Volume 101
Article 10

FISHERY RESEARCH

TROUT STREAM ENHANCEMENT STUDIES: SYNOPSIS OF INFORMATION ON IRRIGATION DIVERSION FISH LOSS

Job Performance Report
F-73-R-17
Subproject 7

By:

John A. Der Hovanisian
Fisheries Research Biologist

IDFG 95-31

September 1995

TABLE OF CONTENTS

Page

JOB PERFORMANCE REPORT

State of: Idaho

Name: Irrigation Diversion
Fish Loss Reduction

Project No.: F-73-R-17

Title: Synopsis of Information on
Irrigation Diversion Fish Loss

Subproject No: VII

Period Covered: April 1. 1994 to March 31. 1995

ABSTRACT

There is little quantitative data available in Idaho to assess the population effects of resident game fish losses to irrigation diversions, or even to determine whether a widespread problem exists. This report provides a synopsis of existing data on irrigation diversion losses that will help direct future investigations.

Factors that contribute to fish loss include physical characteristics of diversions, headgate manipulation, natural phenomena, and fish behavior. Irrigation practices that result in host stream disturbances also potentially impact fish populations. Irrigation operations appear to primarily impact juvenile fish and may limit recruitment; the mechanisms may express themselves directly through losses to diversions and/or indirectly through habitat perturbations in host streams.

If resident game fish losses to irrigation diversions are significant, mitigation methods that are cheaper than those currently being used will be required. Implementation of these methods will require instream habitats capable of supporting recovered fish stocks.

Author:

John A. Der Hovanisian
Fishery Research Biologist

INTRODUCTION

Idaho fishery managers and anglers have long suspected that significant numbers of resident game fish are lost to irrigation diversions. However, there is little in-state quantitative data available to assess the effects of such losses, or to even determine whether a widespread problem exists (Schill 1995). A few studies have attempted to assess the loss of resident game fish in selected diversions (Hauck 1949; Gebhards 1958; Thurow 1980, 1981, 1987, and 1988; Elie et al. 1987), but they only provide point estimates (most likely underestimates) which serve little utility in assessing overall population impacts.

The conditions for potentially harmful repercussions are certainly present. Hundreds of streams are diverted for agricultural purposes statewide, with irrigation diversions ranging in size from a few cubic feet per second (cfs) to 4,500 cfs. Although the majority of diversions in the Salmon River drainage and a handful of diversions in southeastern Idaho are screened to protect against fish loss, most irrigation diversions in the state are not (Schill 1995).

If resident game fish losses are indeed significant, funds for reducing them on a meaningful number of diversions may not be forthcoming. Screening costs using current technology (primarily rotary drum screen) are about $3,000 per cfs (Mike Mitchell, Idaho Department of Fish and Game Engineering, personal communication), but funding of this magnitude is typically unavailable for resident stocks (Sullivan and Mattice 1986). A proposed amendment to the Northwest Power Planning Council's Fish and Wildlife Program would provide funding for up to 40 resident fish screening projects per year in Idaho. Without outside funding of this nature, alternate non-screening methods will be needed to protect resident populations if a problem exists.

A comprehensive investigation to determine the extent of resident game fish losses in the context of population dynamics is needed. If losses of resident game fish to diversions are shown to be biologically problematic, then cheaper methods for protecting resident stocks will need to be developed and/or evaluated.

The goal of this research project is to determine if sport fishing opportunities can be enhanced by minimizing losses of game fish to irrigation diversions. A summary of existing data on losses to irrigation diversions will provide direction for future investigations.

OBJECTIVE

1. To provide a synopsis of the literature on fish losses to irrigation diversions.

METHODS

I conducted a comprehensive search of the literature on fish losses to irrigation diversions. Of specific interest were the physical and structural factors that contribute to fish loss, numerical losses of resident game fish and potential impacts, and methods for reducing losses. I also contacted biologists directly in Idaho, Oregon, and Montana for relevant information.

RESULTS

Factors Contributing to Fish Loss

Clothier (1953a) found a high degree of diversity in the physical characteristics of irrigation diversions on the West Gallatin River, Montana, and reported a substantial variation in fish losses. Although many factors undoubtedly affect fish loss, the most egregious diversions seem to share common attributes: high flow ratios, diversion/headgate configurations that prevent migration back to host streams, and abundant cover. Spindler (1955) found that losses of legal-size game fish in the West Gallatin River were greatest in canals located on river bends and in those associated with wing-dams, i.e., canals with high flow ratios (canal flow volume versus stream flow volume). Diversion/headgate configurations that create velocity barriers or some other type of obstruction can also inhibit up-canal migration out of diversions, particularly for juvenile fish (Gebhards 1959; Good and Kronberg 1986; Fleming et al. 1987; Evarts et al. 1991; Clancey 1993). Finally, the abundance, distribution, and migration of fish back to host streams are influenced by the amount of cover in a canal (Clothier 1954; Gebhards 1958 and 1959; Fleming et at. 1987; Thurow 1988).

Headgate manipulation can also influence fish loss. The highest loss of legal-size salmonids to the Pishkun Supply Canal, Montana, seemed to be associated with elevated canal flows prior to closure (Anonymous 1952). Clothier (1953b) noted that when canal flows were suddenly turned off, trout exhibited little tendency to migrate back to host streams.

Other factors that affect fish loss are linked to natural phenomena and fish behavior. Population density in the vicinity of canal intakes, migratory behavior, and streamflow all seem to be fundamentally important. Hauck (1949) and Gebhards (1959) found that population density and the proximity of spawning areas to canal intakes were factors that contributed to fish loss. Gebhards (1959) also reported that the sensitivity of chinook salmon fingerlings *Oncorhynchus tshawytscha* to lateral flows made them vulnerable to diversions and the lateral canals within them. Munther (1975) thought that losses of juvenile chinook salmon would be higher in the fall as declining water temperatures stimulated downstream migrations. Clothier (1953a and 1953b) noted that the greatest amount of movement of game fish into the Keughan and Low Line canals in Montana occurred during high water periods. Fleming et al. (1987) and Clancey (1993) reported that the coincidence of high stream discharge and the emergence of salmonid fry resulted in the active/passive diversion of fish into irrigation ditches during the drift period. Thurow (1980 and 1981) suspected that the movement of resident salmonids from Blackfoot River, Idaho, into diversions was significant during low-water years when a high percentage of existing stream flows was diverted into irrigation canals.

Losses of Resident Game Fish and Potential Impacts

Resident fish losses in irrigation ditches is not well documented. Although losses of resident game fish have been confirmed in Idaho (Hauck 1949; Gebhards 1958; Thurow 1980, 1981, 1987, and 1988; Elle et al. 1987), Montana (Clothier 1953a and 1953b; Spindler 1955; Good and Kronberg 1986; DosSantos et al. 1988; Evarts et. al 1991; Clancey 1993; Eric Reiland, personal communication, Montana State University), Oregon (Dave Nichols, personal communication, Oregon Department of Fish and Wildlife), Arizona (Roy 1989), and Canada (Fleming et al. 1987), little quantitative data on total losses, particularly in the context of population dynamics, were secured.

Numerous studies have shown that juveniles, or young-of-the-year (YOY), compose the majority of fish lost to irrigation diversions. Hauck (1949) reported that the greatest number of fish lost in diversions on the Big Wood River, Idaho, were juvenile rainbow trout *O. mykiss.* This observation was substantiated by Thurow (1988) who reported that 48% of the fish observed in canals on the Big Wood River were YOY rainbow trout. Thurow (1980 and 1981) also reported that 84% of the cutthroat trout O. *c/arki* observed in canals on the Blackfoot River were juveniles and suggested that the loss of these fish could affect recruitment. Elle et al. (1987) estimated that about 60% of the trout (rainbow, brown, and brook trout) lost to the Egin Canal on Henry's Fork, Idaho, were YOY fish. Finally, Good and Kronberg (1986) estimated that 88% of the salmonids lost in a single canal on the Bitterroot River were YOY fish (primarily whitefish - *Prosopium* spp.).

Despite the lack of quantitative data to assess the potential impacts of fish loss, at least one study suggested that loss of recruitment to irrigation diversions may be a limiting factor for host stream populations. Spoon (1987) considered the loss of YOY trout to be a major problem in the Bitterroot River, Montana. Clancey (1993) indeed documented large losses (up to 41 % of the fry passing the headgate of a single diversion) of YOY rainbow trout in canals on a section of the Bitterroot River. Although he did not directly assess population impacts (Chris Clancey, personal communication, Montana Department of Fish, Wildlife and Parks), recruitment appeared to be limiting.

While these studies did not assess population effects, theoretical analyses suggest that juvenile fish loss can have severe impacts. Jensen (1971) suggested via simulation that even a 5% increase in the mortality of 0+ brook trout S. *fontinalis* (longevity = 5 years) in Hunt Creek, Michigan, could decrease yield. Further, a large portion of production forgone in gizzard shad *Dorosoma cepedianum* (longevity = 7 years, age at maturity/recruitment = 3 years) could be attributed to the loss of age 0 fish by entrainment and impingement in a Lake Erie power plant (Jensen et al. 1988).

Losses of adult fish may also be important, although some studies suggest that larger fish comprise a minor portion of losses. Thurow (1981) reported that only 16% of the cutthroat trout observed in ditches on the Blackfoot River were >300 mm, while Elie et al. (1987) and Thurow (1988) documented that less than 10% of the trout lost to canals on Henry's Fork and the Big Wood River, respectively, were over 300 mm. Still, these studies represent only a snapshot of the losses on a limited number of diversions. Cumulative losses may be substantial and potentially deleterious, particularly when fishing mortality is taken into consideration. Quinn and Szarzi (1994) have shown that when older age classes are excessively exploited (a combination of fishing mortality and irrigation losses in this case), the percentage of older fish in a population decreases dramatically.

Alternate Methods for Reducing Losses

Significant losses of resident game fish will warrant a program characterized by cheaper, alternate methods for protecting resident stocks. Regardless of the methodology, instream habitat capable of supporting recovered fish stocks will be required. The cooperation and participation of irrigators, government agencies, and angler groups will also be necessary.

One possibility for reducing fish loss involves staged flow reductions. Clothier (1954) demonstrated that abrupt flow reductions (as opposed to instantaneous flow termination) at the end of the irrigation season prompted fish to migrate back to host streams. Finnegan (1978) noted the same response to a rapid drop in flow. Clothier (1953b) and an updated reprint issued by the Montana Department of Fish, Wildlife and Parks (Anonymous 1990) describe this procedure and advocate staged flow reductions for a period of three days prior to canal closure in conjunction with habitat removal. Shepard (1990) reported success in reducing fish losses to diversions through flow reductions on the Big Hole River, Montana, and noted that the cooperation of irrigators was vital. The method is relatively time and labor intensive because headgate manipulation and canal maintenance are required. The procedure may also be impractical in canals that have: 1) drop structures which prohibit movement beyond certain points; 2) headgate velocities that prevent exit back to the host stream; and 3) lateral canals that deter passage to the main canal (Evarts et al. 1991).

Behavioral barriers involving light and sound generating devices may represent another possibility for preventing fish loss. Past research in this area has been limited, with efforts primarily directed at reduction of turbine entrainment losses in reservoirs. Little attention has been devoted to instream study. Patrick (1985) found that coho salmon *O. kitsutch,* Atlantic salmon *Salmo salar,* and rainbow trout exhibited a strong avoidance to strobe lights in laboratory tests depending on current velocity and time of day; coho salmon and rainbow trout also exhibited a marked avoidance response at night in field tests conducted in a Canadian reservoir. Sonic devices show less promise, but the outcome of pilot tests may be system-dependent (Ross et al. 1993). Results from tests conducted on salmonids using low frequency sound have been mixed. Vanderwalker (1967) directed steelhead smolts into an irrigation bypass with air-driven vibrators running at 270 cycles per second (cps), but was unable to determine whether the fish were responding to pressure waves, low frequency sound, or water displacement. However, he found that in laboratory tests, juvenile chinook salmon showed an avoidance response and did not become habituated to low level frequencies up to 280 cps. Conversely, Stober (1969) reported that cutthroat trout displayed an initial "start" reaction to low frequency sound, but became habituated with continued exposure. Although the use of sound is complicated by species-specificity (Sullivan and Mattice 1986), a hybrid system using strobe lights and sonic devices may be effective. This was demonstrated by a combined device configuration which diverted 99% of migrant juvenile American shad *Alosa sapidissima* away from turbines at the York Haven Hydroelectric Project, Pennsylvania (Anonymous 1994). Light and/or sound devices require electrical power which would inflate costs, but use of solar panels may be feasible. Operation of these devices could also be limited to spring and fall periods when the potential for entrapment may be higher due to spawning, downstream migration, or other behavioral movements.

Screening technologies are prohibitively expensive, but cheaper versions of current systems are being developed. Bomford and Lirette (1991) described an inclined plane design that was installed in a 1,500 cfs hydroelectric diversion canal at a cost of about $200 Canadian per cfs (1986 dollars). This screen did not require power or full-time operator attendance, and was 80% effective in screening test fish (age 1 + coho salmon). The Oregon Department of Fish and Wildlife has developed relatively cheap fish screens for drainages that lie outside of the Columbia River Basin (Dave Nichols, personal communication, Oregon Department of Fish and Wildlife). One system designed for use on smaller canals involves a six-screen panel. Although it must be manually cleaned, it only costs $1,000. A boxed rotary drum screen has also been designed for use on larger canals at a cost of $7,000 to $8,000.

The diversity of diversion/headgate configurations make it unlikely that any one methodology could be adapted to all situations. A development and evaluation program would necessarily require numerous tests under a variety of conditions.

Benefit Potential

If there are significant losses of resident game fish to irrigation diversions, the "savings" engendered by a program to protect resident stocks may be constrained by conditions in host streams, particularly for small fish species and juveniles. Highly variable flow regimes and other complications associated with irrigation withdrawals and natural phenomena can effect fish differently depending on the way they utilize the stream, and can act to reduce community complexity.

Abiotic, rather than biotic factors appear to control fluvial ecosystems, and summer intermittency is a primary limiting factor for salmonids (Binns 1994). Bain et al. (1988) reported that the density of small fish species and size classes decreased when confronted with unstable shallow-water habitats. Moore and Gregory (1988) documented that YOY cutthroat trout in Mack Creek, Oregon, were virtually eliminated from stream sections where lateral habitat was reduced. Irrigation withdrawals in spawning tributaries may also limit recruitment through interruption of spawning activities or desiccation of redds (Clancey 1988 and 1993; Byorth 1990). Flow reductions can also promote siltation and high water temperatures (Kraft 1972), and inefficient irrigation practices can result in silt-laden return flows (DosSantos et al. 1988). These perturbations can impact reproductive success and availability of interstitial cover (Saunders and Smith 1956), as well as promoting temperature-dependent mortality. Diversions, canals, and dams on mainstem rivers and tributaries can also reduce gravel recruitment and block access to spawning/rearing habitat (DosSantos et al. 1988; Thurow 1988).

Even if fish avoid direct habitat impacts, they may still be vulnerable to indirect flow effects through the food web (Weisberg and Burton 1993). Wipperman (1968) thought that competition for food and space may have been intense in a dewatered section of Blacktail Creek, Montana, and suspected that flow reductions affected the growth rates of YOY brook trout. Moore and Gregory (1988) found that growth rates of YOY cutthroat trout in Mack Creek were generally lower in reduced-lateral habitat treatment sections; however, growth was unaffected by density. Predation on fry by larger fish can also be considerable, particularly when reduced flows force entire populations into a few pools (Rinne 1980).

The effects of flow reductions on catchable-sized fish may be of little consequence if suitable refuges are available. Wipperman (1968) reported that dewatering triggered an upstream movement of yearling and older brook trout and rainbow trout in Blacktail Creek, Montana. He suggested that short term dewatering may not be serious in streams with adequate pool habitat, provided temperatures are not critical or streams do not go dry. Kraft (1972) showed that age I and older brook trout in Blacktail Creek moved from runs to pools when 90% of normal flows were diverted, and that flow reductions did not result in noteworthy mortality. Binns (1994) reported that even though the density of catchable brook trout decreased in Beaver Creek, Wyoming, after an extended drought, density was still higher than before habitat development.

DISCUSSION

Although losses of catchable-sized game fish to irrigation diversions may or may not be significant, the literature suggests that irrigation practices reduce recruitment. The mechanisms may express themselves directly through losses to diversions and/or indirectly through habitat perturbations in host streams.

If losses are shown to be significant, then the protection provided by merely blocking access to irrigation diversions or furnishing a means of escape may be insufficient, regardless of the life stages affected. The need for adequate amounts of suitable instream habitat capable of supporting recovered fish stocks begs for minimum streamflows and healthy riparian zones. Nonetheless, the first step in solving the problem is determining whether one exists. Quantification of game fish losses to irrigation diversions in the context of population dynamics is therefore important.

RECOMMENDATIONS

Age 0+ fish may constitute the majority of losses to irrigation diversions, but the difficulties encountered in estimating numbers for this age group in all but the smallest host streams will be daunting. Even if we were able to estimate age 0 losses in the context of population levels, the results would be difficult to interpret without knowledge of stock-recruit relationships for a given watershed. Still, we should attempt to estimate losses of age 0 fish whenever possible and evaluate them over a range of possible stock-recruit functions. We should also collect age-structured instream abundance, diversion loss, and harvest information to use in dynamic pool and program MOCPOP analyses. The following approach could be used:

1. Choose systems that have canals possessing a diversity of physical characteristics, population life history data complete enough for modeling, viable fisheries in proximity to canals, and cooperative irrigators.

2. Estimate concurrent age-structured instream abundance and diversion losses using trapping and electrofishing population estimates. Estimate numbers of age 0 fish in diversions and host streams whenever possible.

3. Estimate age-structured harvest parameters concurrent with instream population and loss estimates. Treat losses as a component of the harvest.

4. Estimate sustainable exploitation rate using dynamic pool models and/or impacts on future harvest using program MOCPOP.

Steps 2 through 4 need only be applied to target species that appear most frequently in harvests and canal catches. Dynamic pool analyses will indicate a problem if harvests and canal losses combined are not sustainable, but harvests alone are. The MOCPOP analyses will demonstrate the potential impacts of canal losses on future harvests.

LITERATURE CITED

Anonymous. 1952. Fish stranded by the closure of the Pishkun Supply Canal, north fork of the Sun River, Montana. U.S. Department of the Interior, Fish and Wildlife Service. Billings.

Anonymous. 1990. Methods to reduce trout losses in irrigation diversions. Montana Department of Fish, Wildlife, and Parks. Helena.

Anonymous. 1994. 1993 evaluation of behavioral fish protection technologies at the York Haven Hydroelectric Project. Final Report. Prepared by Stone and Webster Environmental Technology and Services, Boston, Massachusetts for the Metropolitan Edison Company.

Bain, M.B., J.T. Finn, and H.E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69:382-392.

Binns, N.A. 1994. Long-term responses of trout and macrohabitats to habitat management in a Wyoming headwater stream. North American Journal of Fisheries Management 14:87-98.

Bomford, J.A., and M.G. Lirette. 1991. Design, operation, and evaluation of an inverted, inclined, outmigrant fish screen. American Fisheries Society Symposium 10:228-236.

Byorth, P.A. 1990. An evaluation of Yellowstone Cutthroat Trout production in three tributaries of the Yellowstone River, Montana. Master of Science Thesis, Montana State University. Bozeman.

Clancey, C.G. 1988. Effects of dewatering on spawning cutthroat trout in tributaries to the Yellowstone River, Montana. American Fisheries Society Symposium 4:37-41.

Clancey, C.G. 1993. Statewide fisheries investigations: Bitterroot Forest inventory. Job Completion Report, 1991-1992. Montana Department of Fish, Wildlife, and Parks, Project F-46-R-4. Helena.

Clothier, W.D. 1953a. Fish loss and movement in irrigation diversions from the West Gallatin River, Montana. Journal of Wildlife Management 17:144-158.

Clothier, W.D. 1953b. Methods of reducing fish losses in irrigation diversions. Montana Fish and Game Department. Helena.

Clothier, W.D. 1954. Effect of water reductions on fish movement in irrigation diversions. Journal of Wildlife Management 18:150-160.

DosSantos, J.M., J.E. Darling, and D. Cross. 1988. Lower flathead system fisheries study. Final Report, 1983-1987, Volume II. Contract No. DE-AI79-83BP3983O. Prepared for the U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Portland.

Elie, S., C. Corsi, and D. Aslett. 1987. Regional fisheries management investigations, region 6 (Idaho Falls) rivers and streams investigations - Big Lost River survey. Job Performance Report, 1986-1987. Idaho Department of Fish and Game, Federal Aid in Fish Restoration, Project F-71-R-11, Job No. 6(IF)-c^2. Boise.

Evarts, L., F. Durgeloh, D. Morigeau, and J. DosSantos. 1991. Irrigation canal fish loss assessment. Bureau of Indian Affairs, Confederated Salish and Kootenai Tribes.

Finnegan, R.J. 1978. A study of fish movement stimulated by reduction in rate of flow. Fisheries and Marine Service (Canada) Data Report 98.

Fleming, J.O., J.S. Nathan, C. McPherson, and C.D. Levings. 1987. Survey of juvenile salmonids in gravity-fed irrigation ditches, Nicola and Coldwater river valleys, 1985. Canadian Data Report of Fisheries and Aquatic Sciences No. 622.

Gebhards, S.V. 1958. Fish loss in irrigation canals on the Salmon River drainage as determined by electrical shocker. Special Report. Idaho Department of Fish and Game, Vol. 4, No. 45. Salmon.

Gebhards, S.V. 1959. The effects of irrigation on the natural reproduction of chinook salmon *(Oncorhynchus tshawytscha)* in the Lemhi River, Idaho. Master of Science Thesis, Utah State University. Logan.

Good, W.R., and C. Kronberg. 1986. Inland fisheries resources and irrigation diversions. Part one: salmonids. Bitterroot Trout Study, Hamilton, Montana.

Hauck, F. 1949. A survey of fish losses in irrigation diversions of Big Wood River in determining the placement of an experimental fish screen. Idaho Department of Fish and Game. Boise.

Jensen, A.L. 1971. The effect of increased mortality on the young in a population of brook trout, a theoretical analysis. Transactions of the American Fisheries Society 3:456-459.

Jensen, A.L., R.H. Reider, and W.P. Kovalak. 1988. Estimation of production foregone. North American Journal of Fisheries Management 8:191-198.

Kraft, M.E. 1972. Effects of controlled flow reduction on a trout stream. Journal of the Fisheries Research Board of Canada 29:1405-1411.

Moore, K.M.S., and S.V. Gregory. 1988. Response of young-of-the-year cutthroat trout to manipulation of habitat structure in a small stream. Transactions of the American Fisheries Society 117:162-170.

Munther, G.L. 1975. Fishery effects of irrigation diversions and related structures - an interim fisheries management plan for the Sawtooth National Recreation Area. U.S. Department of Agriculture, Forest Service, Sawtooth National Forest. Ketchum.

Patrick, P.H. 1985. Behavioral systems to guide or divert fish at hydroelectric facilities. Report No. 352G440. Prepared by Ontario Hydro for the Canadian Electrical Association. Montreal, Quebec.

Quinn, T.J., II, and N.J. Szarzi. 1994. Determination of sustained yield in Alaska's recreational fisheries. In: G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn (editors). 1993. Proceedings of the international symposium on management strategies for exploited fish populations. Alaska Sea Grant College Program Report No. 93-02, University of Alaska. Fairbanks.

Rinne, J.N. 1980. Spawning habitat and behavior of Gila Trout, a rare salmonid of the Southwestern United States. Transactions of the American Fisheries Society. 109:83-91.

Ross, Q.E., D.J. Dunning, R. Thorne, J.K. Menezes, G.W. Tiller, and J.K. Watson. 1993. Response of alewives to high frequency sound a power plant intake on Lake Ontario. North American Journal of Fisheries Management 13:291-303.

Roy, R.R. 1989. Presence of fish in irrigation diversions from the Verde River and Wet Beaver Creek, Arizona. Master of Science Thesis, University of Arizona. Flagstaff.

Saunders, J.W., and M.W. Smith. 1956. Changes in a stream population of trout associated with silt. Journal of the Fisheries Research Board of Canada 22:395-404.

Schill, D. 1984. Evaluating the anadromous fish screening program on the upper Salmon River. Special Report. Idaho Department of Fish and Game. Boise.

Schill, D. 1995. Research project on irrigation diversion losses and possible effects on Idaho fisheries. Pre-proposal. Idaho Department of Fish and Game. Boise.

Shepard, B. 1990. The catchall: of ditches and trout. Montana Outdoors 21(3):11-12.

Spindler, J.C. 1955. Loss of game fish in relation to physical characteristics of irrigation-canal intakes. Journal of Wildlife Management 19:375-382.

Spoon, R.L. 1987. Evaluation of management of water releases for Painted Rocks Reservoir, Bitterroot River, Montana. Final Report. Contract No. DE-AI79-83BP13076. Prepared for the U.S. Department of Energy, Bonneville Power Administration by the Montana Department of Fish, Wildlife, and Parks, Portland.

Stober, Q.J. 1969. Underwater noise spectra, fish sounds, and response to low frequencies of cutthroat trout *(Sa/mo* dark') with reference to orientation and homing in Yellowstone Lake. Transactions of the American Fisheries Society 4:652-663.

Sullivan, C., and J. Mattice. 1986. Assessment of downstream migrant fish protection technologies for hydroelectric application. Research Project 2694-1. Prepared by Stone and Webster Engineering Corporation, Boston, Massachusetts, for Electric Power Research Institute, Palo Alto, California.

Thurow, R. 1980. River and stream investigations: Blackfoot River investigations. Job Performance Report, 1978-1979. Idaho Department of Fish and Game, Federal Aid to Fish and Wildlife Restoration, Project F-73-R-1, Study IV. Boise.

Thurow, R. 1981. River and stream investigations: Blackfoot River investigations. Job Performance Report, 1979-1980. Idaho Department of Fish and Game, Federal Aid to Fish and Wildlife Restoration, Project F-73-R-2, Study IV. Boise.

Thurow, R. 1987. River and stream investigations: Wood River investigations. Job Performance Report, 1986-1987. Idaho Department of Fish and Game, Federal Aid to Fish Restoration, Project F-73-R-9, Study V. Boise.

Thurow, R. 1988. River and stream investigations: Wood River investigations. Job Performance Report, 1986-1987. Idaho Department of Fish and Game, Federal Aid to Fish Restoration, Project F-73-R-10, Study V. Boise.

Vanderwalker, J.G. 1967. Response of salmonids to low frequency sound. In: W.N. Tavolga (editor). Marine bio-acoustics, Vol. 2, Pergamon Press. New York.

Weisberg, S.B., and W.H. Burton. 1993. Enhancement of fish feeding and growth after an increase in minimum flow below the Conowingo Dam. North American Journal of Fisheries Management 13:103-109.

Wipperman, A.H. 1968. Southwest Montana fishery study: effects of dewatering on a trout population. Job Completion Report, 1967-1968. Montana Fish and Game Department, Aid in Fish and Wildlife Restoration, Project F-9-R-16, Job IV. Helena.

Submitted by:

John A. Der Hovanisian
Fishery Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Steven M. Huffaker, Chief
Bureau of Fisheries

Allan R. Van Vooren
Fisheries Research Manager