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DISCLAIMER

BENEFITS OF FISH PASSAGE AND PROTECTION MEASURES AT HYDROELECTRIC PROJECTS

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Abstract

The U.S. Department of Energy's Hydropower Program is engaged in a multi-year study of the costs and benefits of environmental mitigation measures at nonfederal hydroelectric power plants. An initial report (Volume I) reviewed and surveyed the status of mitigation methods for fish passage, instream flows, and water quality; this paper focuses on the fish passage/protection aspects of the study. Fish ladders were found to be the most common means of passing fish upstream; elevators/lifts were less common, but their use appears to be increasing. A variety of mitigative measures is employed to prevent fish from being drawn into turbine intakes, including spill flows, narrow-mesh intake screens, angled bar racks, and light- or sound-based guidance measures. Performance monitoring and detailed, quantifiable performance criteria were frequently lacking at non-federal hydroelectric projects.

Volume II considers the benefits and costs of fish passage and protection measures, as illustrated by case studies for which performance monitoring has been conducted. The report estimates the effectiveness of particular measures, the consequent impacts on the fish populations that are being maintained or restored, and the resulting use and non-use values of the maintained or restored fish populations.

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Introduction

Hydropower projects can have serious adverse impacts on fish populations by blocking upstream movements or causing turbine-passage mortality of entrained fish. Although numerous mitigative measures are available to enhance upstream and/or downstream fish passage at hydropower projects, their costs can be very high and their effectiveness may be poorly understood. As part of its mission to promote environmentally sound hydroelectric development, the Hydropower Program of the U.S. Department of Energy (DOE) is conducting a multi-year study of environmental mitigation. The first phase of this study was an examination of mitigation practices associated with three issues: fish passage, instream flow requirements, and dissolved oxygen. This paper summarizes the findings related to fish passage (Sale et al. 1991) and subsequent efforts to estimate the benefits of fish passage mitigation.

Approach

Federal Energy Regulatory Commission (FERC) licensing records [the Hydroelectric Power Resources Assessment (HPRA) and the Hydropower Licensing Compliance Tracking System (HLCTS) data bases] were used to identify nonfederal hydroelectric projects that were required to mitigate environmental impacts related to either upstream or downstream fish passage. Because the data contained in these data bases were not sufficient to evaluate costs and benefits of site-specific mitigation practices, a major effort was made to acquire new information directly from the developers of projects for which fish passage mitigative measures were required. Developers were contacted via mailings and were asked to describe the mitigation measures that were required by their FERC licenses, the extent to which the requirements have been implemented, the amount of performance monitoring, and the success of mitigation requirements in protecting aquatic resources. We contacted 707 developers and received 280 responses, most of which indicated that no fish passage requirements had been mandated. Positive returns were representative of the geographic distribution of fish passage requirements (i.e., most returns came from the Northeast, West Coast, and the Rocky Mountain states).

In addition, state and federal resource agencies with responsibilities for recommending environmental mitigation at hydropower projects were also asked for information. Two or more agencies in each state, as well as the regional offices of the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS), were asked to provide information on fish passage issues. Agencies were asked to list projects with fish passage mitigative measures, to describe their mitigation policies and practices, and to identify any studies that could be used to quantify benefits and costs. Agencies from 34 states responded to the fish passage information requests.

Status of Fish Passage/Protection Facilities

Based on data provided by hydropower developers, upstream fish passage measures are estimated to be required at 11% of the nonfederal hydroelectric projects licensed between 1980 and 1990, whereas downstream fish passage was required at 28% of the projects. Generally, fish passage requirements are more common in the western regions of the United States than in the East. The percentage of newly issued licenses that have upstream fish passage requirements did not change significantly over the 10-year period. However, the percentage of new licenses that have downstream fish passage requirements increased from 22% in 1980-83 to 35% in the latter part of the decade (Sale et al. 1991).

Upstream Fish Passage

Most upstream passage measures can be placed into three general categories: trapping and hauling, fishways, and fish lifts. Descriptions of the basic types of upstream fish passage measures are provided in Clay (1961), Hildebrand (1980), and Orsborn (1987).

Information on 34 projects that have upstream fish passage facilities was obtained from hydropower developers. More than 90% of these facilities were either in operation or completed. Fish ladders are the most common mitigative measure, accounting for more than 70% of the upstream passage devices reported. Fish elevators and trapping and hauling are less common.

Performance objectives are essential to assessing the benefits of a fish passage facility. Fifty percent of the respondents indicated that "no obvious barriers to upstream movement" was the only criterion used to judge effectiveness (Figure 1). One facility was required to pass a specified percentage, and one facility was required to pass a specified number of migratory adults. Thirteen percent had some other performance criterion, often relating to the goals of a larger fishery restoration program. Operators of one third of the projects were unaware of any performance objective for the mitigative measure.

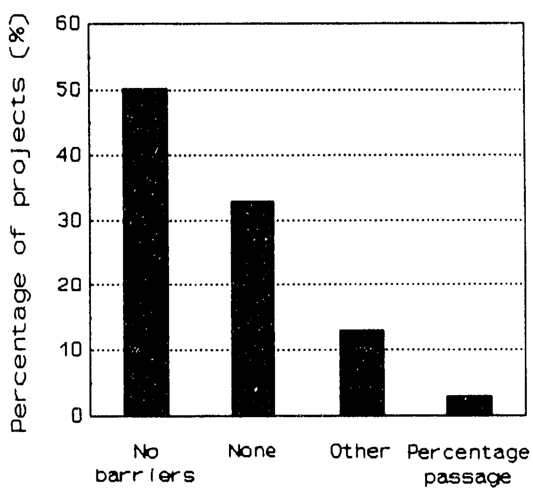

Figure 1. Performance objectives for upstream fish passage

It is important to monitor the operational performance of fish passage facilities in order to make an objective evaluation of site-specific mitigation effectiveness. Performance monitoring at nonfederal hydroelectric projects is relatively rare. Among the 30 operating projects that provided information, 17 (57%) have not monitored the performance of the upstream fish passage measure (Figure 2). Those projects that have monitored the success of upstream passage generally quantify passage rates or, less commonly, fish populations. Forty percent of operating facilities monitor fish passage rates; these are generally fishway counts that are conducted by either the licensee or a fishery resource agency. Monitoring studies that only determine the number of fish that passed through the facility provide an incomplete picture because information about the numbers of fish that did not use the facility (e.g., were unable to find the entrance to the fish ladder) is lacking. Population monitoring studies provide a longer-term view of the success of a mitigative measure because they can estimate whether the fish populations have been maintained or enhanced during the operation of the facility. Twenty three percent of the respondents monitor the fish populations that are protected by the mitigation measure.

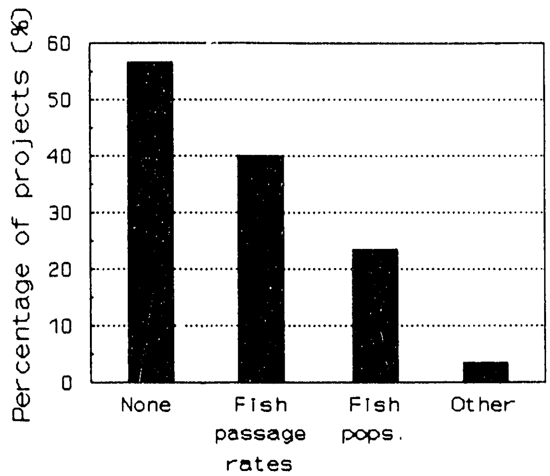

Figure 2. Performance monitoring of upstream fish passage measures

Downstream Fish Passage

Extensive reviews of downstream fish passage mitigation measures are available (Taft 1986; EPRI 1988; Bell 1991). There has been a great variety of measures utilized to reduce turbine entrainment, including spill flows, fixed screens, traveling screens, barrier nets, and sound- or light-based guidance measures. However, no single fish protection system or device is biologically effective, practical to install and operate, and widely acceptable to regulatory agencies.

Information was obtained from 85 hydroelectric projects that have downstream fish passage requirements. The required measures are in operation at 68% of the projects. The single most frequently required downstream fish passage device is the angled bar rack, which is a trash rack that has closely spaced bars (ca 2 cm) set at an angle to the intake flow. Angled bar racks are used by 38% of the projects that have downstream passage facilities and are especially common in the Northeast. Other types of fixed fish screens are found at 34% of the projects and traveling screens were installed at three of the projects (4%).

Seventy percent of the developers reported that no performance objectives had been specified for the mitigative measure (Figure 3). Four facilities (6%) were required to exclude a specified percentage of fish from entrainment, and three facilities (4%) were required to limit mortality of downstream migratory fish to a specified level. Twenty percent had some other performance objective, usually a qualitative goal such as "effective operation."

Performance monitoring for operating downstream fish passage facilities at the nonfederal projects examined in this study was rare (Figure 4). No performance monitoring was reported at 79% of the 66 projects that have operating downstream fish passage measures. Among the 14 projects that have conducted operational monitoring, 11 monitored passage rates, 10 estimated mortality rates, and 1 monitored fish populations.

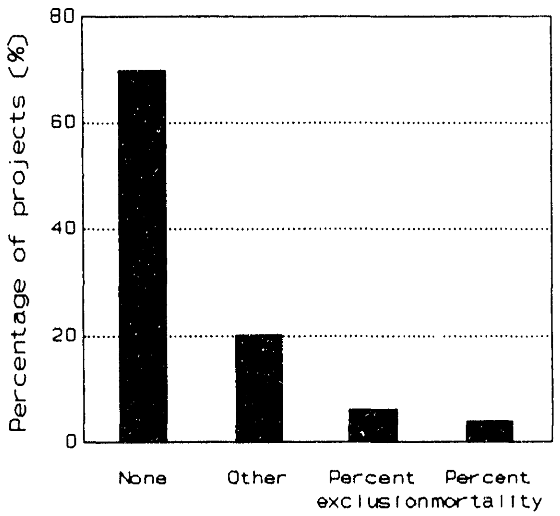

Figure 3. Performance objectives for downstream fish passage measures

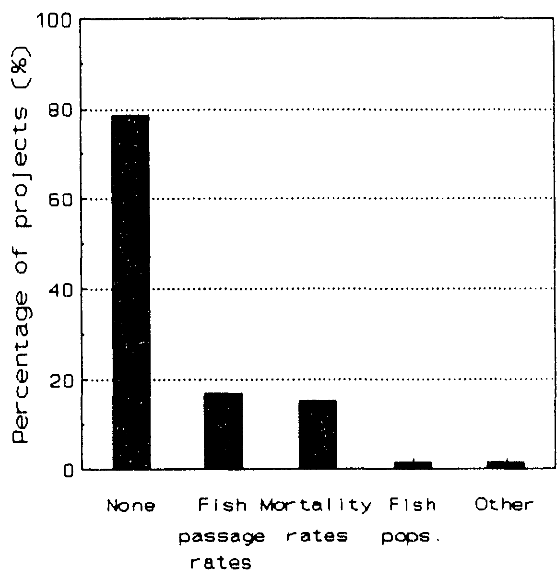

Figure 4. Performance monitoring of downstream fish passage measures

Estimating the Benefits of Fish Passage Mitigation

Whereas Volume I surveyed hydropower mitigation practices and policies for three common environmental issues, i.e., instream flow releases, water quality, and fish passage, Volume II focused solely on the latter issue. In addition to developing more precise estimates of the costs of particular fish passage and protection measures, the report attempted to quantify

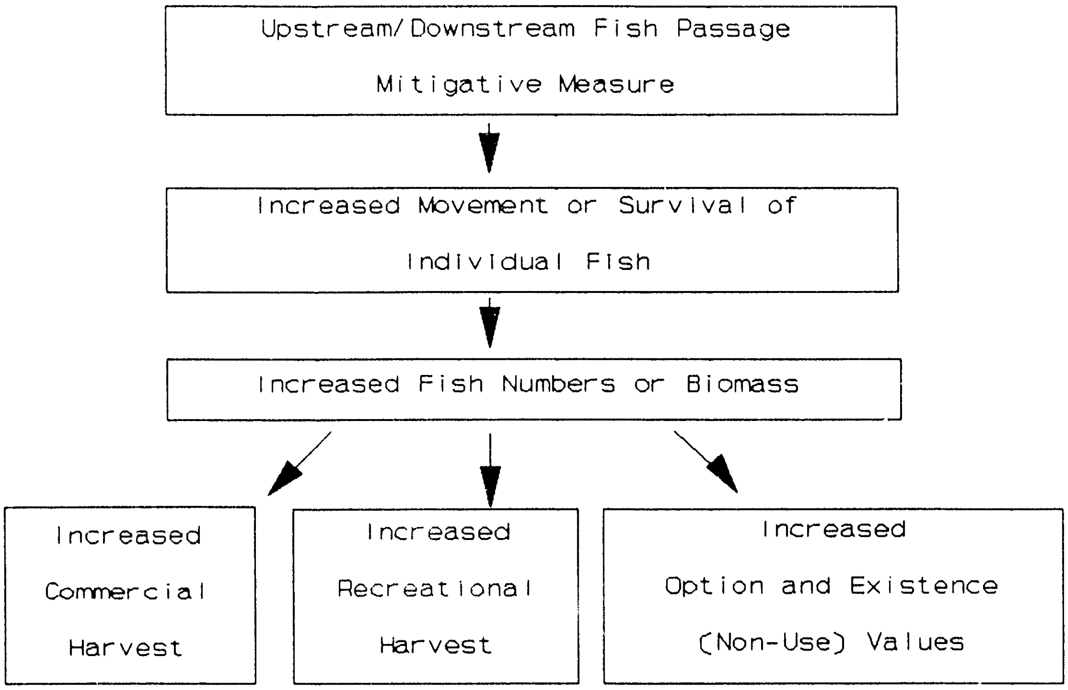

Figure 5. Steps in the quantification of benefits from fish passage mitigation

benefits in economic terms. The benefits of fish passage/protection measures can be estimated through a series of steps illustrated in Figure 5. For example, successful operation of a fish ladder or lift would increase the number of individual fish that are able to move upstream. This, in turn, would increase the number of fish that populate areas upstream from the hydropower dam, either because the fish continue to reside in the newly available habitat or because they reproduce in formerly unutilized spawning habitat. These increases in fish population numbers or standing crop (biomass) may have commercial, recreational, or non-use values that can be expressed in economic terms. Similarly, intake screens may increase the survival of resident or downstream-migrating fish by reducing turbine passage mortality. If the increased survival results in increased fish population numbers or biomass, economic benefits may be realized.

In order to conduct cost-benefit analyses of fish passage/protection measures, values of the fish must be estimated. The values of fish that are harvested commercially (market values) are relatively easy to derive, but estimating other use values (e.g., recreational fishing) and non-use values are much more difficult. For example, the value of a recreational fishery is a complex function of not only the number of fish available, but also the number of anglers, the amount of money anglers are willing to spend to fish, the number of alternative fishing sites, and other qualities of the river (e.g., scenic beauty, remoteness) not directly related to the supply of fish. Enhancement of the values of a recreational fishery brought about by a mitigative measure may not have a one-to-one relationship with the additional numbers of fish produced.

Even more complicated is the concept of non-use values, which can be divided into option values and existence values. Option value involves the possible consumption of a resource in the future; it is the amount of money that an individual will pay today to assure the ability to fish in the future, over and above the later, use value expected to be derived from recreational fishing. Existence value is the value that an individual attaches to the simple existence of a natural resource even though he has no plans to consume or otherwise use it, including even viewing it. Existence values might be attributed to endangered species (that have no present use or option value) or to biodiversity in an area remote from the individual. Also, individuals who have no intention of engaging in fishing either now or in the future may still attach existence value to the restoration of a salmon run. The Volume II report further discusses these concepts of valuing benefits and describes empirical approaches to estimating them.

As reported in Volume I, monitoring of fish passage/protection measures that would permit an estimate of benefits has been relatively rare. Most nonfederal hydropower projects have not monitored changes in distribution or survival of fish (the first step in assessing benefits in Figure 5), let alone the resulting changes in fish numbers/biomass or the changes in use and non-use values. In view of the relatively low degree of performance monitoring, analyses in Volume II relied on evaluation of a small number of projects (case studies) that have collected data that could be used to assess benefits. These case studies were selected to encompass the widest range of mitigative measures, fish species, and geographic regions possible (Table 1). Few studies have been conducted in the Midwest or Southeast, or on river systems which support only resident fish. As a result, most case study sites were located in the Northeast or the Pacific Coast, and nearly all monitoring data concerned salmon or other anadromous fish. Fish ladders were the subject of most upstream fish passage case studies, which reflects the preponderance of ladders as a mitigative measure at nonfederal hydropower projects (Sale et al. 1991). Although a wide range of downstream protection measures is employed by the hydropower industry, performance monitoring has been carried out most extensively at sites with some type of fixed screens, e.g., angled bar racks, inclined screens, or wedge-wire screens.

Evaluation of the benefits of the mitigation at each case study site was based on a review of published performance monitoring data. Case study descriptions included characteristics of the hydropower project and the mitigative measure, the environmental setting, and the fish resource management goals and objectives for which the mitigation was designed. The performance of the measure was compared to stated management objectives or license conditions. In most case studies, the benefits of the measure could only be expressed in terms of the numbers of individual fish that were transported around the dam or protected from entrainment. As might be expected from the types of monitoring that are most commonly conducted (Figures 2 and 4), population-level responses of the target fish species were rarely known.

All parties to hydropower development must have an accurate understanding of both the cost and benefits of fish passage mitigative measures. Construction and operation of often costly fish passage measures may be required at sites where the need is uncertain (e.g, at sites without clearly migratory fish species) or where the subsequent biological benefits remain unknown. Wherever possible the value of fish potentially transported around an impassable barrier should be quantified and compared with construction and operation costs of mitigative measures, to ensure that costs do not greatly outweigh benefits. Obviously such comparisons must be made with caution because the value of species that are being protected from extinction or are undergoing restoration may not be easily expressed in economic terms.

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Table 1. Mitigative measures used at case study projects to enhance fish passage or to reduce turbine passage mortality.

Mitigative Measure	Fish Species	State
Fish ladder	Steelhead trout Chinook salmon	MI
Fixed intake screens	Blueback herring	NY
Angled bar rack	Atlantic salmon	NY
Fish ladder	Atlantic salmon American shad Alewife	ME
Fish ladder Fixed intake screens	Atlantic salmon	ME
Fish ladder Fish lift	Atlantic salmon American shad	MA
Fish lift	American shad	MD
Fish ladder Wedge-wire screens	Chinook salmon Steelhead trout	CA
Fish ladder Fixed intake screens	Rainbow trout	CA
Fish ladder	Chinook salmon Steelhead trout	CA
Fixed intake screens	Chinook salmon	OR
Fixed intake screens	Chinook salmon Steelhead trout	OR
Wedge-wire screens	Chinook salmon	OR
Fish ladder Spill flows	Chinook salmon Sockeye salmon Steelhead trout	WA
Fixed intake screens	rainbow trout cutthroat trout brook trout	WA
Fish ladder Traveling screens	Chinook salmon Steelhead trout	WA

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