National Marine Fisheries Service
Southwest Region

Experimental Fish Guidance Devices
Position Statement of
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NMFS Southwest Region Position Paper on Experimental Technology for Managing Downstream Salmonid Passage

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INTRODUCTION

Numerous stocks of salmon and steelhead trout in California streams are at low levels and many stocks continue to decline. The Sacramento River winter-run chinook salmon is listed as "endangered" under the Federal Endangered Species Act. Petitions for additional listings are pending. It is essential to provide maximum protection for juveniles to halt and reverse these declines.

The injury or death of juvenile fish at water diversion intakes have long been identified as a major source of fish mortality [Spencer 1928, Hatton 1939, Hallock and Woert 1959, Hallock 1987]. Fish diverted into power turbines experience up to 40 percent mortality as well as injury, disorientation, and delay of migration [Bell, 1991], while those entrained into agricultural and municipal water diversions experience 100 percent mortality. Diversion mortality is the major cause of decline in some fish populations.

Positive barrier screens have long been tested and used to prevent or reduce the loss of fish. Recent decades have seen an increase in the use and effectiveness of these screens and bypass systems; they take advantage of carefully designed hydraulic conditions and known fish behavior. These positive systems are successful at moving juvenile salmonids past intakes with a minimum of delay, loss or injury.

The past few decades have also seen much effort in developing "startle" systems to elicit a taxis (response) by the fish with an ultimate goal of reducing entrainment. This Position Statement addresses research designed to prevent fish losses at diversions and presents a tiered process for studying, reviewing, and implementing future fish protection measures.

JUVENILES AT INTAKES

The three main causes of delay, injury, and loss of fish at water intakes are entrainment, impingement, and predation. Entrainment occurs when the fish is pulled into the diversion and passes into a canal or turbine. Impingement is where a fish comes in contact with a screen, a trashrack, or debris at the intake. This causes bruising, descaling, and other injuries. Impingement, if prolonged, repeated, or occurs at high velocities also causes direct mortality. Predation also occurs. Intakes increase predation by stressing or disorienting fish and/or by providing habitat for fish and bird predators.

A. Positive Barriers

Positive barrier screen systems and criteria for their design have been developed, tested, and proved to minimize harm caused at diversions. Positive barriers do not rely on active fish behavior; they prevent physical entrainment with a physical barrier. Screens with small openings and good seals are designed to work with hydraulic conditions at the site, providing low velocities normal to the screen face and sufficient sweeping velocities to move fish past the screen. These screens are very effective at preventing entrainment [Pearce and Lee 1991]. Carefully designed bypass systems minimize fish exposure to screens and provide hydraulic conditions that return fish to the river, preventing both entrainment and impingement [Rainey 1985]. The positive screen and fish bypass systems are designed to minimize predation, and to reduce mortality, stress, and delay from the point of diversion, through the bypass facility, and back the river.

Carefully designed positive barrier screen and bypass systems have been installed and evaluated at numerous facilities [Abernethy et al 1989, 1990, Rainey, 1990, Johnson, 1988]. A variety of screen types (e.g. flat plate, chevron, drum) and screen materials (e.g. woven cloth, perforated plate, profile wire), have proved effective, taking into consideration their appropriateness for each site. Well-designed facilities consistently result in a guidance efficiency of over 95 percent [Hosey, 1990, Neitzel, 1985, 1986, 1990 a,b,c,d, Neitzel, 1991].

The main drawback to positive barrier screens is cost. At diversions of several hundred cubic feet per second or greater, the low velocity requirement and structural complexity can drive the cost for fish protection and the associated civil works over a million dollars. At the headwork, the need to clean the screen, remove trash, and provide regular maintenance (e.g. seasonal installation, replacing seals, etc.) also increase costs.

B. Behavioral Devices

Due to higher costs of positive barrier screens, there has been much experimentation since 1960 to develop behavioral devices as a substitute for barrier screens [EPRI, 1986]. A behavioral device, as opposed to a positive (physical) barrier, requires a volitional taxis on the part of the fish to avoid entrainment. Early efforts were designed to either attract or repel fish. These studies focused on soliciting a behavioral response from the fish, usually noticeable agitation. Using these startle investigations to develop effective fish guidance systems has not been effective.

Experiments show that there is a large response variation between individual fish of the same size and species. Therefore, it cannot be predicted that a fish will always move toward or away from a certain stimulus. Even when such a movement is desired by a fish, it often cannot discern the source or direction of the signal and choose a safe escape route.

Many behavioral devices do not incorporate and use a controlled set of hydraulic conditions to assure fish guidance, as does the positive screen/bypass system. The devices can actually encourage fish movement that actually contrasts with the expected rheotactic response. Thus, the fish gets mixed signals about what direction to move. Another concern is repeated exposure; a fish may no longer react to a signal that initially was an attractant or repellant. In addition to the vagaries in the response of an individual fish, behavior variations are expected due to size, species, life stage, and water quality conditions.

In strong or accelerating water velocity fields, the swimming ability of a fish may prevent it from responding to a stimulus even if it attempts to do so. Other environmental cues (e.g., pursuing prey, avoiding predators, or attractive habitat) may cause a fish to ignore the signal.

A main motivation for opting to install behavioral devices is cost-savings. However, much of the cost in conventional systems is for the physical structure needed to provide proper hydraulic conditions. Paradoxically, complementing a behavioral device with its own structural requirements may lessen much of its cost advantage.

Present skepticism over behavioral devices is supported by the fact that few are currently being used in the field and those that have been installed and evaluated seldom exhibit consistent guidance efficiencies above 60 percent [Vogel, 1988, EPRI, 1986]. The louver system is an example of a behavioral device with a poor success record. In this case, even with the use of favorable hydraulics, performance is poor especially for smaller fish. Entrainment can be high, particularly when operated over a wide range of hydraulic conditions [Vogel, 1988, Cramer, 1982, Bates, 1961]. Due to their poor performance, some of these systems are already replaced by positive barriers.

EXPERIMENTATION PROCESS

However, there is potential for developing new positive screens as well as behavioral guidance devices for the future. Nonetheless, experimental technology must achieve, over the foreseeable range of adverse conditions, a consistent level of success that equals or exceeds that of best available technology. It should be a deliberate, logical process. NMFS will not discourage research and development on experimental fish protection devices if the following tiered study process is incorporated:

(1) Consider earlier research. A thorough review should be performed of past methods similar to that proposed. Reasons for substandard performances of these earlier methods should be clearly identified.

(2) Study plan. A study plan should be developed and presented to NMFS for review and concurrence. It is essential that tests occur over a full range of possible hydraulic, biological, and ecological conditions that the device is expected to experience.

(3) Laboratory research. Controlled laboratory experiments should be developed using species, size, and life stages intended to be protected (or acceptable surrogate species). For behavioral devices, special attention must be directed at providing favorable hydraulic conditions and demonstrating that the device clearly

causes the planned behavioral response. Studies should be repeated with the same test fish to examine any habituation to the stimulus.

(4) Prototype units. Once laboratory tests show high potential to equal or exceed success rates of state-of-the-art screening, it is appropriate to further examine the new device as a prototype under real field conditions. Field sites must be fully appropriate to (1) demonstrate all operational and natural variables expected to influence the device performance, (2) evaluate the species, or an acceptable surrogate, that would be exposed to the device under full operation, and (3) avoid unacceptable risk to resources at the prototype locations.

(5) Study results. Results of both laboratory tests and prototype devices examined in the field must demonstrate a level of performance equal to or exceeding that of conventional, established technology before NMFS will support further installations.

CONCLUSIONS

In the course of the past few decades, we have seen increased demand for water diversions. This trend is likely to continue. Accompanying this demand is a corresponding decline of fisheries. Therefore, prudence dictates that fish protection facilities be held to the highest practicable level of performance.

A major effort was made to examine experimental guidance systems over several decades by a variety of funding agencies. The results were generally poor or inconclusive, with low guidance efficiencies attributable to the particular device used. Often results were based on a small sample size or varied with operational conditions. In addition, unforseen operational and maintenance problems, including safety hazards, sometimes developed.

Nevertheless, some of these experiments show potential. To further improve fish protection technology, NMFS will not oppose tests that proceed in the tiered process outlined above. Further, to ensure no further detriment to fish, experimental field testing should be done with the simultaneous design of a positive barrier and bypass system for that site. This conventional system should be scheduled for installation immediately, if the experimental guidance system, once again, does not prove to be as effective as a conventional system.

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