EXPLORATORY EXPERIMENTS ON THE DEFLECTION OF JUVENILE SALMON BY MEANS OF WATER AND AIR JETS

by

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INTRODUCTION

The need is urgent for an effective, low-cost method of guiding and collecting juvenile salmonids from rivers and streams. Present techniques require costly screening of flow, and where flow volumes are high a structure is both massive and expensive. In addition, the maintenance costs for such facilities are also high and continuing. It is necessary, therefore, to develop a fish guiding and collecting system, which by minimizing the problem of debris, will reduce maintenance costs.

The development of louvers was a partial advance in this direction. Research on sound, lights, air-bubble acreens, and electricity has been directed toward achieving this same end. However, the results have never been sufficiently successful to warrant field application.

The exploratory studies described here were made to determine whether or not water or air jets could meet the requirements. The investigation was carried out during the fall and winter of 1963-64 in a test flume designed specifically for this purpose and located at the Carson Hatchery Fish Cultural Station, Carson, Washington.

DESCRIPTION AND OPERATION OF FLUME

The Carson behavioral flume (fig. 1), measures 50 feet long, 6 feet wide, and 4 feet deep. The flume floor has only sufficient slope to facilitate drainage. A clear plastic window 3 feet high and 6 feet long was installed on one side near the downstream end of the flume to allow observation of fish response. Experimental devices undergoing tests were all contained within the flume, generally positioned close to the downstream end.

A continuing source of crystal-clear water for the flume was provided by Tyee Springs, originating several thousand feet away from the structure. By means of stoplogs this flow of water (45 c.f.s. maximum) could be directed completely, or in part, into the flume. Water temperatures ranged between 46° and 52° Fahrenheit.

A bypass was provided in all cases for fish guided experimentally. An inclined screen of perforated plate with trap was installed to collect all fish, guided or unguided (fig. 2). Efficient collection of guided fish requires not only a properly designed bypass but flow conditions acceptable to the young migrants. On the basis of earlier studies (Bates, et al., 1960), it has been shown that fish preparing to enter into a bypass will do so more readily if certain velocity conditions are provided. In most cases the requirement is for an acceleration of the flow approaching and entering into the bypass. This acceleration is spoken of as a percent-bypass acceleration and is expressed as a percent of the mean approach velocity. At the Carson behavioral flume a bypass acceleration of approximately 140 percent was found to be suitable[1/] Bypass accelerations higher than 140 percent were also acceptable, but were somewhat difficult to secure. Lower acceleration rates caused the young fish to reject the bypass.

MATERIALS AND METHODS

Water-Jet Studies

To carry out the water-jet studies a gasoline-powered water pump having approximate pumping capacity of 1 c.f.s. at a maximum pressure of 110 pounds per square inch was installed adjacent to the flume. Pump pressure could be controlled to meet various test requirements. Water was passed from the pump through a transportation line (fig. 3) and into a manifold pipe. At this point it passed into a series of individual vertical pipes spaced 1.2 feet apart, each 3 feet long, jetting out through the orifices (1/32nd of an inch in diameter) spaced vertically at 1/2-inch intervals the full length of each pipe.

1/ Also expressed as a ratio of the approach flow to the bypass flow; i.e. 1:1.4.

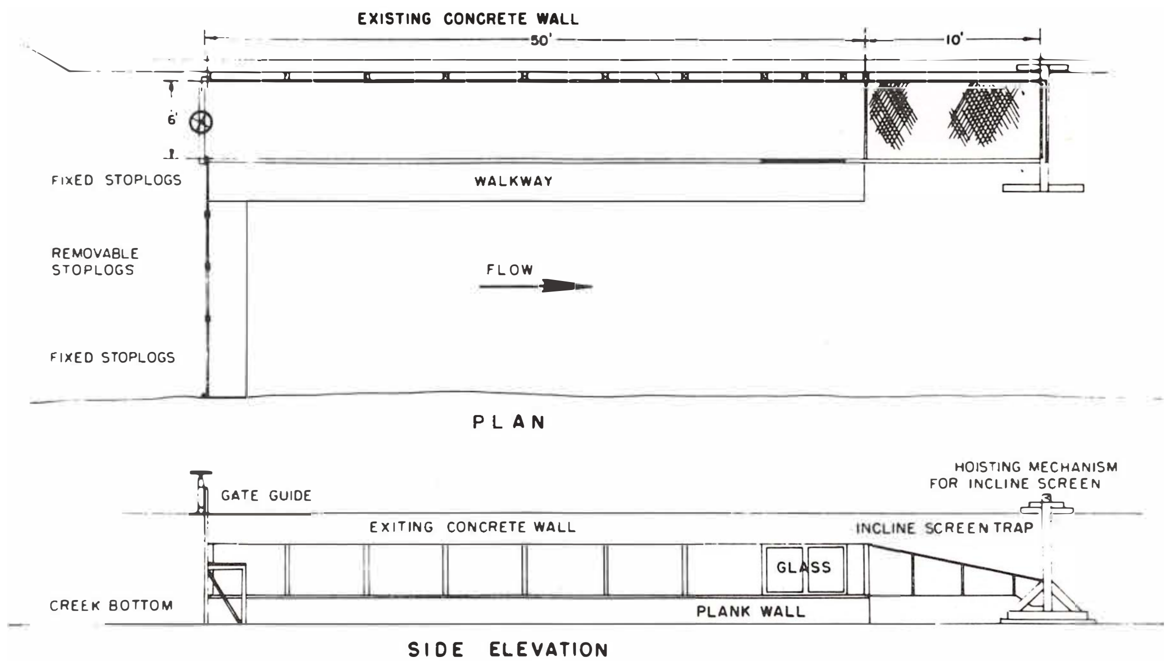

Figure 1.--Diagrammatic sketch showing both plan and elevation of Carson behavioral flume.

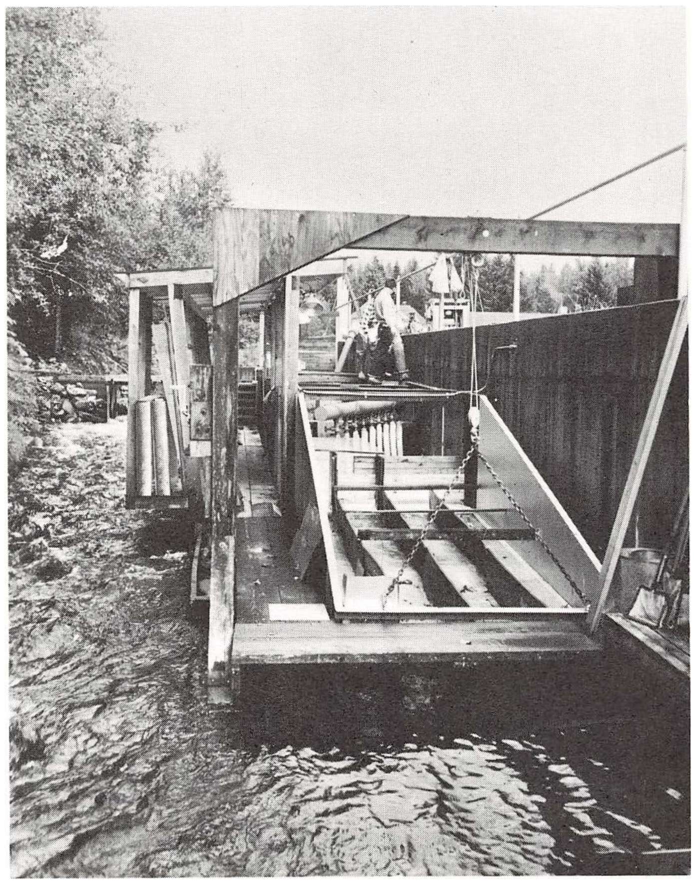

Figure 2.--The Carson flume with the inclined screen traps in foreground.

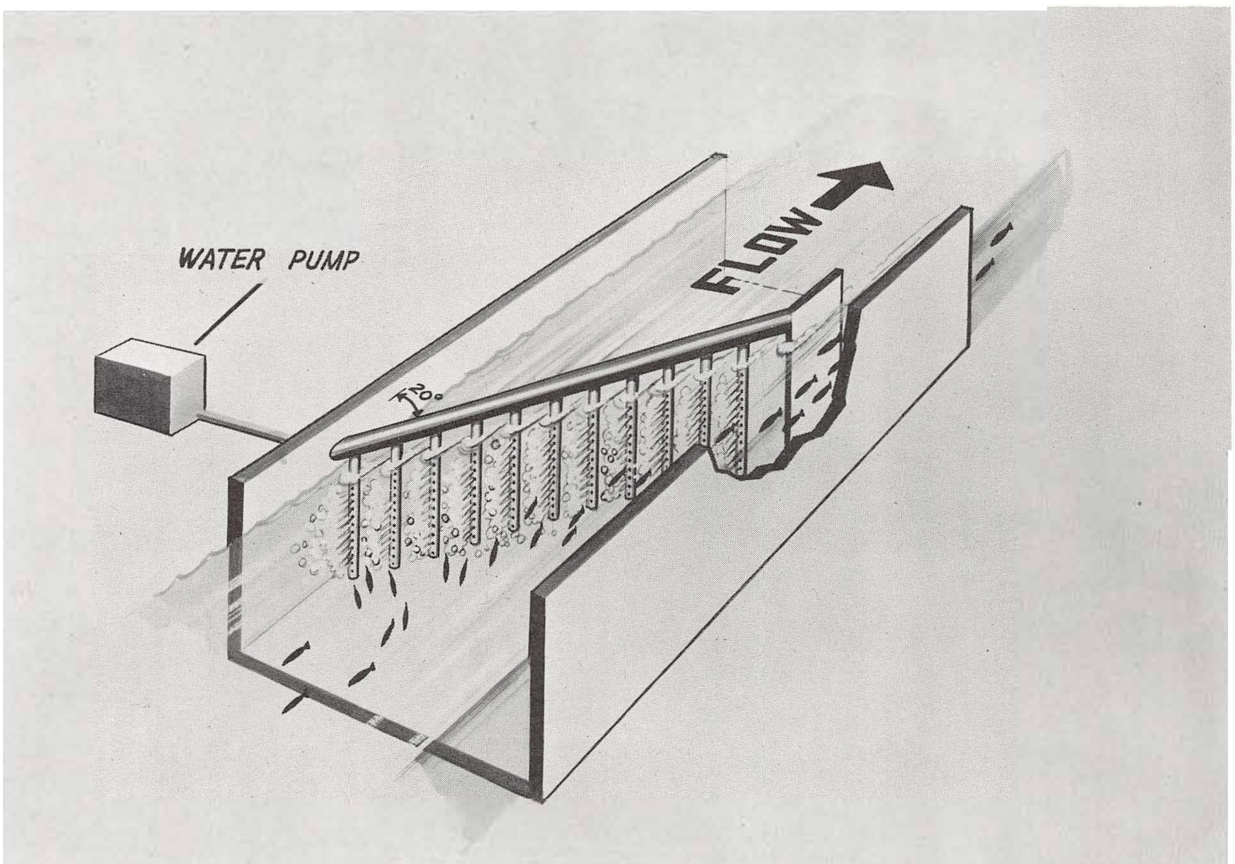

Figure 3.--Diagrammatic sketch of the water-jet system showing water pump, manifold pipe, and individual water-jet pipes in relation to flow direction.

Flow release valves were installed at the juncture of the pipe and manifold. Canvas stockings were placed completely around each pipe, covering all jet above the water line to eliminate undesirable water spray. The line of vertical pipes positioned on a 20° angle-to-flow led into a 1-foot wide bypass. Metal screw caps, originally without orifices, were used to close off the extreme end of each pipe. The caps were later drilled to provide flow after it was found that some fish had been swimming underneath the jet curtain.

Preliminary tests indicated that water pressures of 80 to 110 pounds per square inch physically disoriented the fish, forcing them, in many instances, through the jet barrier. To avoid this, two specific pressures--30 and 60 pounds per square inch--were selected. Because fish response might vary as a factor of the angle of the jet in relation to the velocity of the approach flow, three jet angles of 30°, 60°, and 90° were selected.

To determine the extent and force of the jet as a factor of (1) the approach velocity, and (2) the angle of the jet in relationship to the direction of canal flow at the three jet pressures, dye was introduced into the pump-intake line and photographs were taken of the jet flow displacement into the canal. The relationship is illustrated diagrammatically (fig. 4).

A fish-release tank measuring 30 inches high, 14 inches wide, and 4 feet long, with perforated-plate screen panels at either end was used to hold the test fish prior to each test. Each perforated-plate screen panel could be raised independently by remote control for the release of fish.

For each test, water in the flume was held at a constant 1.2-foot level. Approach velocities were varied, depending on the test requirement, between 2.5 and 3.5 feet per second.

Test fish were spring chinook salmon, hatchery-reared, ranging from 62 mm. to 105 mm. in length with a mean of 87 mm. These fish were first dip-netted from the hatchery ponds, placed in containers, and transported for release into the fish-holding tank positioned at the upstream end of the flume. Here they were held for a minimum of 15 minutes to provide time for their adjustment to the transfer prior to release into the test flume. Approach velocities, water depth, jet direction and pressure, and bypass accelerations were secured and set prior to introducing the fish into the holding tank.

Following the 15-minute (or longer) recovery period, both the upstream and downstream gates of the holding tank were raised, releasing fish into the flume. At approach velocities of 2.5 and 3.5 f.p.s., the hatchery fish would generally begin drifting tailfirst downstream immediately after release.

The results of the various tests are expressed as percentages and show the portion of the total number of fish migrating through the flume that were guided into the bypass.

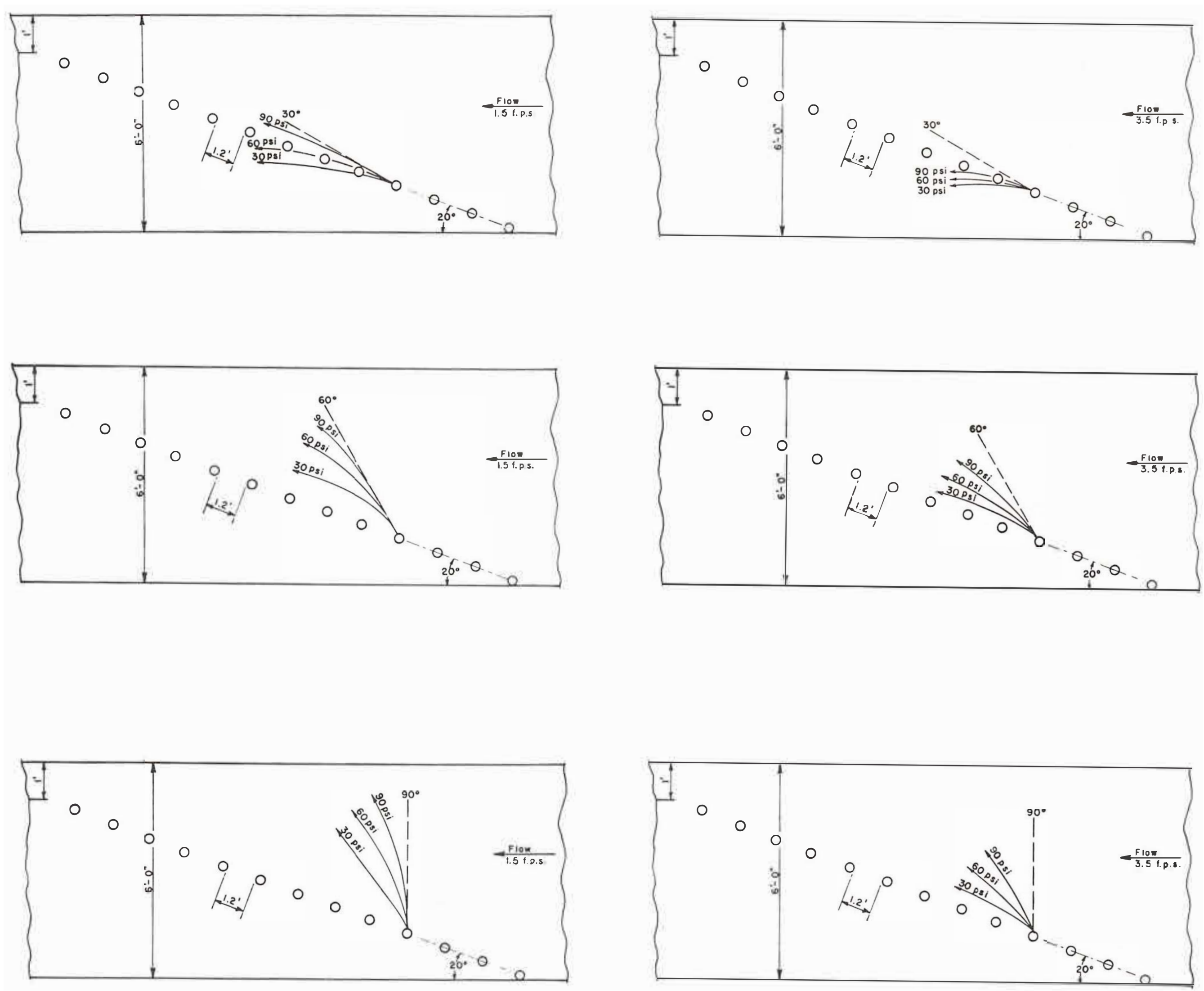

Figure 4.--Diagrammatic sketch illustrating relationship of three jet angles of 30°, 60°, and 90° and flow direction as factors of two different approach velocities.

Air-Jet Studies

The experimental apparatus (fig. 5) used for the air-bubble screen tests consisted of a 210-cubic foot air compressor which forced air through an air filter into a perforated pipe. The pipe, measuring 1 inch in diameter and 11 feet 9 inches in length, had a single line of holes 1/64 inch in diameter drilled every 1/2 inch along its entire length. The pipe extended upstream on a 25° angle from the leading edge of the bypass wall, across the flume floor to the opposite wall where it was joined to a pipe leading to the compressor. Air pressure in the system was indicated by a gauge tapped into the line between the air filter and the perforated pipe. The air pressure was controlled by a valve inserted between the air filter and pressure gauge.

Within the perforated pipe, a pressure of 38 to 48 pounds per square inch was maintained. As the air passed through a single perforation, a jet approximately 3/4 inch high was formed. This jet transformed into large bubbles about 3 inches in diameter, each of which broke down into smaller and smaller bubbles. At the surface the bubbles had a diameter of 1/4 inch or less.

To begin a test, water was diverted into the flume, and the downstream stoplogs within the flume were adjusted to maintain the desired depth and velocity of water. The air-bubble screen was then developed by starting the air compressor and adjusting the pressure. Approach and bypass velocities were measured and adjusted to meet test requirements.

Following the procedure used in the individual water-jet tests, approximately 125 juvenile spring chinook (mean total length 102 mm., range 89-121 mm.) were removed from a hatchery pond and placed in the release chamber where they were held for 15 minutes. At the end of the holding period, both gates of the release chamber were raised, allowing the fish to move downstream toward the air-bubble screen.

Fish guided by the air bubbles entered the bypass and traveled over an inclined screen and into a trap. Fish penetrating the air bubbles also passed over an inclined screen and into a trap. Each of the two groups were then counted and returned to the hatchery pond. This cycle was repeated until at least 500 fish had been exposed to each particular test condition.

Efficiency determination was similar to that used in the water-jet study.

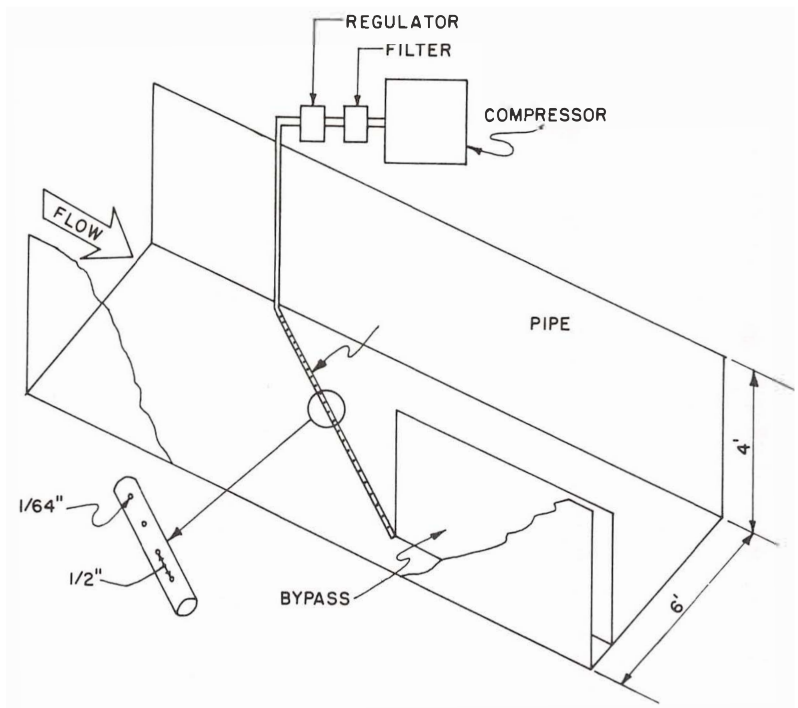

Figure 5.--Diagrammatic sketch of the air jet system showing compressor and perforated pipe layout.

RESULTS AND DISCUSSION

Water Jets

The results of the water-jet deflector demonstrated that a high level of deflection was possible (fig. 6). One factor, commonly associated with the use of hatchery fish, leads to a reduction of deflection efficiencies. Five to 10 percent of all fish within each test group, without hesitation, swam excitedly and rapidly headfirst downstream and through the jet barrier. The majority of the fish displayed a more normal response by traveling downstream tailfirst, avoiding the jet streams by lateral deflection (fig. 7).

Although the preliminary results indicate some promise in the use of water jets as a method of deflecting fish, a number of inherent limitations characterized the technique. For example, screening of a 1.2-foot depth of water 6 feet wide required approximately 1 second-foot of water. Therefore, to screen a river 15 feet deep and 500 feet wide would require a continuing flow in the magnitude of 1,250 second-feet. In addition, the jet orifices required extensive maintenance as they were continuously subject to clogging from debris and rust.

Visual response by fish to the water jet was low due to the limited contrast between the main-canal flow and the water jet. As nighttime and daytime water-jet deflection efficiencies were comparable, it might therefore be presumed that the sense of touch was more dominant than the sense of vision.

The results of the tests using an air-bubble screen are shown in figure 8. Best results were obtained during daylight hours, with an approach velocity of 1.9 f.p.s. All nighttime tests resulted in poor guiding.

The effectiveness of an air-bubble screen in deflecting downstream migrants is a function of the fish's ability to see it (fig. 9). This ability is at least limited, if not entirely absent, during nighttime periods or in areas with highly turbid water. The use of artificial lights may offer a solution to this problem; however, brief tests conducted at the end of this study indicate that the use of artificial light does not increase the efficiency during nighttime test periods. Additional night studies using different lighting techniques and exposing the test fish to light for longer periods in the release chamber may result in better guiding.

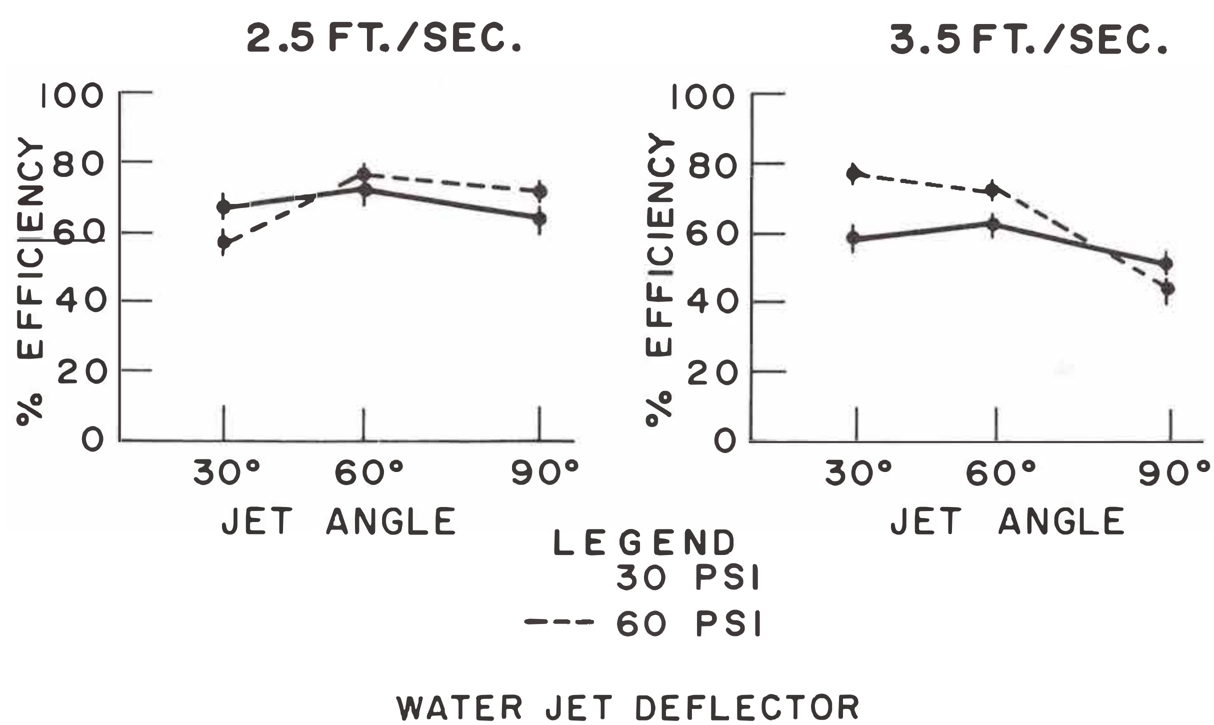

Figure 6.--Relation between rate of approach velocity and percentage deflection for jet angles of 30°, 60°, and 90° at 30 pounds per square inch and 60 pounds per 60 pounds per square inch.

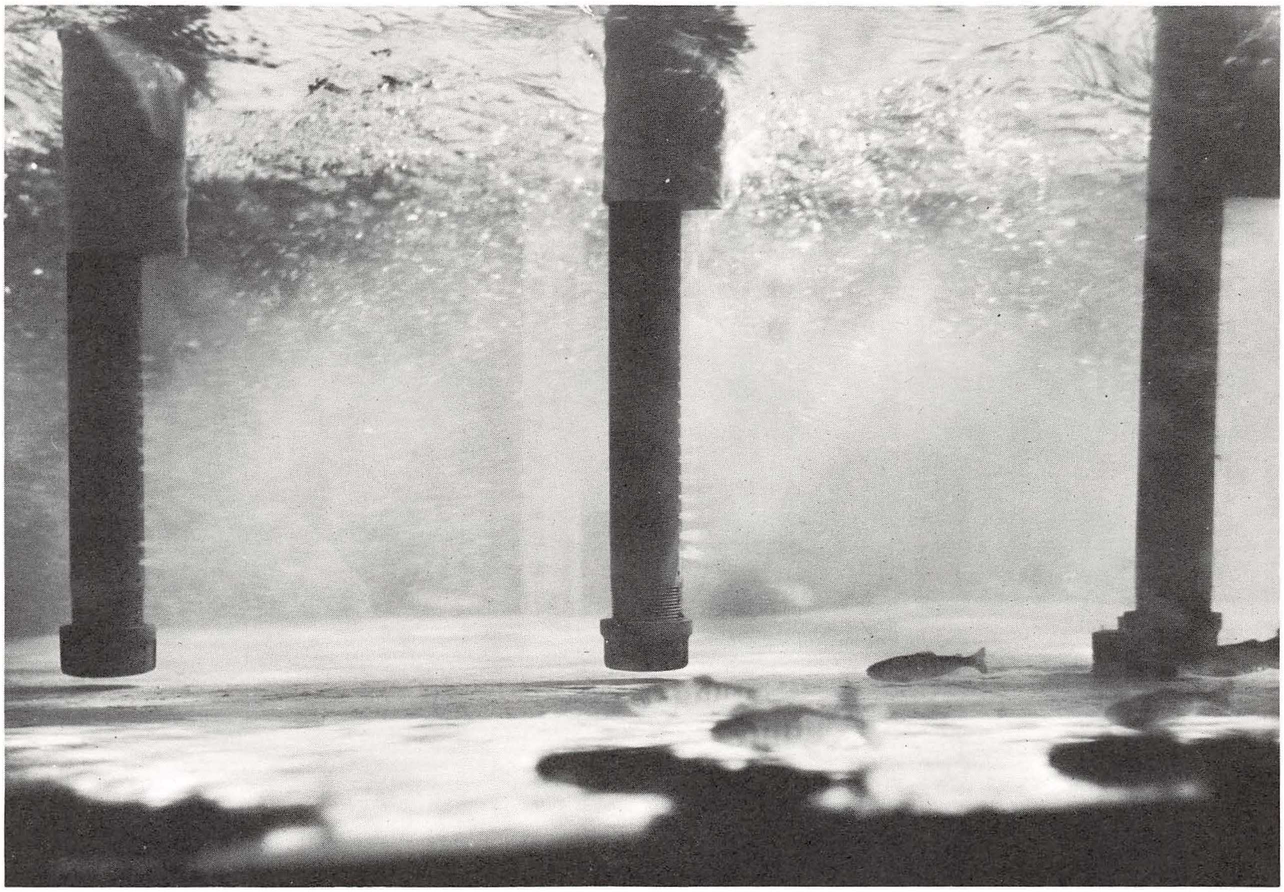

Figure 7.--Fish deflecting away from water jets.

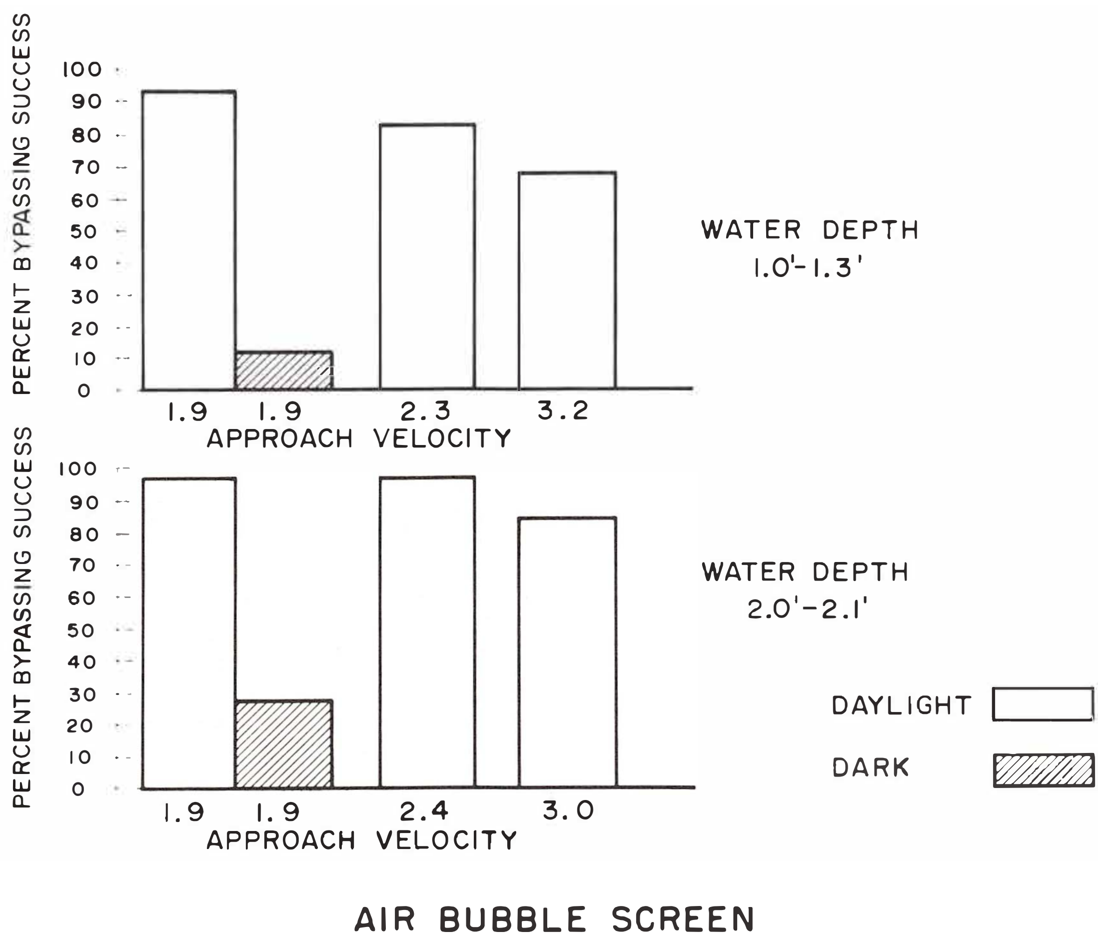

Figure 8.--Relation between rate of approach velocity and percentage deflection for two different water depths under daytime and nighttime conditions.

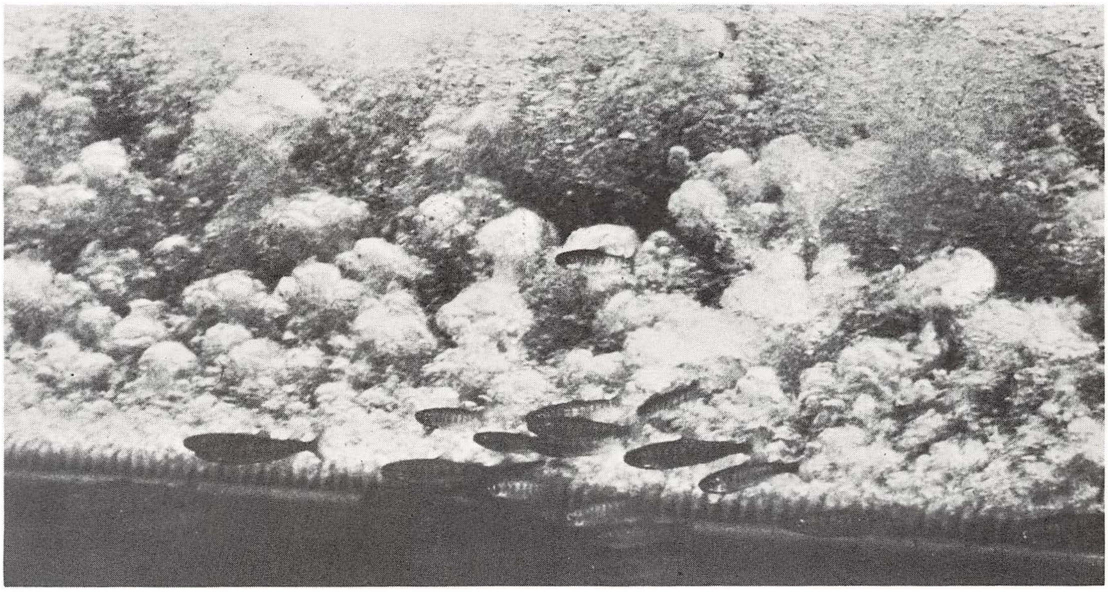

Figure 9.--Fish deflecting away from air bubble screen.

RESUME

The experimental water-jet deflector showed potentials when an appropriate combination of approach velocities, angle, and pressure of jet was employed. However, extensive maintenance and need for large volumes of water made continued consideration of this technique impractical.

Fish exposed to an air-bubble screen deflector under the described condition exhibited a definite response during daylight hours. However, the poor deflection obtained during nighttime hours precludes its use as a functional barrier to downstream migrants.

LITERATURE CITED

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1960. Efficiency evaluation of the Tracy fish collecting facility, Central Valley Project, California. U. S. Fish and Wildlife Service.