Report of the Independent Scientific Advisory Board

Review of the U.S. Army Corps of Engineers
Capital Construction Program

Part III.

A. Adult Passage

Independent Scientific Advisory Board
for the Northwest Power Planning Council
and the National Marine Fisheries Service

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INTRODUCTION

The Northwest Power Planning Council (the Council) has been directed by the Congress, in the Conference Report accompanying the Energy and Water Development Appropriations Act for the Fiscal Year 1998, to review "the major fish mitigation capital construction activities proposed for implementation at the Federal dams in the Columbia River Basin." The Council was directed to conduct this review by June 30, 1998, with the assistance of the Independent Scientific Advisory Board (ISAB).

We previously submitted reports, ISAB 98-4, covering questions from the Council about the ecosystem context for mainstem fish passage measures as well as the questions about the specific measures for John Day and Bonneville dams, and ISAB 98-7 and 98-8, respectively, covering the surface collection and gas saturation questions.

This report (ISAB 99-2) addresses issues concerning adult passage as part of our review of the Corps' capital construction program. With respect to specific adult passage measures identified for improvement, the ISAB had information from the "Technical Background Paper for Review of the Corps Capital Construction Program" addressed to the System Coordination Team (SCT) from Council staff on February 9, 1998. We also had the Corps of Engineers Work Plans for 1997 and 1998, which identified measures for improvement of adult passage that the Corps proposed to undertake.

We also were aided in our review of adult fish passage improvements through a briefing by Dr. Ted Bjornn (University of Idaho) and Lowell Stuehrenberg (NMFS) on November 16, 1998, that was attended by Corps representatives. In addition, we had Council Staff's Technical background paper (NPPC-document # 97-18) and reports on radio-tracking of Snake River fall chinook by Glen Mendel of the Washington Department of Fish and Wildlife (memo of November 16, 1998 to the ISAB) and the conversion factors on dam counts from Mike Matylewich (Columbia River Intertribal Fish Commission). The latter two reports were solicited by the ISAB. We also greatly appreciate the assistance of Larry Basham of the Fish Passage Center in gaining an understanding of the problems encountered in monitoring of numbers of adults passing the dams.

QUESTIONS TO THE ISAB

The immediate questions before the ISAB with respect to adult passage are:

1) Are the proposed measures for improvement of adult passage at the Corps projects necessary and desirable; and
2) Do they represent a complete list of necessary and desirable measures to assist in accomplishing the region's goals for restoration and recovery?

RECOMMENDATIONS

The ISAB's technical evaluation concludes that the subject of adult passage at Columbia River dams has not been adequately dealt with. There appears to be a widely held assumption in the region that problems of adult passage have, for the most part been solved. The Corps of Engineers' Capital Construction budget for adult passage addresses what we consider to be minor fixes and adjustments of existing systems. These planned site-specific measures are supportable, but probably are not sufficient to ensure that adult spawning migrations are unimpeded and completed with minimal mortality induced by passage. Additional evaluation, field research, and (probably) capital projects will be needed before the problems of adult passage may be considered to have been adequately addressed.

Question 1. Are the proposed measures for improvement of adult passage at the Corps projects necessary and desirable?

Answer. Yes. While the proposed measures are all relatively small changes and improvements to existing adult fish passage systems, this is not to minimize their importance. Each appears to offer an improvement in the context of the specific dam site and fishway configuration in response to problems that have been observed. Many address what might be considered operations and maintenance issues, or provide back-up systems to reduce the possibility of interruption of fishway operation. The list was arrived at with input from the System Configuration Team (SCT). [1]

[1] The Corps' Capital Construction Program is influenced by recommendations from a regional team, the System Configuration Team (SCT). The SCT was established to fulfill the requirements of the NMFS 1995 Biological Opinion (FCRPS Biological Opinion reasonable and prudent action #26), and to serve as a technical coordinating

Recommendation. Implement the sixteen capital construction measures proposed by the Corps to achieve improved adult passage at individual projects.

While the sixteen proposed projects are necessary and desirable, they do not attempt to address larger-scale problems and uncertainties for upstream migrating adult salmon and steelhead.

Question 2. Do the proposed measures for improvement of adult passage at the Corps projects represent a complete list of necessary and desirable measures?

Answer. Probably not. At any specific dam site or fishway, there are undoubtedly additional measures that could be adopted to maintain or marginally improve fish passage performance. On a broader scale, major or dramatic changes may be desirable if better data and further analysis shows that losses of adults associated with passage is a larger cause of poor salmon production than has previously been recognized. Our review shows that the questions associated with adult passage are not well resolved, and better information is needed than we now have available to us.

Problems with adult passage deserve more attention than they have received. Many questions remain about the effects of delay or extra energy expenditure en route upstream on the ultimate ability of adults to spawn successfully. We are aware of no research program that is designed to satisfactorily answer these questions. Uncertainties about adult passage must be viewed in a larger context than simply a project-by-project review of desirable modifications of ladders and their associated facilities at mainstem and Snake River dams. For example, are the present measures successful in allowing an adequate number of adult salmon and steelhead to reach their spawning grounds in a physical condition required for successful spawning?

Counts of adult fish in the ladders are the primary source of information on the numbers of fish that are successful in passing the dams. These numbers are critically important for monitoring the effectiveness of passage measures for adults, for evaluating effectiveness of restoration and recovery measures, and for setting and maintaining appropriate spawning

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committee in NMFS Columbia Basin Anadromous Fish Program Implementation process of February, 1996. The SCT is responsible for reviewing, discussing and making recommendations to whatever agency is responsible, for implementation of physical improvements to fish passage facilities in the Columbia River Basin, based on actions or measures identified in the NMFS FCRPS Biological Opinion, and Recovery Plan; The Northwest Power Planning Council's Fish and Wildlife Program; and the tribal 1995 Columbia River Anadromous Fish Restoration Plan. Membership on the SCT is open to the Corps of Engineers, Northwest Power Planning Council, NMFS, BPA, Bureau of Reclamation, USFWS, and state and tribal fishery agencies. The SCT is co-chaired by representatives from NMFS and the Council.

escapement goals. Our review of those counts led to a concern that these numbers probably are not sufficiently reliable for the purposes for which they are being used.

Recommendations.

a. More emphasis should be placed on monitoring and evaluation of adult salmon numbers by the Corps, the Council, NMFS and the harvest management entities.
b. Include an annual operating project to determine the accuracy and precision of the counts of adult salmon passing the dams. Install PIT tag detectors for adults at each project to provide data for estimates of survival in upstream passage, and to adjust the counts.
c. Critically evaluate sources of error in estimation of escapement to spawning grounds and hatcheries.
d. Support research to record temperatures experienced by adults during upstream migration.
e. Consider reestablishing a bioengineering test facility for adult fish passage in the Columbia River basin where engineering designs for passage improvement can be tested in full-scale with adult salmon. Fish behavior is a critical element in fish passage design and it cannot be ignored. Current investigations by the Corps' using scale-models at their Vicksburg, Mississippi facility do not appear to incorporate fish behavior to this degree.

DESCRIPTION OF THE REPORT

We address two principal issues in this report. The first relates to the Corps' capital construction program as described for specific projects in the Corps' Work Plans for 1997 and 1998 and the Council staff's Background Paper. The second relates to a larger perspective, the monitoring of adult passage on a systemwide basis through the facilities at the Corps projects. The report is accordingly divided into two sections, Section 1: The Corps of Engineers Capital Construction Program for 1997 and 1998, and Section 2: Monitoring and Evaluation of Adult Passage in the Columbia and Snake Rivers. The second section addresses the issue of larger problems in adult passage that may exist. These sections are preceded by a background section that describes basic ecological factors relevant to adult fish passage at the Columbia and Snake river mainstem projects.

BACKGROUND ON ADULT PASSAGE

Adult salmon and steelhead return from the ocean with considerable precision to the streams, most often to the very locations within streams where they originated. It is well established that their positive response to flow directs their movements upstream, and that their sense of smell is the primary mode of identifying their home stream once they enter freshwater (Hasler, et al., 1978). Construction and operation of the hydroelectric system has altered patterns of flow in two ways, by putting most of the flow through powerhouses or spillways where the dams themselves are obstacles to passage, and by creating reservoirs where velocities of flow and turbulence are reduced. In the authorizations for construction of the Corps of Engineers projects on the mainstem Columbia and Snake rivers, Congress specified that passage for adult salmon is to be provided at all of them except Chief Joseph and Grand Coulee dams. Fish ladders were included in the capital construction costs at each of the eight other projects. The engineering design of ladders for salmon is an ancient art, and there is a tendency to think of it as being well perfected. However, provision for fish passage at dams as high as 100 feet, such as Bonneville Dam had never before been attempted (Mighetto and Ebel, 1995).[2] Grand Coulee Dam, at 300 feet was thought to be too high to be provided with effective fish ladders (Whitney et al., 1997).

Description of the process of development of the fish ladders at Bonneville Dam brings out the uncertain nature of the process (Mighetto and Ebel, 1995). In 1995, the Corps constructed a special laboratory for fisheries engineering research (FERL) at Bonneville Dam to resolve some of the uncertainties in fish ladder design with respect to such factors as dimensions of the fishway needed for a given number of fish, maximum velocities of flow, levels of turbulence, the maximum grade that salmon may ascend, and the maximum length of a ladder with a given grade that may be ascended by salmon.[3] Obviously, the ladders at Bonneville Dam

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[2] Rock Island Dam on the mid-Columbia reach predates Bonneville Dam. Though not quite as high, some of the same problems were encountered with design and construction of ladders there.

[3] The laboratory continued to operate until 1980 when heavy snow collapsed the building and its functions were transferred to the Waterways Experiment Station in Mississippi (Mighetto and Ebel, 1995). A major, and possibly critical, effect of transferring the engineering faciility to Mississippi was to remove the work from the fish that the projects are to protect. The move eliminated the ability to directly test engineering designs with fish behavior in situ. Increasing reliance has been placed on physical models that test hydraulics at reduced scale, forgetting that fish behavior cannot be scaled down. It is essential that fish behavior be reinstated as an integral part of the design and testing work.

(completed in 1938) were designed and constructed before information from these rigorous studies was available.[4] The volume of water that can be accommodated in the ladders themselves is not sufficient alone to attract the adults to the ladder entrances in the face of the large volumes exiting the Bonneville powerhouse and spillway. Additional "attraction" water had to be provided in the tailrace near the ladder entrances, either from special pumps or outfalls of small generators to help the fish locate the ladders. Once in the ladders, the adults are provided with velocities of flow that will stimulate upstream movement, in steps or gradients which they are known (by the laboratory studies and observations elsewhere) to be able to negotiate. The science and art establishing criteria for adult salmon passage at such large facilities as those on the Columbia River are relatively new. The challenge is to provide the appropriate hydraulic cues to stimulate swimming behavior, but to remain within the physical capabilities of the fish throughout the length of the fishway. We have more to say on that subject in Section 2.

RELATIVE IMPORTANCE OF ADULT PASSAGE

Rebuilding salmon populations in the Columbia River basin is most likely to be successful when conditions are improved simultaneously across the spawning, rearing and migratory habitats. Simultaneous improvements in freshwater habitat quality to increase egg to smolt survival of wild spawners, increased juvenile salmon production, and improved survivals during downstream passage through the hydroelectric system would be necessary to permit rebuilding depressed salmon runs (Fryer and Mundy 1993). By the same token, improved survival of adults passing upstream would likely enhance the probability of rebuilding runs. However, even a relatively large decrease in any single mortality source without decreases in the others is unlikely to be effective in rebuilding salmon numbers.

The reason that single factor approaches to rebuilding salmon runs are unlikely to be effective is due to the cumulative nature of the impacts on population growth of wild salmonids. In addition, there are numerous other factors that interact to affect salmon abundance, such as the recently discovered predation by Caspian terns in the lower river, and cyclic changes in ocean conditions, to name two. Variability in the effects of these factors may obscure results of changes

[4]The designs were developed by extension of principles developed with smaller fishways and intuitive projections of Milo Bell (engineer) and Harlan Holmes (biologist), (Mighetto and Ebel 1995).

in survival rates in the river in the short term. Nevertheless, we are convinced that corrective management measures are essential where possible at all the stages of the life cycle wherever there has been an impact reducing survival or carrying capacity.

The hydroelectric system presents two opportunities to improve survivals of salmon and steelhead during the life cycle, once as juveniles and later as adults. Smolt survivals are tightly linked to changes in marine conditions, which have been highly variable - apparently due to factors such as climate and its effects on ocean conditions (Hare, Mantua, and Francis, 1999). Once the adults begin their upriver migration, there is no such linkage of their survival rate to these highly variable and extreme conditions, although adult survival is affected in the river by disease, harvest, and other river conditions, which we previously discussed. However, adult salmon in the hydroelectric system are not more than five months from reproduction, so there is less time during which mortality factors can act to prevent adults from completing the life cycle. Consequently, improvements in adult passage and reductions in adult in-river mortality may yield greater biological benefits than juvenile passage improvements.

Each adult salmon passed to the spawning grounds is the biological equivalent to successfully passing hundreds of smolts to below Bonneville Dam. For example, using survival data from the Lower Snake River Compensation Program, juvenile spring chinook are currently expected to return as adults to the Snake River at the rate 0.65%, or roughly seven adults per thousand juveniles, as an optimistic figure. Based on this rate of return a loss of 154 smolts in hydroelectric project passage is equivalent to the loss of one adult spring chinook returning to the Snake River Basin. The efficiency is even greater for fall chinook. Using reasonable figures for ocean harvest and natural mortality rates applied to fall chinook in the ocean, the loss of a four-year old fall chinook returning to the Basin is equivalent to 1500 smolts (assuming a 1% marine survival of smolts to Age 2 recruits) successfully passed through the hydrosystem. These ratios will vary with species and stocks but the examples serve to demonstrate the cost of losing adults once they have returned to the Columbia River.

Simple numerical ratios of juveniles per adult return, such as 154:1, do not capture the relative evolutionary significance of juveniles as compared to adults. Each successful spawner has demonstrated that it is capable of surviving the challenges of the full life cycle, whereas a smolt has not.

The region has devoted major efforts to improve survival of juvenile salmon in their downstream migration. Given the greater biological value of a returning adult than an outmigrating juvenile, similar efforts to keep adult survival as high as possible and to expedite their passage to the spawning grounds in as good condition as possible may be fruitful. After all, the primary goal for increasing survival of juveniles is to produce more adult spawners. Intervention to improve adult survival is likely to be a good investment in terms of expected increases in population growth over the long term.

RIVER CONDITIONS AFFECTING ADULT MIGRATION

In addition to the concrete barriers to upstream migration and the slower velocities of flow in the reservoirs created by the dams, there are other effects of the hydroelectric system on adult and juvenile salmon and steelhead. Operation of the hydroelectric system has led to supersaturation of gases in the water and increases in temperature. Supersaturation of gases is brought about by spill at the dams, where the spilled water plunges into pools below the dam and forces entrapped air under pressure into the water. Increased levels of spill have been provided in recent years for the benefit of juvenile salmon whose rate of survival is increased by passage in spill. At the same time, these high spill levels can lead to difficulties for the adults as they encounter high velocity water shortly after exiting the upstream end of the fishway which sometimes leads them to fall back downstream. For example, Liscom et al. (1985) found higher rates of fallback of chinook at Bonneville Dam when there was spill than when there was no spill. Swan et al. (1994) found that adult sockeye showed a 13% rate of fallback when there was spill at Wells Dam, whereas no fallback was observed when there was no spill. Water temperatures in the reservoirs increased as the hydroelectric system was developed. Late summer water temperatures in some years now reach lethal limits for salmon. Both supersaturation of gases and elevated water temperatures currently present obstacles to upstream migration of adult salmon at times. No completely satisfactory method of dealing with these obstacles is available at this time. Problems such as these that go beyond the individual project level are discussed further in the text below.

1) Flow

It is the adults' natural tendency to move against the flow in their upstream migration. Intuitively, transformation of most of the free-flowing river to slower-moving reservoirs through development of the hydroelectric system should ease the burden on adults and allow more rapid upstream movement, as long as water quality is maintained and the necessary directional and olfactory cues are present.[5] Recent studies by Bjornn (briefing to ISAB on radiotelemetry studies of adult migration timing) suggest this might be so. On the other hand, the adults' efforts to locate fishway entrances at dams and to successfully navigate the transition from tailwater to fishway to reservoir have historically added delays and additional sources of mortality. On balance, it is not yet possible to determine what the net effect has been to the adults in their complete upstream journey.

Flow characteristics (volume, velocity, turbulence, etc.) relative to the ability of adults to detect and respond accordingly were generally described in laboratory studies (Mighetto and Ebel, 1975). Despite documented loss of upstream orientation at the upstream ends of fishways in quiescent dam forebays (shown by radio telemetry) and fallback of adults through turbine intakes and spillways (leading to delay and mortality), there has been little application of the induced-attraction-flow concept to adult guidance in forebays, once the fish have exited the ladders. Induced flows for salmonid directional guidance in dam forebays should be useful for both juveniles and adults (Coutant 1998). It should provide a method to make the dam forebay more "normative" (ISG 1996) for adults, which would reduce fall back and delay and increase adult survival during upstream migration. Both provision of attraction flows and selection of its source might be important to provide necessary hydraulic and olfactory cues. The concept appears worthy of additional study.

2) Temperature

Recently, the Corps of Engineers initiated a Snake River Water Temperature Control Project that was subsequently continued by the Environmental Protection Agency with support

[5] The significance of olfactory cues as aids to upstream migration of adult salmon in a highly regulated river, such as the Columbia River, may not have received the attention it deserves. As an example of the possible implications, Chapman et al. 1997 found that juvenile chinook released on the north side of the river below Bonneville Dam were more likely to choose the north ladder as their passage route than fish emigrating freely in-river. The mechanism for their ability to locate that route deserves further study. Olfactory cues might be one possible explanation.

from National Marine Fisheries Service (Karr et al. 1998). High water temperature may be a greater factor in salmonid declines than has been appreciated. Upstream migrants, particularly Snake River summer and fall chinook and summer steelhead, experience warmer temperatures for a longer duration during migration than they experienced prior to construction of the major upstream water storage projects. Delay of summer chinook and steelhead at the mouth of the Snake River in summer by high Snake River temperatures has been documented (Stuehrenberg et al. 1978). Similar delay of sockeye salmon at the mouth of the Okanogan River has been documented (Swan et al., 1994). In addition, the effects of altered annual temperature regimes created by the reservoirs on timing of migration may reduce the overall fitness of sockeye salmon populations in the Columbia Basin (Quinn and Adams 1996).

Hatchery personnel have long recognized that chinook salmon held before spawning at temperatures above 60°F (15.6°C) have a lowered reproductive potential (Boles 1988). The Snake River regularly exceeds this temperature in summer during the migration season (Karr et al. 1998), and even exceeds temperatures in the lethal level (>70°F (21°C)) for adult salmon and steelhead (Coutant 1970). Fish ladders regularly exhibit temperatures a few degrees higher than mainstem river temperatures (see separate discussion), and some fish ladders may be substantially above the upper incipient lethal temperature of 68°F for long periods of time. For example the temperature in one of the fish ladders at John Day Dam exceeded 70°F for 61 days in the summer of 1996 (Dalen et al. 1996 in Karr et al. 1998).

Pre-spawning mortality could be a function of the increased energy expenditure experienced by immigrants as a result of elevated temperatures resulting from impoundment (Karr et al. 1998). Higher temperatures cause salmon to use limited bodily energy reserves faster, and they also increase the pathogenecity of warm water disease organisms (Karr et al. 1998). Due to the migratory timings of adults and juveniles, summer and fall chinook, coho and sockeye are particularly vulnerable to problems associated with prolonged elevation of mainstem water temperatures. Adult spring chinook are vulnerable to water temperature problems in the tributaries where loss of riparian vegetation and alteration of stream hydrology contribute to prolonged elevation in temperatures.

Six years of observations (1991–1996) on the cooling effects of controlled releases of cold water in summer from the hypolimnion of Dworshak Reservoir (Clearwater River basin, tributary to the Snake River) have been analyzed (Karr et al. 1998). The results have shown success, with lower Snake River reservoir and dam scroll-case temperatures lowered as far downstream as Ice Harbor Dam by 3-5 °F (1.7 – 2.8°C) (Karr et al. 1998). The cooled river is closer to acceptable migration conditions for adult salmon, but is still above temperatures considered ideal for migration and optimal reproductive success (Boles 1988).

However, actual temperatures experienced by adult migrants in the mainstem are not well understood. Stratification of temperatures in the reservoirs of the lower Snake River in July, August and September provides the opportunity for migrating salmon to avoid high temperatures while seeking temperatures appropriate to homeostasis (Karr et al. 1998). Adult spring chinook have been shown to occupy cool thermal refuges (microhabitats of cooler water) while holding during the summer prior to spawning in tributary waters such as the upper Yakima River (Berman and Quinn 1991). The historical Columbia and Snake rivers undoubtedly had numerous cool refuges in seeps, back-channels, and sloughs, many of which have been drowned or eliminated by impoundments. Alternative proposals for hydrosystem configuration and operation could contribute to protection or loss of such thermal refuges.

The technology is available to record temperatures experienced by adult salmon during migration, and such studies would be valuable additions to our understanding and preparation for additional mitigating actions. For example, temperature-sensing ultrasonic and radio transmitters allow external monitoring of fish body temperatures or water temperatures occupied, so long as the transmitter signal is received by a monitoring station or manual tracker (Coutant and Carroll 1980; Schaich and Coutant 1980).

Another technique is to insert miniature temperature recorders (archival tags) into a fish, which can be retrieved at a later date and the thermal history downloaded to a personal computer (technology available from several sources). Externally tagging adult salmon and steelhead with commercially available quarter-sized recording thermographs as they enter the hydroelectric system at Bonneville Dam would provide a complete temperature record during the migration (Karr et al. 1998). External thermographs could be collected without killing the fish by using the fish trap at Lower Granite Dam, or from carcasses on the spawning grounds and at hatcheries. On the spawning grounds, association of temperature doses with spawning success as measured by gamete retention in dead fish, could provide insight on the role of temperature elevation in salmon extirpation. Unfortunately, this technology has the problem of recovering only the survivors, so the information needs to be interpreted accordingly. Fish that did not survive may have experienced a different temperature regime than those that survived to the point of tag recovery.

A major concern is the expense of applying large numbers of recording thermographs to mixtures of stocks at Bonneville in an attempt to get some recordings from fish bound for the Snake River. Adult PIT tag detection capability at the federal adult fish handling facility at Bonneville Dam (FERL) now makes it feasible to identify some of the salmon bound for the Snake River prior to tagging with the archival tag (recording thermograph). Research had begun to develop a transponder tag (similar in operating principle to the PIT tag) that would archive temperature data and would download the information at detectors located in fish ladders. However, funding for the development is no longer available. This technology would ensure that data were obtained from fish that did not survive to the final destination.

Identification and protection of thermal refuges that might exist for upriver migrants would be one objective of such research. Attraction to such refuges may contribute to delays in migration identified by other monitoring techniques, such as the radio tracking studies, but be vital for maintaining tolerable temperatures during migration. Such refuges are not well defined nor their roles understood for migrating salmon and steelhead in the Columbia Basin, but they are well known elsewhere to be critical for survival of many coldwater fish in warm seasons.

3) Gas Supersaturation

As discussed in a separate report on the Corps Gas Abatement Program (ISAB 98-8), spilling of water at dams during the high spring runoff season and during managed spill for juvenile fish passage can cause water in the mainstem Columbia and Snake rivers to become supersaturated with atmospheric gases. Levels in the 120-140 percent range were common during the high-flow years of 1996 and 1997 from above Lower Granite Dam to below Bonneville Dam. Even in normal-flow years, levels are nearly always above the water quality standard of 110%. This supersaturation (relative to water surface pressures) can cause bubbles to form in fish tissues and cause increased mortality rates, either directly or indirectly (e.g., through increased vulnerability of smolts to predation). Most concern has been directed toward effects on downstream-migrating juveniles that are present concurrent with high rates of spill (Panel on Gas Bubble Disease 1996; annual reports by the National Marine Fisheries Service to the Oregon Department of Environmental Quality related to waiver of dissolved gas standard for the managed spill program). However, adult salmonids are also in the river system during spring periods of high gas supersaturation, particularly spring chinook salmon, a listed stock in the Snake River system. Supersaturation of gases has been documented as a cause of death for upstream migrating adult salmon and steelhead, as well as adults held in hatchery raceways where the water was drawn from the Columbia River (Mighetto and Ebel, 1975).

The relative dearth of information on adult salmonid responses to gas supersaturation has been noted repeatedly (Panel on Gas Bubble Disease 1996). There has never been a comprehensive monitoring program for pathological signs in adult fish comparable to that now in place for juvenile outmigrants. "Headburns" noted on adult migrants at dams and hatcheries were speculated to be related to supersaturation in some way, but the idea was never adequately tested. Some bubbles have been found in skin and fins of adults during examinations for other purposes (e.g., radio-tagging). It has been speculated that development of gas bubble disease symptoms in adults may be prevented by their migrating near the river bottom well below the gas compensation depth (the depth where water pressure equals the gas pressure), except during passage through fishways. However, adult depth distribution between dams is poorly documented.

The ISAB's previous recommendation (ISAB 98-8) that the Corps carry out its Gas Abatement Program with all possible speed to reduce gas levels to as low as practicable should help adults without a great deal of additional expensive biological monitoring. However, the ISAB noted that additional information on adult exposures and biological effects would be needed if a biologically based criterion for acceptable gas levels were to be implemented.

4) Ecological Context

The individual physical conditions discussed above contribute to various aspects of increased stress and mortality due to the hydropower system. Yet the loss of fish during ascent of the river system results from the cumulative conditions encountered by the migrating fish. Trends in salmon population sizes reflect, in part, the cumulative conditions for adults of recent years relative to the conditions under which the fish evolved. The effect of those cumulative conditions over the entire life cycle must be considered when devising management strategies for the various salmon species and stocks.

For example, adult fall chinook salmon arrive at the spawning areas in the fall after temperatures decline and use mainstem waters for spawning. Juveniles out migrate in the spring before temperatures inhibit their growth and survival. This life history strategy can place lethal thermal bounds at each end of the time window of reproductive opportunity, as well as rate-controlling influences within the window (see analogous work on sockeye by Quinn and Adams, 1996). The two ends of the window are not independent, for late adult arrival and spawning can cause damagingly late emigration of juveniles, depending on the temperature-regulated rates of incubation and rearing in between. Historically, as adults moved upstream, they had the advantage of encountering cooler tributary inflows mixing with the mainstem to ameliorate warm mainstem temperatures (the tributaries cool faster in autumn than the mainstem).

The hydrosystem has generally caused an increase in autumn temperatures, which elevates and extends adult fall chinook thermal exposures. Increased fall temperatures are due to the lag times from water storage, which have been modeled in the past and are the subject of recent modeling refinements (EPA Temperature Workshop, December 3-4, 1998). Adult fall chinook salmon now enter the river at near peak river temperatures. They traverse the hydrosystem while that system is discharging water at temperatures that are actually in the lethal range for exposures of one-week duration (Coutant 1970; Karr et al. 1998). The fish now have less opportunity to make use of mixing zones from cooler tributary inflows in their mainstem migrations, because these inflows no longer remain as distinct in the larger volume of the impounded mainstem.

In the lower Snake River, adult fall chinook salmon, which may migrate in the deeper waters of reservoirs (often marginally cooler in August and September), must leave to enter the shallow (and frequently warmer) waters of the fishways and dam forebays. Whether or not fish ladder temperatures warm during passage from forebay to tailwater (the issue discussed in the ISAB briefing as being one of concern), the relevant comparison is between deep channel temperatures below the dam and the warm temperatures of upper fish ladders and the dam forebays. Migratory behavior that forces entry into this forebay zone of warm water (often in the high temperature range that would otherwise be avoided by adults) occurs at the same place where the directional cues of river flow disappear. From the high-velocity, turbulent fish ladder, the fish is immediately dropped into the still forebay. At this point, there is no "attraction flow", only the volume of flow needed to supply the ladder itself, or at some distance, the large volume leading to the powerhouse or spillway. Where is upstream? How to find it when in thermal distress? Diving to find cooler water (a normal high-temperature avoidance behavior) only brings the risk of fallback either by entrainment into deep turbine intakes or through the spillway. Maintaining a constant, or even cooling, temperature down the length of a fish ladder is only part of the environment of dam passage that faces an adult fall chinook salmon. Pumping deeper, cooler forebay water to fill the fish ladder (a mitigative option proposed to the SCT and the Corps) does nothing to provide the needed transition for fish as they leave the ladder and must reenter the river flow upstream of the forebay.

5) Conclusions

Correction or prevention of problems with adult passage deserve more attention than they have received. Many questions remain about the effects of delay or extra energy expenditure en route upstream on the ultimate ability of adults to spawn successfully. There is currently no research program of which we are aware that is designed to satisfactorily answer this question. The question whether the proposed measures in the Corps' capital construction budget represent a sufficient set must be viewed in a larger context than simply a project-by-project review of desirable modifications of ladders and their associated facilities at mainstem and Snake River dams. The larger perspective would address questions about whether those specific measures succeed in allowing an adequate number of adult salmon and steelhead to reach their spawning grounds in a physical condition required for successful spawning.

Measures to improve passage for adult salmon should bring the cumulative conditions for passage closer to what was probably experienced in the evolutionary history of the fish, i.e. examining what the normative condition might be. While the design of facilities for upstream passage of adult salmon has by necessity considered the adaptation of adults to upstream movement, it is apparent that there is still much to be learned, as reflected in the continuing modifications of fishways, which involve capital construction costs. Innovative measures, such as inducing upstream attraction flows in dam forebays or providing cooler water taken from lower strata, may be possible for some dam sites. Minimizing the delay and expenditure of energy by adult salmon are important passage criteria. Uninterrupted provision of passage at each individual fishway is important to smooth transit of adults upstream.

SECTION 1. THE CORPS OF ENGINEERS CAPITAL CONSTRUCTION PROGRAM FOR 1997 AND 1998

There are annual maintenance and operation costs associated with the fish ladders at the Corps' projects, which include such things as operation of the fish counting stations in the ladders, along with ordinary maintenance of the engineering features of the ladders. In addition, as new information is obtained relating to problems that may be encountered by fish, or as the physical layout of the project itself is modified, changes in design and configuration of the ladders become necessary or desirable. For example, some designs from the 1940s and 1950s for operations such as trash rack cleaning relied upon manual operations and can now be automated to achieve lower personnel costs and higher reliability. Such changes predominate in the capital construction costs for adult passage in the Corps' budget, and they are the subject of this section of the report.

MEASURES PROPOSED FOR IMPROVEMENT BY THE CORPS'

With respect to specific adult passage measures identified for improvement, the ISAB had information from the "Technical Background Paper for Review of the Corps Capital Construction Program" addressed to the System Coordination Team (SCT) from Council staff on February 9, 1998. We also had the Corps of Engineers Work Plans for 1997 and 1998, which identified measures for improvement of adult passage that the Corps proposed to undertake.

1) Council Staff's Technical Background Paper

The Technical Background Paper to the SCT identified three general objectives and requirements along with seven specific measures for the Corps to address with respect to improvement of adult passage.

The general objectives and requirements identified were:

a) As called for both by NMFS and the Council, leave the turbine intake screens in place beyond the period of juvenile outmigration in order to provide some protection for adults that fall back. In addition, NMFS, the Council and the Tribes call for installation of automated fishway control systems, adult fishway modifications, and improvements at McNary, The Dalles, and Bonneville dams; evaluation of effectiveness of covering existing fish ladders or alternative means to reduce ladder water temperatures; and improving the effectiveness of entrance attraction flows and fishway hydraulics, including improvements (and emergency back-up capability) in auxiliary water supply systems.

b) The tribal plan also calls for the Corps and mid-Columbia P.U.D.s to finish structural assessments of all mainstem fishways, and take necessary corrective actions, including improving attraction flows, installing additional pumps, gravity flow systems, automated systems, and additional fish ladders; and modifying ladder exits to reduce adult fall back. Additionally it calls for remedies to reduce the incidence of the non-native adult shad in the ladders and to evaluate and implement new fishway designs.
The tribal objective is to reduce adult delay by 50% by the year 2001, reduce adult energy expenditures and increase distribution to upstream spawning habitats. The tribe also believes jumping should be encouraged because it is more efficient than swimming in gaining elevation.

c) While the Fish and Wildlife Program and Biological Opinion on the Hydroelectric System call for an evaluation of the need for measures to help reduce summer temperatures in mainstem fish ladders, the tribal plan calls for implementation of measures to reduce temperature in fishways, including pumping cooler water at depth from the forebays into ladders. Temperature problems in particular ladders will be identified in 1998, with a recommendation for a prototype to be constructed and tested at one of the Snake River projects in FY 1999 (if a temperature problem is identified).

Specific measures identified in the Technical Background paper

The specific measures identified to be tested are shown in Attachment A (excerpted from Council Staff's Technical Background Paper).

2) Corps' Capital Construction Projects

According to the Corps of Engineers Letter Report of September, 1997, the Corps identified twelve measures relating to improvement of adult passage that went beyond ordinary maintenance. According to the Corps letter, the SCT added four measures, bringing the total to sixteen. The Letter Report states that subsequently, the SCT approved and allocated funds for these sixteen measures in 1997. The sixteen specific measures are listed in Attachment B.

For 1998, the Corps of Engineers Annual Work Plan (dated March, 1998) listed five measures related to improvement of adult passage:

a) temperature studies at the Lower Granite and Ice Harbor dam fishways,
b) evaluate adult exit modifications at McNary Dam,
c) further evaluate alternatives for auxiliary water supply for attraction water,
d) complete study of feasibility of modifications of channel entrances to provide for inspection and maintenance,
e) analysis of fall-back rate of adults over spillway at Bonneville Dam for fish that exit the north ladder at Bradford Island. (Scoping in 1998; study to commence in 1999.)

In addition to these, the Corps is funding research on adult salmon, steelhead and lamprey migrations past dams and through reservoirs in the lower Columbia River and its tributaries by means of radio tracking of fish; evaluating the effects of the fences installed in the ladders at Little Goose and Lower Granite dams; determining the effects of cold water releases from upstream reservoirs on migratory behavior of adult steelhead and fall chinook; evaluating effects of project operations at Lower Snake River projects on rate of fall back of adult salmon; and identifying spawning sites and activity of salmon near McNary Dam.

CONCLUSIONS

We have carefully reviewed the descriptions of the measures proposed to the SCT as well as the Corps' Capital Construction projects relating to adult passage and see no reason to modify or delete any of them. They appear to be justified by particular concerns at specific sites and a desire to work toward goals set in various restoration and recovery plans for salmon and steelhead. On the matter of their sufficiency, we have more to say in Section 2.

RECOMMENDATION

Uninterrupted provision of passage at each individual fishway is essential for smooth transit of adults upstream, which is one of the factors important for salmon recovery and restoration. Assuming the policy choice is made to maintain the existing mainstem and Snake River dams in place in their present operating modes, the Corps should proceed to implement the sixteen measures proposed to achieve improved adult passage. Most of these measures would have benefits even if implemented for a short duration (probably 10 years) before specific dams were breached or their reservoirs lowered. Two possible exceptions would be the tribe's proposals for correction of "numerous structural problems" in the fishways at John Day Dam, and for construction of additional ladders at Snake River projects now equipped with only one ladder. Without analyzing the full scope of the structural problems at John Day Dam, it appears to us that the time required for design and construction of revised fishways might impinge on the schedule for design and construction of new fishways that would probably be required by drawdown. As for providing additional fishways at the upper Snake River projects, Bjornn (briefing) informed us that the average passage time for adults at those two projects is lower than at any of the lower river projects. Identification of a passage problem would be required to justify construction of new ladders, particularly considering the potential for breaching of these dams that is being evaluated at a policy level.

SECTION 2. MONITORING AND EVALUATION OF ADULT PASSAGE IN THE COLUMBIA AND SNAKE RIVERS

The question of whether the proposed measures in the Corps' capital construction budget represent a sufficient set of measures must be viewed in a larger context than simply a project-by-project review of necessary modifications of ladders and their associated facilities (such as pumps for attraction flow and the like), a subject we discussed in Section 1. The larger perspective would address questions about whether those specific measures succeed in allowing an adequate number of adult salmon and steelhead to reach their appropriate spawning grounds in a physical condition required for successful spawning. Accomplishing that larger objective is not exclusively a Corps responsibility. The Corps' responsibility can be viewed as a requirement to provide for the smooth passage of adults through the system. Above and beyond the smooth passage criterion is the implicit requirement that adequate numbers of adults reach their natal streams in spawning condition. The Corps' responsibility is that there should be neither inordinate delay of adults at the Corps projects that might lead to incapacitation of the adults with respect to their ability to spawn successfully, nor losses of adults in transit that are associated with the hydroelectric system.

MONITORING AND EVALUATION IN THE COLUMBIA AND SNAKE RIVERS.

1) Counting Adult Fish in the Columbia River.

Monitoring by means of counts of fish in the ladders is important not only to the Corps for evaluating the overall effectiveness of fish passage facilities, but it is critical information for all entities involved in salmon management. The counts are important to the Council for evaluating the effectiveness of measures in the FWP designed to increase numbers of salmon and steelhead. The counts are important to NMFS for detailing the status of the ESU's included in the Recovery Plan, and they are vitally important to the harvest management entities for regulation of harvest for ocean fisheries under the treaty with Canada, and for management of fisheries in the Columbia River itself, which includes maintenance of spawning numbers and setting permissible harvest levels.

For all of these purposes, it is essential to have reliable counts of adults passing the projects, to account for turnoff into tributaries and losses that are expected as the fish move upstream. At the present time, these counts, along with some radio tracking data, are the primary or only sources of information on the question whether passage of adults through the hydroelectric system adversely affects the ability of adults to reach the spawning grounds in appropriate numbers. For counting, each of the Corps projects is equipped with a counting station in at least one fish ladder. The original counting stations consist of a viewing window where a narrow passage in the ladder crowds the fish so that they can be identified and counted.

Prior to 1994 all mainstem adult passage counts at Corps projects were unaided visual counts taken from adult fish passage facilities during daylight hours. Since 1994, monitoring of adult passage at Columbia River mainstem dams has been accomplished by a variable combination of unaided human visual counts and videotaped observations in the fish ladders. Videotaped observations offer the advantage that "stop action" is possible, which aids in the identification process and counting when large numbers of fish may be in the window at the same time and movement in opposite directions occurs. The visual counts are made during 16 daylight hours (usually 0400 – 2000 hours) in the spring, summer and fall migration seasons. Typically, the personnel doing the counting are provided a 10-minute break each hour. The counts are subsequently expanded to estimates for the full 60 minutes. In addition to the visual counts, videotape monitors are used at night and during the winter season to provide a 24 hour record at a number of federally operated dams including, Bonneville, Ice Harbor, Little Goose, Lower Monumental and Lower Granite dams.[6]

There are unexplained discrepancies between the dam counts of salmon, as demonstrated by the conversion rates between dams. A conversion rate is the ratio of upriver to downriver counts, adjusted for known removals by fishing and losses due to fish exiting into tributaries and hatcheries. The tables of conversion rates (Michael Matylewich, Columbia River Intertribal Fish Commission) are used by fishery managers as an accounting tool for harvest management purposes. If counts were accurate and no unexplained loss of adults occurred, the conversion factor ought to be close to one. If it is less than 1, it indicates there is a loss between dams due to

[6] Dams operated by the Public Utility Districts in the mid-Columbia reach also maintain counting stations in the ladders and the data are transmitted to the Corps for inclusion in the Corps' Annual Reports. These counts are essential for monitoring the status of stocks in the mid-Columbia reach, including the Hanford Reach stock of fall chinook.

uncounted mortality or other reasons for failure to continue the migration. In fact, the conversion rates shown in the conversion rate tables indicate a substantial inability to account for differences in counts at successive dams. This could be due to unexplained losses between dams, inaccurate counts or both. For example, adult spring chinook conversion rates between Bonneville Dam and McNary Dam ranged from about 0.4 to about 0.8 over the years 1979 to 1996. The conversion rates within the McNary reservoir ranged from about 0.8 to 1.1, while the conversion rates from Bonneville Dam to Lower Granite Dam ranged from about 0.3 to 0.8 over the same years. Fall chinook conversion rates from Bonneville Dam to Lower Granite Dam ranged from about 0.3 to 0.6 from 1986 to 1996. The conversion rate per project in the lower Columbia River was about 0.96 on the average, while it was 0.78 per project in the Snake River. The wide variability of these conversion factors and the fact that they often are well below the value of one is alarming considering that they underlie the estimates of escapement numbers and lead to projections of allowable harvest rates. We must raise the question whether these differences simply reflect the inaccuracies of the counting process or do they reflect mortality rates on adult salmon that are bound for upstream spawning grounds? If it is the latter, then these are serious losses to future production and a set-back to efforts to restore or recover spawning populations in the Basin.

The large count discrepancies that have been observed at times raise concerns about the reliability of the counts in general. There are numerous possible sources of error.[7] Videotaping the fish as they pass, and using the tapes for visual counting removes or reduces some of the problems, but not all of them. A description of the process of migration and dam passage by adult salmon will reveal some of them

As they move upstream and encounter the dams, adult salmon and steelhead, as well as lamprey and sturgeon, can find passage upstream either through the fish ladders or through the navigation channels. There is no means of counting those fish that choose the navigation channel for passage. Some projects have more than one ladder, the primary one of which typically includes a number of entrances across the lower face of the powerhouse in the tailrace, and another associated with the spillway. Where only one ladder is present (upper Snake River projects), it is at the powerhouse. As they pass through the ladder, the fish go through a narrow chamber where a window is located, allowing them to be counted. Some fish are observed by the

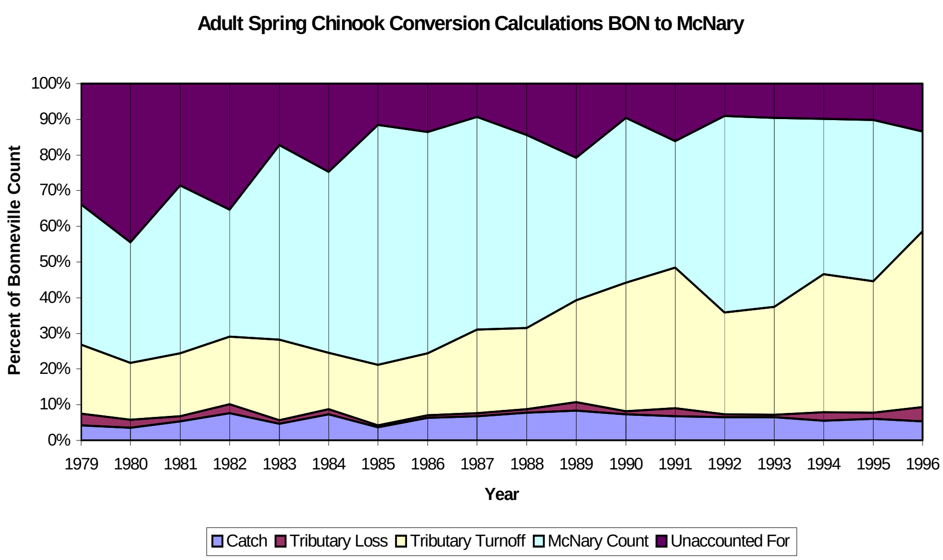
[7] Mike Dell of Grant County P.U.D. in 1991 enumerated 25 possible reasons for differences in fish counts at consecutive dams. (Memo to Mid-Columbia Coordinating Committee of September 26, 1998)

personnel doing the counting to "fall back" downstream through the ladder. These fish are also counted and the numbers are subtracted from the upstream passage totals. However, fish that fall back can do so by five routes; either through the ladders, through the navigation channels, through the turbine intake bypass system (designed for juveniles) if it is in place, through the turbines themselves, or over the spillway, if there is spill. Because only the fish that fall back through the juvenile bypass or through the ladders are counted, not all of the fish that fall back are counted. If those fish that fall back through the navigation channels, turbines or spill later re-ascend by way of the ladders they are counted again as new fish, resulting in a double count. Rate of fallback, as measured in radio tracking studies, can be nearly 20%, and some fish fall back more than once (Bjornn briefing to ISAB). Magnitudes of the fallback rate and upstream migration rate likely vary from year to year depending on temperature, amount of spill, and other factors (Bjornn briefing to ISAB).

At the counting windows, immigrants may be misidentified as to species. Jacks, small salmon returning after one winter in the ocean, can be particularly difficult to identify to species. Cloudy water during high spring runoff sometimes hampers fish identification. A variable proportion of immigrants (typically small) may pass at night when no counting occurs, although a number of the dams now use video tape recording at night. The proportion passing at night may differ by species and season. Variable proportions of some stocks, particularly steelhead, may hold in lower river tributaries for extended periods of time before ascending to their (presumably natal) streams to spawn.

Several additional natural and human-made factors cause count discrepancies. For example, each year, harvest and tributary loss and turnoff do not account for a large proportion of the spring chinook "loss" that occurs between Bonneville and McNary dams (Figure 1). Based on ladder counts and estimates of turnoff into tributaries, Chapman et al. (1991) estimated a 5% average interdam loss of spring and summer chinook (combined) between John Day Dam, McNary Dam and the next project upstream, either Priest Rapids Dam or Ice Harbor Dam. Young et al. (1978) found that interdam losses of chinook were affected by flow in the particular years he examined. With radio telemetry, Bjornn (briefing to ISAB) reported that 70% of the fall chinook that fell back at Bonneville Dam were detected upstream, while 75% of those that did not fall back were detected upstream, suggesting some loss of fish associated with fall back. At the opposite extreme, counts at upstream dams have been observed at times to be higher than counts downstream (Larry Basham, personal communication),[8] as indicated by conversion rates greater than one. Such results would be an obvious impossibility if the fish counts were accurate estimates of true fish numbers passing upstream.

The bottom line is that accuracy and precision of the dam counts and the adjustment values needed to provide correct numbers are suspect, and the present monitoring does not deliver data needed to resolve the outstanding questions. While the counts arguably might be satisfactory for determining rough estimates of the total numbers of salmon and steelhead in the river, *it is doubtful that they are sufficiently reliable for purposes of the Corps, the Council, NMFS or the harvest management entities. We recognize that our brief evaluation merely identifies a problem that should be the subject of a more thorough and detailed evaluation by others.*



[8] Larry Basham pointed out that in a sample of counts of fall chinook from recent years (1993-1997), the counts at McNary Dam were higher than the counts at John Day Dam downstream in two of the five years. (By 1,000 fish in 1994 and 4,000 fish in 1995). He pointed out that steelhead counts are often higher at John Day Dam than at The Dalles Dam downstream. The discrepancy in 1998 (40,000 higher at John Day Dam) was the highest he could recall. Counts of sockeye at Priest Rapids Dam are usually higher than at McNary Dam, and not uncommonly are higher than at Bonneville Dam, which he attributes to the probable tendency for sockeye to choose the navigation channels for passage in the lower river. There is no such channel at Priest Rapids Dam.

Further Implications for Harvest Management

When dam counts are used as a basis for estimates of escapements, any errors in counts have potentially serious consequences for management of harvest in ocean and river fisheries for salmon. Harvest rates in ocean salmon fisheries are, in simplest possible terms, ratios of ocean catch to total catch plus spawning escapement. That is -

Exploitation rate = (*ocean catch*) / (*total catch* + *escapement*).

Interdam conversion rates are estimates of the proportion of fish passing one project that will be counted at an upstream project after adjustment for harvest and tributary turnoff (Mike Matylewich, letter to Chip McConnaha dated October 30, 1998). The conversion rates are used to plan fisheries and project escapement at upstream points and to calculate adult equivalents for allocation purposes under the Pacific Salmon Treaty with Canada. In the simplest form, the formula for calculating conversion rates is -

Conversion rate = (*count at upper dam*) /
(*count at lower dam – number harvested – tributary turnoff*).

Calculation of conversion rates and exploitation rates obviously depend directly on the dam counts which have unknown accuracy and precision. Some sources of bias may tend to overestimate escapement (e.g., fallback through routes other than the ladders), while others will tend to underestimate escapement (e.g., upstream passage through navigation locks). Uncertainty in the counts owing to errors in fish identification during the counting process and errors in stock assignment in the expansions, constitute another source of imprecision which warrants further investigation in order to quantify the uncertainty realistically, and perhaps also to develop some corrections for possible bias.

Therefore, management programs that rely on dam counts to set harvest rates either in the ocean or in tributaries could make harvest decisions injurious to the stocks due to error resulting from wandering by adults or by double counting fish that fall back through routes other than the ladders. For example, for stocks such as spring / summer and fall chinook, or A-run and B-run steelhead, counts to estimate tributary escapement are defined between the same two dates each year. To the extent that members of these populations may interrupt their migration after passing

Bonneville Dam to spend time in tributaries, they could be counted both as inter-dam losses, and as members of the wrong stocks of salmon or steelhead before and after the time when they resume migration. It has to be remembered that these cutoff dates for counting of the spring, summer and fall chinook and the A-run and B-run steelhead stocks are to some degree arbitrary so that such errors merely compound what is already an uncertain situation. Without adjustments for wandering, catches reported from tributaries could lead to overestimates of stock size and productivity for the affected watershed, leading in turn to overharvest. The concept of "incidental" catch of stocks that are low in abundance comes into play as well in the discussion of wandering. How do we manage for the incidental take of fish that wander into non-home stream tributaries?

In the ocean fisheries, if escapement is overestimated, then the preceding ocean harvest rate is underestimated. Underestimating harvest rates that correspond to a high estimate of escapement can lead to regulations that unknowingly permit overharvest. Overestimation of escapement can be particularly dangerous for harvest management of fall chinook. Fall chinook have high harvest rates in ocean fisheries and substantial potential for pre-spawning mortalities due to prolonged exposure to elevated freshwater temperatures once they leave the ocean. A cycle of overestimation of escapement followed by underestimation of the associated harvest rate followed by overharvest in the next cycle could have contributed to the decline of Snake River fall chinook and it could be limiting production of other Columbia River fall chinook populations.

RADIO TRACKING OF ADULTS

The Corps of Engineers, NMFS and the mid-Columbia P.U.D.s have funded several studies using radio-tagged adult salmon to track upstream migration performance. The adult fish are fitted with a small transmitter inserted into the stomach and equipped with an external antenna. Current technology makes possible the tracking of individual fish. Information has been obtained on percentages of fish that choose various routes of passage both upstream and downstream, rate of fallback, extent and magnitude of wandering or straying, reactions to particular features at the dams, and other characteristics of the migration.[9]

Blankenship and Mendel (1997) found that adult fallback over the dams and wandering leads to overcounting adult fish in the lower Snake River. They hypothesized that because fall chinook normally spawn in the Snake River mainstem, rather than the upper tributaries (as do spring and summer chinook), they tend to wander more before spawning. Current research is underway which corroborates substantial fallback and wandering of adults during upstream migration for other species (Bjornn briefing to ISAB). Some immigrants, particularly steelhead, but also spring chinook and to a lesser extent fall chinook, have been found to enter non-natal tributaries and remain there for substantial periods of time (days, weeks and, in the case of some steelhead, several months). According to Bjornn (briefing to ISAB), from 1 to 7% of chinook detected upstream dip into tributaries on the way. He found surprisingly high wandering rates in some cases (30%+ for some steelhead).

While the radio tracking studies should provide much useful information relating to the larger question arising with respect to adult passage, the results of most recent studies are not finalized in written reports. The Corps has funded a project that would produce such a report in 1999.

There are questions that probably are not addressed by the radio tracking studies, such as whether egg retention rates or other indications of incomplete spawning might be associated with delay of upstream migration. Another source of relevant information might be comparative studies of egg retention rates or survival to spawning of adult salmon or steelhead in undammed rivers with those in the Columbia Basin.

PIT TAGS: UNTAPPED POTENTIAL FOR ADJUSTING LADDER COUNTS

PIT tag detectors for adults are another possible technology that could be used to adjust the ladder counts. The PIT tag is a transponding tag that can identify an individual fish throughout its lifetime. The technology has received wide application in the basin for marking

[9] The transmitters now used do not record or relay data such as temperature en route. As discussed in the introduction, the technology is now available to add this feature, which would greatly extend the amount of useful data obtained from these telemetry studies.

and relocating juvenile salmon during downstream migration, and it is the basis for major advances in understanding of the survival of smolts in the inter-dam reaches of the Snake River. It is applicable for identifying those same individual fish when they return as adults and to follow their progression and survival as they move upstream through successive fish ladders equipped with detectors, and as they reach the spawning grounds using portable detectors. Additional PIT tags could be applied to adults at Bonneville Dam using a facility in the ladder to collect them and to aid in the study of upstream migration success.

At present, the only PIT tag detectors for adults are at Bonneville and Lower Granite dams. It would be necessary to equip additional upstream projects. Operating the data collection system could be handled by the present PIT-tag information system (PITAGIS). Because the detection range of PIT tags with current technology is not much over a foot or so, detection probability will be low in large passageways such as navigation locks, but it can be reasonably high in the counting chambers in the ladders. The advantages of PIT tags are low cost, automated detection, and small effect on the fish.

Both PIT tags and radio tags, make possible the identification of individual fish, which allows the recording of multiple detections of the same individual, as it repasses the same station (if there is fallback or wandering), and as it progresses past sequential stations. This, in the context of modern versions of the Jolly-Seber statistical procedures, permits valid estimation of numbers and survival rates. To our knowledge, this procedure has not been used in the analysis of adult passage, though the data to do so are probably available within the radio tracking studies.

CONCLUSIONS

In addition to the engineering types of problems which are not to be neglected (see Section 1), there are overarching questions regarding the sufficiency of the present site-specific measures to improve adult passage. A first question concerns the level of reliability of counts of adults in the fish ladders for management applications; for use by the Corps for determining the effectiveness of fish passage facilities; for the Council in determining the effectiveness of measures under the FWP; for NMFS in monitoring the status of endangered stocks; and for the harvest management entities in setting and maintaining appropriate escapement goals and harvest rates. Our review suggests that these counts are not sufficiently reliable for these applications.

Counts of adult salmon and steelhead at the dams need to be adjusted annually by means of data from other sources. Radio tracking of adults provides one source that can be used to estimate the percentages of fish that use the navigation channels for upstream migration and are not counted in the ladders, and to estimate the percentages of fall back through spill, the turbines and navigation channels where they would not be counted. PIT tags offer another possible method for adjusting the counts. There is also a need to develop estimates of wandering rates, defined as temporary entry into tributaries other than the one where the adults end up spawning. Necessary adjustments probably will differ annually depending on variations in system operations, flow, temperature, and other factors that affect choice of passage routes by adults and their survival in upstream passage.

Obviously, problems at individual projects will have an impact on the overall performance of the system, but the ultimate interest should be in evaluating the performance of the passage system as a whole. Evaluation in that context should include analysis of the rate of success of adults in completing their migration and spawning successfully. While radio tracking studies will provide information on completion of migration and make it possible to relate the success rate in achieving the destination to delays or diversions caused by obstacles that have been encountered by salmon, questions have been raised about the effects the passage might have on energy reserves required to successfully complete the spawning act once the destination is reached. No information of which we are aware is available on this subject.

RECOMMENDATIONS

1. Place more emphasis on adult passage measures and their monitoring and evaluation by the Corps, the Council, NMFS and the harvest management entities.

2. Include an annual operating project to determine the accuracy and precision of the counts of adult salmon passing the dams. At a minimum, conservative correction procedures for adult dam counts should be developed based on radio-tracking information or PIT tags. Annual radio-tracking or PIT tagging across species will be necessary to estimate numbers

of adults passing upstream through navigation channels and falling back through juvenile bypasses, the spillways and navigation channels. Annual adjustments will probably be necessary because these kinds of errors depend on project operation, flow, and frequency of barge traffic, which all vary seasonally and annually.

3. Critically evaluate sources of error in estimation of escapement to spawning grounds and hatcheries. Engineers typically employ a safety factor in design of a structure. In a similar manner, escapement goals and estimates, along with estimates of allowable harvest should include safety factors, if runs are to be rebuilt.

4. Implement research on temperature and its effects.

Given the present paucity of temperature information relevant to anadromous fish in the hydroelectric system, it is not possible to foresee all necessary data gathering needs and methods at this time. The following emerge as important issues at this time:

a. Support research to record temperatures occupied by adults during migration.
b. Support research to identify, enhance and protect existing thermal refuges for upriver migrants.
c. Include annual operating projects to measure the ambient temperatures experienced in the hydroelectric system by adults. This would include monitoring of the temperatures in all fish ways at all times when adult salmon and steelhead are present, monitoring of the temperature regimes in the reservoirs during the migration, and monitoring of the degree-days experienced by adult migrants in the hydroelectric system. Such monitoring programs are critical for all summer and fall migrants, but they may also be important for spring migrants.

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APPENDICES

APPENDIX A: SPECIFIC MEASURES FOR IMPROVEMENT OF ADULT PASSAGE

The specific measures to be tested were identified in the “Technical Background Paper for Review of the Corps Capital Construction Program” addressed to the System Configuration Team (SCT) from Council staff on February 9, 1998. The measures include the following.

1. Test the effectiveness of fences that were installed at adult channel entrances to fish ladders at Lower Granite and Little Goose dams in 1997.
2. Evaluate the emergency water supply system for adult ladders for each of the Lower Snake River projects. Prepare a design memorandum which will identify an alternative if it is determined there is a need.
3. Determine whether a water temperature problem exists in the fish ladders and forebays at Lower Granite and Ice Harbor dams that might affect adult salmon and steelhead passage. A technical report is due in 1999.
4. Simplify and improve the ladder exits at McNary Dam. An engineering design was completed. The plan is to replace the tilting weirs with fixed vertical slot weirs, similar to the design at other mainstem projects. The tribes call for temperature control measures in the ladders at McNary Dam. An extra intake screen for the south shore fishway should be procured as a replacement in the event an existing screen fails.
5. At John Day Dam the Corps is installing electrical equipment to modify the north shore auxiliary water supply system for the ladder. An automated trash raking system for the south shore auxiliary water system is to be completed by February 1999.
   The tribes maintain that numerous structural problems exist at both fishways at John Day Dam. They call for
   a) structural improvements at the fishway exit to prevent adults from jumping out of the ladder and to reduce delays experienced exiting the ladder,
   b) reconfiguration of the conduit and fishway to improve flows into the fishway, and
   c) provide pumps for emergency back-up water supply as well as improve temperatures in the fishway.

6. At The Dalles Dam, all three plans call for improvements in adult passage. The need for emergency water supply is identified along the powerhouse and south of the spillway in the event of failure of the existing system. Analysis of alternatives was completed in 1997, but action was delayed pending results of a study to examine a proposal to combine this action with a potential relocation of the ice and trash sluiceway outfall. An additional study is designed to determine the feasibility of dewatering the lower portions of the fish ladder entrances and transport conduit for the south shore ladders to aid in inspection and maintenance. The study is scheduled for completion in 1998,with a decision to follow then.
7. At Bonneville Dam, two major problems have been identified, excessive fall-back of adults (15%) over the spillway of fish that exit the north ladder at Bradford Island, and voluntary and involuntary spill increase the Bradford Island fallback problem in addition to exposing the fallbacks to unacceptable levels of total dissolved gas. Alternative solutions are being explored with model studies. The tribes want this work completed by 2001.

Other items recommended by the fishery agencies and tribes are 1) evaluate debris buildup at the second powerhouse fish unit intakes, b) provide emergency back-up water supply at the second powerhouse, c) design an automated trash raking system at the first powerhouse for the auxiliary water supply system, d) evaluate the means of reducing fish impingement during dewatering at the first powerhouse. (Scheduled for 1999)

The tribes call for modifications in the second powerhouse fishway in 1998 to allow for tribal shad harvest and to increase the efficiency of the ladders in passing salmon. The tribes also call for temperature control measures for the fishways. By 1999 the tribes want modification of the first powerhouse fishway entrances so that standard fishway criteria can be met even under low tailwater conditions, which is not now the case.

APPENDIX B. LIST OF THE CORPS' CAPITAL CONSTRUCTION PROJECTS 1997-98

Projects in the Corps' 1997-98 Capital Construction Program are identified in the following four documents. We present abbreviated summaries and refer the reader to the original sources for more complete descriptions.

1. 1997 Adult Passage Improvements – Letter Report, COE and SCT

Introduction

The COE (page 6 of the Letter Report of September 1997) indicates that the Corps in 1997 identified twelve measures relating to adult passage improvement that went beyond ordinary maintenance. The SCT added four measures, bringing the total to sixteen. Subsequently, the SCT approved and allocated funds for the following sixteen measures in 1997.

1. Modify John Day north shore auxiliary water system to meet existing passage criteria. Existing pumps are inadequate. Estimated cost $65,000. Completion planned for early 1998.
2. Automate intake trash rack cleaning system for Bonneville Powerhouse 2 fish units FU-1 and FU-2. A one-year study was to be funded. Estimated cost $200,000
3. Construct fish rack for the intake of the Bonneville Powerhouse 2 ice/trash sluice chute. A one-year study was to be funded. Estimated cost $200,000.
4. Automate John Day north shore AWS trash rack cleaning system. Planning and installation expected to take one year. Estimated cost $500,000
5. Modify The Dalles powerhouse collection channel system to allow it and the AWS to be dewatered. A report was to be prepared that would look at means of dewatering and provide a cost estimate. Completion, October, 1997.
6. Replace John Day fishway collection channel bulkheads. Determined to be within the scope of ordinary maintenance.
7. Automate AWS intake trash rack cleaning system for Bonneville Powerhouse 1 valve FV1-1. Expected to take one year. Estimated cost $500,000.
8. Automate AWS intake trash cleaning system for valve FV3-9. Duration, one year. Estimated cost $500,000.
9. Automate trash raking on The Dalles north shore AWS intake. Duration, one year. Estimated cost $500,000.
10. Automate AWS trash rack cleaning system for Bonneville valve FV5-9. Duration, one year. Estimated cost $500,000.
11. Develop and implement a solution to reduce impingement of fish on the main unit drain screen at Bonneville Powerhouse 1 during turbine dewaterings. Study duration, four months. Estimated cost of study $50,000.
12. Replace existing stoplogs at The Dalles north fishway entrance. Determined to fall within ordinary maintenance.
13. Modify the upper ladder add-in diffuser systems and flow control sections for each fish ladder at John Day. Study proposed for 2-month duration. No further action will be taken until the study is completed.

14. Install additional pumps to provide emergency back-up system for John Day south shore fishway. No action was proposed. Replacement of bulkheads may allow use of one existing pump as a backup.
15. Investigate potential pollution problem at John Day north shore AWS intake area. Proposed to continue daily visual inspection for pollutants by project biologists.
16. Automate John Day north shore AWS trash rack cleaning system. Project personnel determined this is not a problem. There is no trash on the north shore AWS intake.

2. 1998 Adult Passage Improvements - COE Annual Work Plan

For 1998, adult passage improvements are included in the COE Annual Work Plans, March, 1998 (excerpted from Enclosure 3 of the Annual Work Plans)

1. Temperature study in fish ladders at Lower Granite and Ice Harbor dams.
   Ted Bjornn. $60,000 per year - "several years". The SCT has concurred.
   - Collect temperature data 1995-2000?
   - Correlate adult fish passage behavior to ladder and fishway temperature data
   - Determine physiological consequences of high thermal exposure
   - If drawdown is implemented, this study becomes irrelevant

2. McNary Dam. Evaluate adult exit modifications. Begin in yr. 2000.

3. The Dalles Dam auxiliary water supply for attraction water.
   To provide for possible breakdown of generators now supplying attraction water.
   - Alternatives were explored in 1997.
   - Action has been delayed pending decision on relocation of ice and trash sluiceway outfall.
   - Savings may be accomplished by combining the two actions.
   - Development of design to commence in 1999.

4. The Dalles Dam entrance channel dewatering study.
   To modify entrance channel, providing for inspection and maintenance.
   - Feasibility study initiated in 1997.
   - Completion scheduled April 1998.
   - Decision will then be made on action.

5. Analysis of fallback over spillway at Bonneville Dam for fish that exit the north ladder at Bradford Island. Radio telemetry indicates 15% fall-back of adults.
   - Review of information and identification of alternative solutions.
   - Scoping in 1998. Studies to be initiated in 1999.

3. FY99 Study Summaries

(Excerpted from Enclosure 4 of COE Work Plan)

Evaluation of Adult Salmon, Steelhead, and Lamprey Migrations Past Dams and Through Reservoirs in the Lower Columbia River and into Tributaries. [Note: These are identified as Operation and Maintenance measures, not capital construction. They are radio telemetry studies.]

1) Based on data obtained in FY96, FY97, and FY98, analyze and further clarify the results of the following study objectives.
   a. Determine the proportion of fish passing Bonneville Dam that ultimately pass the upstream dams, enter tributaries, enter hatcheries, are taken in fisheries, and are "losses" between dams.
   b. Assess the time for fish to pass each dam (Bonneville, The Dalles, John Day, and McNary) and migrate through the reservoirs between dams.
   c. Evaluate entrance use and passage through the fishways at selected dams. Due to documented problems at John Day ladders, these areas were given special attention.
   d. Evaluate the effects of various spill volumes and patterns n fish passage at selected dams
   e. Evaluate the effects of operation of the Bonneville Navigation Lock on movement of adult salmon and steelhead in passing the dam or entering the hatchery.
   f. Assess the amount of fallback at each of the dams with naturally occurring flows, spill, and powerhouse operations.
   g. Assess adult salmonid passage prior to drawdown of the John Day pool.
   h. Assess adult lamprey passage through Bonneville Dam and through their migrational corridors

2) Based on the results of these analyses, determine and develop the necessary evaluations to be conducted in FY99 and FY00

4. Anadromous Fish Evaluation Program

(Excerpted from Enclosure 5, FY99 Miscellaneous Study Summaries)

1. Evaluate passage through fishways at Little Goose, and Lower Granite dams following installation of fallout fences.
   - Consider fences at Lower Monumental and Ice Harbor. Schedule - 1997-2000?
   - (Fences were completed at Little Goose and Lower Granite dams in 1997.)

2. Determine effects of cold water releases on migratory characteristics of adult salmonids in Lower Granite reservoir.
   a. Determine the three-dimensional migratory patterns of adult steelhead and fall chinook before, during and after cold water storage reservoir releases.
   b. investigate correlations between water temperature and water temperature.
   c. Determine whether migratory characteristics are correlated with survival to spawning or spawning success.
   d. Identify physiological indicators of acute and chronic thermal stress.

4. Evaluate fallback of adult salmon in response to project operations at Lower Snake River projects.
   a. Quantify adult fall back rates by species and stock (or known origin) in relation to powerhouse operations and increasing spill volumes. Determine reported versus actual fall back rates at for different stocks at Ice Harbor.
   b. Determine the differential injury rate between fall back and non-fall back adults. Differentiate injuries according to route of passage - turbines or spill.
   c. Track fall back injured fish to spawn location and calculate prespawn survival and spawning success.

5. Identify spawning sites and activity near McNary Dam
   a. Identify habitat availability near McNary Dam for fall chinook and utilization by chinook.
   b. Collect additional data on extent of further spawning by fall chinook downstream of McNary Dam.

6. Physiological stress and delay of adult salmon passing Lower Snake River dams associated with hydraulic conditions during spill.
   a. Determine effects on cardiovascular/respiratory metabolism variables and developing reproductive organs of a range of TGS concentrations for representative reservoir (110-140%) and stilling basin (130-160%) hydraulic conditions in which adult salmon must pass.
   b. Quantify cumulative physiological and behavioral responses of adult chinook and steelhead to TDG-related and non-TDG related hydraulic condition variables at Ice Harbor and Lower Granite dams (and possibly Priest Rapids).

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