timber sale administration costs have increased as a result of salmon protection measures and that timber sale revenues had been reduced due to foregone timber sales, but the Service was unable to provide an estimate of these costs.

³Costs reported by the Department of the Interior's Bureau of Indian Affairs include expenditures, for 1989 through 1991, by the Bureau's Portland Area Office for salmon protection under Indian self-determination contracts and to meet regulatory requirements.

⁴Total costs reported by the Department of the Interior's Bureau of Land Management include expenditures made by the Bureau's Idaho State Office. Costs reported for the Oregon State Office, while of benefit to salmon stocks, were excluded since they were not incurred specifically for salmon protection purposes.

⁵Costs reported by the Department of Agriculture's Soil Conservation Service include expenditures incurred by the Service's Oregon State Office. Costs reported for the Washington and Idaho State Offices, while of benefit to salmon stocks, were excluded since they were not incurred specifically for salmon protection purposes.

⁶Total costs reported by PUD #1 of Douglas County include salmon hatchery operations and maintenance and fisheries studies.

⁷Total costs reported by PUD #1 of Chelan County include fisheries studies and associated costs incurred for two dams operated by Chelan and costs for adult fishways and hatcheries.

⁸Total costs reported by the PUD of Grant County include costs incurred for development of fish bypass systems, fish studies, construction of adult fishways, hatcheries, and monitoring.

⁹Total costs reported for Idaho Power include hatchery costs incurred by Idaho Power but reported to us by the state of Idaho.

¹⁰Total costs reported by Portland General Electric include capital costs for fishways at dams operated by the company, salmon hatchery costs, and expenditures for fisheries staff.

¹¹Costs reported for Tacoma City Light include hatchery costs incurred by Tacoma City Light but reported to us by the state of Washington.

¹²Costs reported for PACIFICORP include hatchery costs incurred by PACIFICORP but reported to us by the state of Washington.

¹³Costs reported for Cowlitz PUD include hatchery costs incurred by Cowlitz but reported to us by the state of Washington.

¹⁴Boise Cascade also estimated that it forgoes \$100,000 in revenue annually because of actions it takes to restrict timber harvesting and grazing in riparian areas.

Salmon Protection Costs Reported to GAO Prior to 1981 or in Indeterminate Years^a

Millions of nominal dollars

Reporting entity	Categories of costs incurred				Total
	Hatcheries	Passage	Habitat	Research	
Corps of Engineers ^b	\$ 84.31	\$101.72	\$0.0	\$ 78.17	\$264.20
National Marine Fisheries Service ^c	105.55	0.0	0.0	7.72	113.27
Bonneville Power Admin. ^{d,e}	0.0	0.0	0.0	2.36	2.36
Fish and Wildlife Service ^f	1.71	0.0	0.01	0.32	2.04
Bureau of Land Management ^g	0.0	0.03	0.01	0.0	0.04
State of Washington	0.0	0.49	0.31	0.0	0.80
PUD of Grant Co., Washington ^h	9.70	42.52	0.0	6.09	58.31
PUD #1 of Chelan Co., Washington ^{h,i}	2.88	30.90	0.0	0.83	34.61
Portland General Electric ^j	2.82	2.60	0.0	2.60	8.02
PUD #1 of Douglas Co., Washington ^{h,k}	0.80	5.18	0.0	0.0	5.98
Idaho Power ^l	4.06	0.0	0.0	0.0	4.06
Shoshone- Bannock Tribes	0.0	0.0	0.30	0.0	0.30
Boise Cascade Corp. ^m	0.02	0.0	0.04	0.0	0.06
Total	\$211.85	\$183.44	\$0.67	\$98.09	\$494.05

^aFive organizations reported a total of \$43.3 million in costs not readily allocable to either before 1981 or after 1980.

^bCosts reported by the Corps include estimated capital costs for salmon protection at Corps facilities in the Columbia River Basin and the costs of the Corps' Fish Passage Development and Evaluation Program. Operation and maintenance costs were not available.

^cCosts reported by the National Marine Fisheries Service include costs incurred under its Columbia River Fisheries Development Program from 1949 to 1980.

^dTotal costs reported by Bonneville are based on obligations for those portions of its fish and wildlife program that are specifically directed at salmon protection, and funding for hatcheries in the Columbia River Basin that are operated by other agencies.

^eThese organizations also reported electric power revenue foregone in order to provide water to aid in salmon migration.

^fCosts reported by the Fish and Wildlife Service cover 1980, including resource management funding for the Service's Region 1.

^gCosts reported by the Bureau of Land Management were not readily allocable to either before 1981 or after 1980 and represent expenditures made by the Bureau's Idaho State Office. Costs reported for the Oregon State Office, while of benefit to salmon stocks, were excluded since they were not incurred specifically for salmon protection purposes.

^hCosts reported by the PUD of Grant County include costs incurred between 1959 and 1980 and development of fish bypass systems, fish studies, construction of adult fishways, hatcheries, and monitoring. Also included is \$21.11 million in costs not readily allocable to either before 1981 or after 1980.

Appendix II
Salmon Protection Costs Reported to GAO
Prior to 1981 or in Indeterminate Years^a

^bCosts reported by PUD #1 of Chelan County include fisheries studies and associated costs incurred between 1976 and 1980 for two dams operated by Chelan and costs for adult fishways and hatcheries. Also included is \$20.06 million in costs not readily allocable to either before 1981 or after 1980.

^cCosts reported by Portland General Electric include capital costs for fishways at dams operated by the company, salmon hatchery costs, and expenditures for fisheries staff, covering 1970 through 1980. Also included is \$2.05 million in costs not readily allocable to either before 1981 or after 1980.

^dCosts reported by PUD #1 of Douglas County cover the period from 1977 through 1980 and include salmon hatchery operations and maintenance and fisheries studies.

^eCosts reported for Idaho Power include hatchery costs incurred by Idaho Power but reported to us by the state of Idaho.

^fCosts reported by Boise Cascade include \$39,500 not readily allocable to either before 1981 or after 1980. Boise Cascade also estimated that it forgoes \$100,000 in revenue annually because of actions it takes to restrict timber harvesting and grazing in riparian areas.

Historical Salmon Runs Into the Columbia River

Thousands of adult fish

Year	Type of salmon				Total
	Chinook	Sockeye	Coho	Steelhead	
1970	799	95	873	291	2,059
1971	748	151	528	418	1,844
1972	694	123	269	371	1,457
1973	869	61	284	308	1,522
1974	578	44	448	247	1,316
1975	717	58	283	167	1,225
1976	655	44	326	203	1,228
1977	663	100	88	351	1,202
1978	643	18	298	232	1,191
1979	481	53	264	261	1,058
1980	473	59	289	258	1,079
1981	459	56	163	285	962
1982	565	50	436	254	1,304
1983	405	101	95	308	908
1984	497	162	399	483	1,540
1985	558	200	356	483	1,597
1986	737	60	1,507	559	2,863
1987	1,141	145	300	456	2,042
1988	1,060	100	653	422	2,235
1989	801	47	679	396	1,924
1990	587	50	187	297	1,121

Note: Individual salmon runs may not add to totals due to rounding.

Note: Totals do not include salmon caught in the ocean prior to returning to the Columbia River to spawn.

Source: Status Report: Columbia River Fish Runs & Fisheries, 1960-90, Oregon Department of Fish and Wildlife and Washington Department of Fisheries.

Agencies and Organizations Contacted Regarding Salmon Protection Costs

Federal Agencies

Agricultural Stabilization and Conservation Service, Department of Agriculture
Bonneville Power Administration, Department of Energy
Bureau of Indian Affairs, Department of the Interior
Bureau of Land Management, Department of the Interior
Bureau of Reclamation, Department of the Interior
Fish and Wildlife Service, Department of the Interior
Forest Service, Department of Agriculture
National Marine Fisheries Service, Department of Commerce
Soil Conservation Service, Department of Agriculture
U.S. Army Corps of Engineers
U.S. Coast Guard

State and Interstate Agencies

Alaska Department of Fish and Game
California Department of Fish and Game
Columbia Basin Fish and Wildlife Authority
Idaho Fish and Game Department
Montana Department of Fish, Wildlife, and Parks
North Pacific Fishery Management Council
Office of the Governor of Alaska
Office of the Governor of Idaho
Office of the Governor of Montana
Office of the Governor of Oregon
Office of the Governor of Washington
Oregon Department of Fish and Wildlife
Pacific Fishery Management Council
Pacific Northwest Electric Power and Conservation Planning Council
Washington Department of Fisheries
Washington Department of Wildlife

Public and Private Electric Utilities

Benton Rural Electric (Washington)
Benton County Public Utility District (PUD) (Washington)
Big Bend Electric Cooperative (Washington)
Blachley-Lane County Cooperative Electric Association (Oregon)
Blaine City Light (Washington)
Bonners Ferry Electric Department (Idaho)
Burley Municipal District (Idaho)
Canby Utility Board (Oregon)
Centralia Electric Light Department (Washington)

**Appendix IV
Agencies and Organizations Contacted
Regarding Salmon Protection Costs**

Central Lincoln PUD (Oregon)
Chelan County PUD (Washington)
City of Cheney Light Department (Washington)
Clark Public Utilities (Washington)
Clatskanie People's Utility District (Oregon)
Clearwater Power Company (Idaho)
Columbia Power Cooperative Association (Oregon)
Columbia River PUD (Oregon)
Consumers Power, Inc. (Oregon)
Cowlitz County PUD (Washington)
Douglas County PUD (Washington)
Douglas Electric Cooperative (Oregon)
Emerald PUD (Oregon)
Eugene Water and Electric Board (Oregon)
Fall River Rural Electric Cooperative (Idaho)
Ferry County PUD (Washington)
Flathead Electric Cooperative (Montana)
Forest Grove Light and Power Department (Oregon)
Franklin County PUD (Washington)
Glacier Electric Cooperative (Montana)
Grant County PUD (Washington)
Grays Harbor County PUD (Washington)
Harney Electric Cooperative (Oregon)
City of Heyburn, Idaho
Hood River Electric Cooperative (Oregon)
Idaho Falls Electric Division (Idaho)
Idaho Power Company
Inland Power and Light Company (Washington)
Kittitas County PUD (Washington)
Klickitat County PUD (Washington)
Kootenai Electric Cooperative (Idaho)
Lane Electric Cooperative (Oregon)
Lewis County PUD (Washington)
Lincoln Electric Cooperative (Washington)
Lost River Electric Cooperative (Idaho)
Lower Valley Power and Light (Wyoming)
Mason County PUD #1 (Washington)
Mason County PUD #3 (Washington)
McCleary Light and Power (Washington)
McMinnville Water and Light Department (Oregon)
Midstate Electric Cooperative (Oregon)
Milton-Freewater Light and Power (Oregon)
Missoula Electric Cooperative (Montana)

**Appendix IV
Agencies and Organizations Contacted
Regarding Salmon Protection Costs**

City of Monmouth (Oregon)
The Montana Power Company
Nespelem Valley Electric Cooperative (Washington)
Northern Lights, Inc. (Idaho)
Northern Wasco County People's Utility District (Oregon)
Okanogan County PUD (Washington)
Oregon Trail Electric Cooperative (Oregon)
Pacific County PUD #2 (Washington)
PACIFICORP (Oregon)
Pend Oreille County PUD (Washington)
Peninsula Light Company (Washington)
Port Angeles Light and Power Department (Washington)
Portland General Electric Company (Oregon)
Puget Power and Light Company (Washington)
Raft River Rural Electric Cooperative (Idaho)
Ravalli County Electric Cooperative (Montana)
Richland Energy Services Department (Washington)
Rupert Electric Department (Idaho)
Rural Electric Company (Idaho)
Salmon River Electric Cooperative (Idaho)
Springfield Utility Board (Oregon)
City of Sumas (Washington)
Tacoma Public Utilities (Washington)
Tillamook People's Utility District (Oregon)
Umatilla Electric Cooperative Association (Oregon)
Vera Water and Power (Washington)
Vigilante Electric Cooperative (Montana)
Wahkiakum County PUD (Washington)
Wasco Electric Cooperative (Oregon)
The Washington Water Power Company (Washington)

**Indian Tribes and
Tribal Organizations**

Board of Trustees of the Confederated Tribes of the Umatilla Indian
Reservation
Burns-Paiute Tribe
Coeur d'Alene Tribal Council
Columbia River Intertribal Fish Commission
Colville Business Council
Confederated Salish and Kootenai Tribal Council
Confederated Tribes of the Warm Springs Reservation of Oregon
Fort Hall Council of the Shoshone-Bannock Tribes

**Appendix IV
Agencies and Organizations Contacted
Regarding Salmon Protection Costs**

Kalispel Business Committee of the Kalispel Tribe of Indians
Kootenai Tribal Council
Nez Perce Tribal Executive Committee
Northwest Indian Fisheries Commission
Shoshone-Paiute Tribes of the Duck Valley Indian Reservation
Spokane Tribes Business Council
Upper Columbia United Tribes
Yakima Tribal Council, Confederated Tribes and Bands of the Yakima
Indian Nation

**Major Timber
Companies**

Boise Cascade Corporation
Potlatch Corporation
Weyerhaeuser Corporation

**Environmental
Organizations**

Idaho Rivers United
Oregon Trout
Trout Unlimited
West Coast Representative, Trout Unlimited

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Matthews, Gene M. and Donn L. Park, Evaluation of Transportation of Juvenile Salmonids, 1986, Seattle, WA, National Marine Fisheries Service, Jan. 1987.

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