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RESEARCH ON ANADROMOUS FISH PASSAGE AT DAMS

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The multitude of dams resulting from the development of our water resources for power, irrigation, navigation and flood control is seriously threatening the existence of our anadromous fisheries. If anadromous fish populations are to survive the adult fish returning from the sea must have access to spawning areas. Fingerlings, likewise, must be able to migrate safely to the sea. There are several serious aspects to the problem of fish versus dams, but the most immediate concern is that of providing safe passage at dams for both upstream and downstream migrants.

The Columbia River watershed provides one of the most spectacular examples of the fish passage problem. A series of large dams is planned in the main Columbia and in the Snake River, and lesser dams are proposed in most of the tributaries. Adult fish ascending to their present spawning areas may have to surmount as many as nine dams. Even small losses, injuries or delays at each dam could prevent spawning and result in decimation of the run. The small fish migrating downstream to the sea will also have to run this gauntlet of dams, and, because of the cumulative effects of such a series of hazards, relatively minor losses at each dam could jeopardize the entire fishery. If the fishery is to be protected, the passage of both adult fish and fingerlings must be achieved with the maximum efficiency.

The problem is urgent! There are already two major dams on the Columbia without fish passage facilities. These dams, Grand Coulee and Chief Joseph, cut off over 1,000 lineal miles of streams that were formerly available to salmon. This was not done through neglect, but because we were unable to provide an economically practical solution to the problem of fish passage at high dams. Plans and preparations are in progress for many other dams, and time, so badly needed for research, is growing shorter. The fate of the once-abundant runs of salmon and shad on the East Coast provides a grim reminder of the price of delay or failure in seeking the necessary answers.

Fishery agencies on the West Coast, well aware of the critical nature of the problem of fish passage, are expanding their research in an all-out effort to solve the problem while there is yet time. The personnel and facilities of colleges and universities are being enlisted in the search for ways and means of getting fish safely past dams. The U. S. Army Corps of Engineers, as a major dam building organization, is

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providing funds for a broad program of "Fisheries-Engineering" research directed toward an economic solution of their fish passage problems in the Columbia River. In both the United States and Canada, fishery agencies are pooling information and coordinating research programs in an effort to insure that no promising possibility remains unexplored.

DOWNSTREAM MIGRANTS

A major part of the research effort will be directed toward that aspect of the fish passage problem which appears to be most difficult to solve—the protection of the downstream migrants. The migrating fingerlings move downstream following large water flows into diversions, turbine intakes and under spillway gates. Injuries and losses are often difficult even to measure and at this point of our knowledge, almost impossible to prevent. Mechanical screening has been used successfully at small installations but is impractical for the huge volumes of flow at large dams. There is need for an inexpensive method by which fingerlings can be directed away from dangerous areas into bypasses that will transport them safely below dams.

Experiments are being conducted both in the laboratory and in the field, examining the use of a wide variety of stimuli to direct the salmon fingerlings. These exploratory tests involve the use of electricity, lights, sound, odors, screens of air bubbles, dyes, louvers and other mechanical deflectors. At the moment, the most promising approaches appear to be in the use of electricity, lights and louvers.

The use of electric fish screens is not new, some installations having been in use for over 30 years. Most of such applications have endeavored to establish an electrical field as a barrier or "fence" to prevent the entrance of fish into a given area, the fish being repelled by the electrified area. These electric screens have generally proved to be unsatisfactory with migrating fish and particularly so with downstream migrants. The fingerlings seem unable to avoid the electrical field where they are stunned or even killed rather than diverted. In our present research, attention has been turned toward the use of the directional properties of electric fields. When fish are subjected to a field of pulsating direct current, the fish tend to move toward the anode. The experiments now in progress are attempting to take advantage of this electrotaxis in guiding fingerlings. Instead of attempting to repel the fish, the field is designed so that the fingerlings enter the field and are then oriented in the desired direction.

The use of electricity in guiding fingerlings is being approached cautiously, however, for while electricity can control the movements of fish, it can also injure or kill them. The voltage gradients necessary to affect the movements of small fish are frequently dangerous for large fish. This creates a complicated problem, for at some locations there are times when fingerlings of several sizes and species are present as well as large adult upstream migrants. A solution to this situation is being sought in electrical fields with progressively increasing zones of voltage gradients that will affect larger fish first, directing them out of the area before they can enter the voltage zones necessary to direct the small fish. As experiments proceed investigating the wave forms, pulse frequencies, pulse durations, voltage gradients, current densities, and field patterns most effective in directing fingerling movements, parallel experiments explore the ranges of these same charactristics that may be injurious to the fish or that might modify normal reactions temporarily in such a way as to affect their survival. Long-range experiments are also in progress to test the possibility that exposure of fingerlings to an electrical field might affect their future reproductive ability.

The application of the principle of electrotaxis to the problem of protecting downstream migrants has much promise, and it is being investigated on a large scale by several research agencies. However, the method will require a detailed knowledge of the relation between the electrical energy levels producing electrotaxis and those with detrimental effects on the fish.

The use of phototaxis in directing fingerling movements is also not new. Experiments in which lights have been used in various ways to either attract or repel fingerlings have met with varying degrees of success but never with enough to justify their general application to the problem of fish protection. However, laboratory and field tests now in progress once again are calling attention to the extreme sensitivity of young salmon to light. It is hoped that with an increased knowledge of the nature of this phototactic reaction a more successful application can be made. Current research interest centers upon the use of a barrier of light, sharply defined on the upstream side, located diagonally across the direction of stream flow to deflect the fingerlings, taking advantage of their reluctance to pass into an area of higher light intensity.

There are serious obstacles to be overcome in developing a satisfactory technique utilizing light as the guiding stimulus. One of these is the problem of making such a method function satisfactorily in the daytime. Although our present information seems to indicate that the largest part of fingerling downstream migration is at night, a technique that was ineffective in daylight hours could only be looked upon as a partial solution. The avoidance of the light deflector at night might result only in the delay of the normal downstream movement of a large part of the fingerlings until daylight. The excessive turbidity of many of the streams concerned may also make application of a light technique very difficult. The great advantage of a method of guiding fingerlings with light, and a strong incentive to expend every effort to develop such a technique, is that the method would not involve the danger of injury to the fish that is ever present in electrical and mechanical methods and the method would have the further advantage of a minimum of interference with water flow.

A third technique showing promise as a means of collecting migrating fingerlings from a large volume of water is the use of louvers. The louver screen consists of a series of vertical baffles or louvers placed diagonally across the stream flow with a bypass located on the extreme downstream end. Fingerlings seem reluctant to pass through the narrow openings between the louvers and are thereby deflected into the bypass. Experiments with the use of a louver screen now being conducted at a large water diversion at Tracy, California, indicate that this type of screen is equally effective by day or night, and the experiments show very little evidence of any injury to the fish. The chief disadvantage of this technique appears to be in a large structure of louvers required, which, from the standpoint of initial cost, maintenance and interference with flow, probably limits its usefulness at major dams.

While all of the methods for guiding fingerling so far explored seem to have limitations, it must be borne in mind that most of this research is still at a preliminary stage. If a general solution to the problem of directing fish that will be applicable to all situations and circumstances, all sizes and species of fish is not found, the problem of fingerling passage might still be solved satisfactorily by applying a variety of techniques, each adapted for a particular set of conditions. It is of the greatest importance, therefore, to examine carefully every potential method for its possible use even in restricted circumstances, not only alone, but in combination with other methods.

UPSTREAM MIGRANTS

By comparison to the problems involved in providing safe passage for downstream migrants, the task of passage facilities for upstream migrants seems relatively easy. Yet, we have little reason to feel complacent about our knowledge relating to passage of adult fish. There is evidence that our present fishways are oversize, inefficient and far too expensive. The reduction of fishway costs is becoming increasingly important to the protection of the fishery resource. The cost of construction and maintenance of fishways has now reached such proportions that many people concerned with river development policy are beginning to ask if the value of the fishery warrants such expenditures. For example, the estimated construction cost of fishways at six new dams planned on the Columbia River is in excess of $100,000,000, with the maintenance and operation costs estimated to be more than $1,000,000 annually. Precedents have already been established on the Columbia River for dams without any facilities for fish passage. An important part of the research on adult fish passage will be concerned, therefore, with finding more economical methods for providing adult passage.

The high cost of fish passage facilities can in many cases be traced directly to a lack of definite knowledge on fish behavior and of the principles involved in fish passage. This lack of information is reflected in fishways designed with huge safety factors in size and auxiliary flows, and, in the expensive provision made for duplication of facilities (*i.e.*, both fish-ladders and fish locks at major dams.)

To provide a means of acquiring the information a special type of laboratory is being planned in which it will be possible to measure the reactions of the migrating fish under controlled experimental conditions. The structure will be located on a bypass into which fish can be diverted from one of the major fishways at Bonneville Dam. The fish will swim into the laboratory where they can then be subjected to a variety of experimental conditions without interfering with the normal passage of fish in the main fishway. When the fish have passed through the experimental area and their reactions are recorded, they will swim out of the laboratory and reenter the fishway. Experiments are planned investigating the swimming abilities of the fish, their reactions to light, form, water turbulence and spatial relationships. An effort will be made to discover the factors controlling their rate of movement through fishways and the size of fishway required for given numbers. By the use of choice techniques the preferences of the fish for various flow properties, water temperatures and chemical conditions will be measured. The behavior of fish in tunnels and conduits, open channels and pools will be examined using the actual full scale dimensions and flows used in fishways at major dams. The construction of this unique type of laboratory will make possible an entirely new experimental approach to the problem of fish passage.

PRINCIPLES OF FISH PASSAGE

As intensive efforts to solve fish passage problems get under way, one point becomes increasingly clear—that, although our concern is for the application, little progress will be made until we have an understanding of the basic principles involved. What are the principles involved in providing passage for fish? The answer will only be found in the behavior of fish. Whether the problem is—How to attract adults into fishway entrances without delay? How to collect fingerlings to prevent them from entering dangerous areas? How to design bypasses? or, How to disperse fingerlings at bypass exits to reduce predation?—all of these require an intimate knowledge of the factors influencing the direction and rate of fish movement. The biological term for this aspect of fish behavior is fish orientation. It includes all of those reactions that determine the position and movement of the fish in relation to its sourroundings. Principles of fish orientation are the basic principles involved in providing passage for fish. A systematic search for the principles of fish orientation may provide the shortest and surest route to a solution of the problem of fish passage at dams.