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Feasibility of Reintroduction of Anadromous Fish Above or Within the Hells Canyon Complex

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Executive Summary

The feasibility of reintroducing anadromous fish above Hells Canyon Dam has been discussed in numerous forums. In the late 1980s during a workshop initiated by Senator James McClure, the workshop participants concluded that reintroduction was possible if three prerequisites could be met: 1) smolt passage problems at existing lower Snake and Columbia river dams were solved, 2) flows in the lower Snake River reservoirs were improved to enable successful smolt passage, and 3) a reintroduction program were not developed at the expense of existing fisheries programs in the Snake and Columbia rivers. In the final recommendations to the National Marine Fisheries Service, the Snake River Salmon Recovery Team recommended that the issue of reintroduction for fall chinook salmon (*Oncorhynchus tschawytscha*) be examined again in the future, especially if smolt collectors that were harmless to the fish could be developed.

The issue of the feasibility of reintroducing anadromous fish was also identified by regional interests represented in the Aquatic Resources Work Group as part of the relicensing process of the Hells Canyon Complex (HCC). In addition, the issues of anadromous fish passage and habitat availability continually arise in discussions relating to other Idaho Power Company (IPC) projects along the mainstem Snake River above the HCC that are also involved in the process of relicensing.

Reintroducing anadromous fish involves many considerations. Aspects of history, present-day habitat quality, multiple land uses and their effects on habitat and passage, limitations of passage technology at tributary and mainstem dams, risks of deleterious pathogen introductions, limitations of smolt-to-adult returns below Hells Canyon Dam, and potential impacts to existing federally protected stocks all need to be carefully weighed in relation to the cost, benefit, risks, and likelihood of success of a reintroduction program. This study was intended to be the first phase toward addressing the question of feasibility. It was also intended to highlight the many uncertainties of reintroduction and to identify areas within the historical distribution that have the greatest potential for successful reintroduction. A second phase would require more research targeted to examine key uncertainties of the reintroduction alternatives showing the greatest promise.

Historical Overview

We estimate that during the pre-development era (pre-1860), the area above Hells Canyon Dam produced between 1 and 1.7 million adult Pacific salmon (*Oncorhynchus* spp.) and steelhead (*Oncoryhynchus mykiss*). This estimate includes an estimated 0.76 to 1.19 million spring/summer chinook salmon, 135,000 to 214,000 fall chinook salmon, 117,000 to 225,700 steelhead, and 14,400 to 57,400 sockeye salmon (*O. nerka*). The distribution and abundance of Pacific lamprey (*Lampetra tridentata*) is unknown.

Over a period of approximately 70 years, anadromous fish above the present-day Hells Canyon Dam on the Snake River were gradually extirpated from their historical distribution by the construction of federal and private dams and by habitats degraded by multiple land uses. Habitat losses began primarily with placer mining, which was distributed throughout the entire basin and

literally turned over stream valleys, created water diversions, and input tons of sediment into stream channels. As mining activity increased, so did industries that could serve a growing population base. Quickly, the Snake River basin was developed for agricultural production, timber harvest, and livestock production. Some of the most profound changes to aquatic habitats began with the development of irrigation systems and the grazing of livestock. Irrigation systems decreased instream flows, increased instream temperatures, increased fine sediment inputs into aquatic habitats, and created partial or complete migration barriers. Livestock grazing impacted riparian corridors by decreasing stream shading and increasing stream temperatures. We believe these effects were especially pronounced in high-elevation desert basins such as the Malheur, Burnt, and Owyhee rivers.

As irrigation systems expanded, construction of large storage reservoirs began to eliminate production of anadromous fish from river basins. The Bruneau River was the first basin eliminated when a dam was constructed in the lower 1.5 miles (mi). Constructed in 1890, the dam was originally built for placer mining but was soon used for irrigation purposes. It was a complete barrier to anadromous fish.

In 1901, the Trade Dollar Mining Company of Silver City constructed the Swan Falls Dam. This dam was not constructed for irrigation, but to generate electricity for mines in the Owyhee Mountains. It became the upstream terminus for salmon in the Snake River, and, to a large extent, the dam was a barrier to steelhead. Swan Falls Dam blocked approximately 157 mi (253 kilometers [km]) of mainstem Snake River, or approximately 25% of the entire anadromous section of the mainstem Snake River. In addition, the dam blocked fish access to Salmon Falls and Rock creeks, which were the uppermost basins to support spring/summer chinook in the Snake River basin. Also, many smaller tributaries were blocked with construction of Swan Falls Dam. Although a fish ladder was installed at Swan Falls Dam during the initial construction, it was not functional for salmon and was probably not functional for steelhead.

In 1922, after IPC had taken ownership of Swan Falls Dam, the ladder was reconstructed. Unfortunately, the ladder was still ineffective for passing salmon around the dam. But some steelhead were probably able to pass. There are reports that a small run of steelhead ascended the river to C.J. Strike Dam (constructed in 1952), which was a complete barrier. Pacific lamprey could apparently use the fish ladder to pass Swan Falls Dam: Stanford (1942)[1] reported that "Pacific lamprey…[was] taken in the spring as it made its way with apparent ease, over the fishway or attempted to climb the lower face of the dam."

Following construction of Swan Falls Dam, large irrigation dams continued to be constructed. Dams on the Boise, Payette, and Owyhee rivers eliminated production of anadromous fish in those basins. Black Canyon Dam, constructed in 1924 in the lower Payette River, eliminated the only sockeye salmon production area above Hells Canyon Dam. The Malheur, Burnt, and Powder rivers all had large production areas eliminated by dams. In addition, land uses in the Malheur, Burnt, and Powder rivers had left even accessible areas of the basin unable to support anadromous fish.

[1] Stanford, L.M. 1942. Preliminary studies in the biology of the Snake River. Ph.D. dissertation. University of Washington, Seattle. 120 p.

Immediately before Brownlee Dam was constructed, only a few tributary basins were still producing spring/summer chinook salmon and steelhead. Approximately 75% of the anadromous production area above Hells Canyon Dam had been eliminated. Fall chinook salmon were limited to below Swan Falls Dam. Spring/summer chinook and steelhead production areas were primarily limited to the Weiser River, Eagle Creek (tributary to the lower Powder River), Wildhorse River, Pine Creek, and Indian Creek. Some steelhead production was also occurring in smaller tributaries to the Burnt, Powder, and Snake rivers. We estimate that adult returns to the area above Hells Canyon Dam immediately before the dam's construction consisted of approximately 16,400 fall chinook salmon, 1,900 spring chinook salmon, and 7,500 steelhead. Sockeye salmon had been eliminated. Although Pacific lamprey were present, their distribution and abundance at the time of closure by the dam is unknown.

The construction of the HCC followed a long and often virulent competition between public and private power interests. In question was whether power would be privately or publicly produced, not whether or not dams would be built. There were several proposals for dam construction in Hells Canyon. A 600-foot-high Hells Canyon federal dam was first proposed by both the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers. Other dams were proposed for Hells Canyon besides the three-dam HCC. Pacific Northwest Power Company proposed Mountain Sheep and Pleasant Valley projects downstream of the present site of Hells Canyon Dam. A group of Washington public utility districts proposed a 700-foot-high dam downstream of the Salmon River confluence.

Once the Federal Power Commission (now the Federal Energy Regulatory Commission) issued a permit for construction of the HCC, everything associated with fish passage went on a fast-track schedule. From issuance of permit (August 1955) to closure of Brownlee Dam (May 1958), only about 33 months were available to decide on mitigation techniques and to build the various passage facilities once passage was chosen. In August 1954, IPC was asking whether fish ladders or elevators should be constructed to permit adult fish passage and whether runs should be relocated in other streams. Article 34 of the Federal Power Commission license required the licensee to carry out detailed studies of the project area's fishery resource and to devise means and measures for mitigating losses to that resource. In accord with that requirement, state and federal fishery agencies investigated or considered all known methods for mitigating losses to the anadromous runs. These methods included passage, translocation, artificial and semi-artificial propagation, and natural redistribution of fish in streams below the projects. Of the methods, fish passage appeared most promising for protecting the resource. It retained the possibility of restoring runs in the historic spawning and rearing areas and focused mitigation on natural production. The main emphasis by the agencies and by IPC was on successfully passing adult and juvenile salmon and steelhead at the HCC, not on operating fish hatcheries or translocating stocks.

Adults were passed successfully above the projects using a trap-and-haul program. The adult migration at Brownlee Dam succeeded. From 1956 to 1964, adult chinook and steelhead were hauled successfully to a point 1.5 mi upstream of the dam. From there, the fish migrated through Brownlee Reservoir to the spawning grounds. However, passage of downstream migrating juveniles was much less certain. As early as fall 1953, a barrier net and gulper system was visualized as a means of passing juvenile fish. But how to pass juvenile salmon successfully through a deep reservoir, such as Brownlee Reservoir, was not known. IPC developed the

engineering concept for a mesh-barrier system to collect juveniles before they reached the dam. Fish were to be collected and transported by truck below the dam. Fish management agencies expressed concern about the untried nature of the barrier-net system, but given both the fast-moving construction schedule and the understanding at that time that additional dams would be constructed downstream of the HCC, agencies felt forced to accept the approach.

By 1962, it had become apparent that the barrier-net system would not work. Unfortunately, the condition of the barrier net was not the most important factor in the net's failure to capture large numbers of juvenile salmon and steelhead. Water temperature, dissolved oxygen (DO) levels, and inability of fish to find their way through the reservoir were more important factors. In December 1963, the Federal Power Commission ordered IPC to abandon the downstream collection efforts prior to the outmigration of 1964. The order also led to developing a hatchery mitigation program.

With completion of Oxbow Dam (1962) and Hells Canyon Dam (1968), production areas for spring chinook and steelhead were lost in the Wildhorse River and Pine Creek. Indian Creek was primarily a steelhead production area, but may have supported low numbers of spring chinook. The HCC inundated approximately 93 mi (150 km) of mainstem Snake River habitat and blocked access to approximately 118 mi (190 km) of free-flowing Snake River up to Swan Falls Dam. A total of 211 mi (340 km), or 34%, of mainstem Snake River habitat was lost. This loss plus the loss above Swan Falls Dam accounted for approximately 59% of Snake River mainstem habitat.

During the same general time period of construction of the HCC, dams were being built in the lower Snake River. In 1962, Ice Harbor Dam inundated approximately 32 mi (51.5 km) of the lower mainstem habitat. Construction of Lower Monumental and Little Goose dams followed in 1969 and 1970, respectively. Finally, Lower Granite Dam was built in 1975. Combined, these four dams inundated a total of 135 mi (217.3 km; 24%) of mainstem habitat that had been used for fall chinook production. By 1975, the total loss in Snake River mainstem habitat, based on river miles, was approximately 83%.

Fall chinook habitat and production potential have declined significantly in the Snake River. In addition to changes in the quantity of physical habitat, there have been significant changes in the thermal regimes available to fall chinook salmon since pre-development. We found that the quantity of physical habitat can be divided into three periods. Each period marks not only significant loss of physical habitat, but also marks a different thermal regime available to fall chinook. The first period is the pre-development period (pre-1860).

The second period is the post-Swan Falls Dam period, one marking the loss of highly productive spring-fed habitats in the middle Snake River above C.J. Strike Dam. The primary shift in thermal regime from the pre-development period to the post-Swan Falls period was not a result of a physical change in the thermal regime but of the inaccessibility of the spring-influenced sections of the middle Snake River to fish. Major spawning activity had occurred in the reach between Swan Falls Dam and Marsing, Idaho, a reach referred to as the Marsing reach.

The third period is present day. The construction years for the HCC and the lower Snake River dams mark the transition to this period, one of greatest loss of habitat for fall chinook salmon.

The HCC significantly altered the thermal regime of the Snake River below Hells Canyon Dam, resulting in extended warm periods in the fall and extended cool periods in the spring.

To describe the thermal regimes available to fall chinook during the different periods, we used present-day water temperatures from various reaches of the Snake River: above C.J. Strike, Marsing, downstream of Weiser, upper Hells Canyon, and lower Hells Canyon (below the Grande Ronde River). We were also able to locate continuous temperature readings from the years 1954 to 1957 from the Oxbow area; we used these temperatures to represent the pre-HCC thermal regime for the area below Hells Canyon Dam, at least to the Salmon River. The important thermal regimes for fall chinook include those that affect the pre-spawn adult, spawning, and incubation and post-emergence life stages—or the months from September through June.

Present-Day Conditions

Despite these historical changes in thermal regimes, we conclude that timing of both adult migration and spawning in present-day Hells Canyon is the same as that indicated by historical accounts of timing in the various reaches. However, we found that emergence timing in the various reaches differed because of the differences in thermal unit accumulation through the incubation period. We found that emergence timing was correlated with river mile and that the altered thermal regime in the present-day period below Hells Canyon Dam has shifted emergence in that reach to a date earlier than what occurred during the pre-HCC era. The present date is more similar to that of the Weiser reach today. Before HCC construction, emergence was earliest in the reaches above C.J. Strike Dam and latest at the Oxbow area. Estimates of emergence timing for the upper Hells Canyon reach overlapped those from above C.J. Strike downstream to the Weiser River. Today, the warmer over-winter temperatures probably allow the Hells Canyon reach to have a higher production potential with available habitat than the reach had during the pre-HCC era. Similarly, present-day emergence below the Salmon River occurs at warmer temperatures than during the pre-HCC era, probably allowing that section of river to reach the production potential of available habitat.

Despite higher production potential being available below Hells Canyon Dam today than during the pre-HCC era, the pre-development production areas above the HCC had a higher production potential in relation to the geomorphic template (i.e., greater quantity of suitable habitat) and a thermal regime more conducive to production than did the historical Hells Canyon reach. Even with the improved thermal regime below the HCC, the Hells Canyon reach will never be capable of the production that was historically available within spawning areas above the HCC.

Although the present-day Hells Canyon reach is warmer during the incubation period than it was before HCC construction, the entire production area available today is cooler than was the area above the HCC historically. That is, even though emergence times in the Hells Canyon reach today overlap with those that occurred in both the upper Snake River and the Marsing reaches historically and though thermal unit accumulation occurs at a faster rate today, fish emerge into a cooler thermal regime in the Hells Canyon reach today than did fish above the HCC historically. Despite the cooler regime during the rearing/outmigration period than that of historic production areas, fall chinook growth rates in the Hells Canyon reach appear to be exceptional. Reported growth rates are 1.4 millimeters per day, a rate that is among the highest observed.

Present-day temperature conditions below the HCC are more optimal for smolts migrating through the month of June than are temperature conditions represented by inflows to the HCC or by the Oxbow area in the pre-HCC period. However, delays to migrations through the lower Snake River reservoirs subject later migrating smolts to elevated water temperatures.

Present-day conditions above the HCC, within the historic fall chinook salmon spawning areas below Marsing, have probably continued to degrade since construction of the HCC. Currently, the Snake River below Swan Falls Dam is listed by the Environmental Protection Agency (EPA) as a water quality impaired section. The section below Swan Falls Dam to the Boise River has been included on the EPA's 303(d) list for Idaho because of sediments, nutrients, pH, bacteria, DO levels, and flow alterations. High organic and nutrient loads into the Snake River, along with high-suspended sediments, can directly affect the hyporheic environment (the area below the gravel or substrate of a streambed where river water and groundwater mix). In this environment, fine particulates can accumulate in the interstitial spaces of the gravel and increase microbial action and biological demand within the substrates.

Despite this habitat degradation, at two historic spawning sites studied on the Snake River below Swan Falls Dam, sediment permeability and substrate quality appear to be suitable for fall chinook salmon spawning and egg incubation. We based this conclusion on the following findings: 1) hydraulic conductivity and specific discharge values were moderate to high, 2) the percentage of fines was relatively low, and 3) the sediment size distribution suggested incubation and emergence success was moderate to high. Although the surface of the bed appeared armored, the maximum size of the surface sediment was within the size range that adult fall chinook salmon are capable of moving.

Based on findings from the sediment permeability analysis, the historic spawning areas below Swan Falls Dam appear to be suitable for incubating fall chinook. However, analysis of the environment in artificial redds suggests that survival may be impaired by low DO levels in the redd environment toward the end of the incubation period. DO levels measured in our artificial redds suggest that oxygen levels are adequate for redd environments to support survival of pre-hatch eggs through the hatch stage. However, whether the post-hatch period, with its higher oxygen requirement, has adequate DO is questionable at best. During year 1, DO levels in some of the redd clusters during the post-hatch to pre-emergence period were above 6.4 milligrams per liter (mg/l). However, most DO levels were below 4.0 mg/l. Approaching the estimated emergence period during year 2, none of the redd clusters had DO levels above 4.0 mg/l.

Habitat remaining in the tributaries upstream of the HCC is predominately upstream of tributary dams. We estimated that of the 41,338 square miles (mi^2) of basin located above the current site of Hells Canyon Dam, approximately 27% (11,358 mi^2) comprises the Effective Useable Basin (EUB)—habitat that would be suitable for spawning and rearing stream annulus chinook and steelhead today based on temperature and natural accessibility. Of all the tributary basins, the Weiser River and the Bruneau River represent the largest EUB area and stream kilometers that are unblocked within the basin.[2] Tributary dams currently block approximately 74% of the EUB.

[2] The Bruneau and Weiser rivers both have several mainstem water diversions that may present complete or partial barriers to anadromous fish. The reference to unblocked habitat refers to the absence of large dams greater than 10 feet high.

Within the EUB, we estimated that, based on temperature and gradient, 12,529 km (7,780 mi) of naturally accessible streams (third order[3] or greater with less than a 10% gradient) would be suitable for spawning and rearing stream annulus chinook and steelhead. However, approximately 69% of these stream kilometers are blocked by tributary dams and would still be inaccessible if fish passage at mainstem dams were provided. Of the stream kilometers that are fourth order and greater, or those that may be most productive for salmon, we estimate 6,714 km (4,169 mi) within the EUB. Of these stream kilometers, 68% are blocked by tributary dams and would be inaccessible if passage were provided at mainstem dams.

Using water-temperature information, literature review (Weiser and Payette rivers), and judgment (Boise River), we roughly estimated how much of the lower extent of tributaries would be unsuitable for rearing anadromous fish. Given the large spatial scale, there are undoubtedly exceptions to our estimated boundaries. However, we feel that our approximations of the downstream boundaries of suitable rearing habitat within the basins are reasonable. In addition, the distribution of anadromous fish prior to closure supports the estimated boundaries. The temperature-limited area accounts for approximately 20% of the basin area.

Nearly all the area within the historical distribution is affected by water diversions. We believe that anecdotal accounts support the hypothesis that land uses over the last century and a half have severely degraded the natural thermal regime of the Snake River basin. The desert basins located south of the Snake River, such as the Malheur and Burnt river basins, were especially fragile in terms of the importance of their riparian systems and the maintenance of a coldwater thermal regime. We believe that the absence of anadromous production before construction of the HCC, in what were accessible areas of many of these basins, demonstrates the severity of the habitat degradation. We believe that these same land uses and stream channel degradations have led to a much warmer thermal regime today, not only in the lower portions of many of these tributaries, but also in the mainstem lower Snake River, where, below the Weiser River, maximum summer temperatures commonly approach 28 ºC (82.4 ºF), a temperature lethal to anadromous fish.

Prospects for Reintroduction

For the areas upstream of the HCC, we calculated potential smolt yield under three options for fish passage (Options A−C). Option A estimated potential smolt yield if passage were to become available at all of IPC's mainstem Snake River dams. Our estimates begin with passage at Hells Canyon Dam. Then we continue estimating passage at successive dams to the uppermost Snake River dam that lies within the historical distribution of anadromous salmonids (Upper Salmon Falls Dam). Option A assumes that all dams and reservoirs would remain in place. Option B estimates potential smolt yield if passage were to become available at all IPC mainstem dams on the Snake River, as well as at all other manmade obstacles that would present a barrier to fish moving upstream or downstream. Option B begins with passage at Hells Canyon Dam and sequentially adds passage at upstream dams to the point of uppermost historical distribution of anadromous fish, including tributaries. Option C estimates potential smolt yields from the

[3] Stream order refers to the hierarchical ordering of streams based on the degree of branching. A first-order stream is unforked or unbranched. Two first-order streams flow together to form a second-order stream, two second-order streams combine to make a third-order stream, and so on.

portion of the historical production area currently blocked by manmade obstacles in tributaries. Option C is calculated as Option B minus Option A. Option C indicates blocked potential yield not associated with the effects of the dams that IPC owns on the mainstem Snake River.

The greatest present-day production potential (smolt production) for spring chinook salmon and steelhead is distributed above manmade barriers in tributary basins above Brownlee Dam. The Bruneau River basin provides the second greatest production potential. Approximately 73% of the spring chinook potential above the HCC is upstream of tributary dams. In the area between Brownlee and Swan Falls dams, approximately 94% of the production potential for spring chinook is behind tributary dams. This estimate includes blocked potential from the Powder, Burnt, Malheur, Owyhee, Payette, and Weiser rivers. Similarly, approximately 72% of the steelhead production potential above the HCC is upstream of tributary dams. Approximately 90% of the steelhead production potential is above tributary dams between Brownlee and Swan Falls dams. Most of this area was out of production before Brownlee Dam was built.

With mainstem passage only (Option A), the greatest potential for spring chinook and steelhead production is in the Bruneau River. If passage were included at tributary dams (Option B), the Payette, Boise, and Bruneau river systems would have the greatest production potential. Present-day production potential (smolt production) for fall chinook is concentrated in three reaches of the Snake River. The river sections above Brownlee Dam and above C.J. Strike Dam have comparable potential. The area above Swan Falls Dam was blocked before Brownlee Dam was built.

We assume that passage would be feasible at IPC dams as passage technology certainly exists for upstream and downstream passage at low head dams such as those upstream of the HCC. However, the challenges of providing such a passage system for the HCC are significant. No successful model exists for upstream passage within the height and distance ranges present in the HCC. Juvenile migration downstream through Brownlee Reservoir was and still is perhaps the most significant challenge for reintroducing fish above the HCC. Although smaller projects have demonstrated that fish runs can be established above natural river obstructions or smaller dams with shorter reservoirs, no successful prototypes exist for high dams with long, slow reservoirs like Brownlee Reservoir.

A conceptual design review was conducted for existing technology alternatives that may be suitable for the HCC. For upstream passage, fish traps or fish ladders were the alternatives for all three HCC dams, with fish traps having the lower construction cost. For downstream passage, diversion screens at both Oxbow and Hells Canyon dams were selected for the best conceptual approach. At Brownlee reservoir and dam, alternatives for upstream reservoir collection and for collection where water enters the turbines were included. Upstream collection alternatives included three fish-floating gulpers at the upper end of Brownlee Reservoir and one gulper at the mouth of the Powder River. A delivery system and a fleet of trucks would be necessary for this downstream passage alternative. Downstream alternatives for Brownlee Dam also included a forebay collection system using floating gulpers in the intake channel and a retrieval system that might use a crane to deliver juveniles from the gulpers to a holding area located near the top of the dam. Collection facilities in the forebay of Brownlee Dam would require a full draft of Brownlee Reservoir and, therefore, would result in substantial lost revenue from lost power generation. Another alternative for Brownlee Dam included spill release with a behavioral

guidance structure or guide wall. These alternatives could be applied separately or in conjunction with each other for downstream passage of anadromous smolts.

We also considered the availability and suitability of anadromous fish stocks that could be used for reintroduction. The goals of a reintroduction program would determine the stocks most suited for reintroduction of anadromous fish, but stocks would probably include those with characteristics close to the original stocks above the HCC. The likely candidates are steelhead from Oxbow Hatchery, spring chinook salmon from Rapid River Hatchery, and fall chinook salmon from Lyons Ferry Hatchery. Oxbow Hatchery stock steelhead could possibly be enhanced with locally adapted resident redband trout, although the two appear genetically similar. Determining suitable stocks for sockeye salmon for Payette Lake reintroduction would require further research to test the possibility of using a genetically endemic stock that may still reside in the lake.

With reintroduction there is potential for introducing deleterious pathogens to resident fish above the HCC. Little is known about the distribution of pathogens within natural fish populations generally, and the area above Hells Canyon Dam is no exception. The greatest risk is probably the introduction of pathogens that were not endemic to the area prior to HCC construction, in particular *Myxobolus cerebralis*. This pathogen has not been documented in basins immediately within the influence of the HCC, such as Pine Creek, Indian Creek, Wildhorse River, Eagle Creek, or the Weiser River. However, the pathogen has been documented in the Imnaha and Grande Ronde rivers, both below the HCC. The greatest risk of pathogen transfer may be with resident migratory fish, such as bull trout and resident redband trout, allowed to pass above the complex. Resident fish range over a wide geographic area, including those basins testing positive for *M. cerebralis*. Adult steelhead and chinook salmon returning to the Oxbow Hatchery have not had *M. cerebralis* detected. Because factors other than presence of the pathogen, such as habitat and environmental conditions, dictate the occurrence of disease, pathogen transmission into a basin does not necessarily imply that an adverse effect will occur. A pathogen risk assessment conducted by fish pathologists would be required for each area in which reintroduction is pursued.

Ultimately, the decision of defining and accepting risk is the responsibility of the management agencies. Risks need to be carefully weighed against other factors that will ultimately influence the success of a reintroduction program.

Reintroduction Scenarios

To further evaluate potential success of a reintroduction program, we evaluated a number of scenarios for reintroducing anadromous fish to the Snake River basin. We based our evaluations for each scenario on estimated potential adult returns to Hells Canyon Dam from subbasin smolt production estimates that we also developed. We assumed that smolts (from production numbers that we provided based on estimates of fully seeded basins) would enter the mainstem Snake River and arrive at the tailrace of the Lower Granite Project by either transportation or some combined means of downstream passage. Therefore, the specific criteria for each evaluation are 1) the estimated number of smolts from the subbasin or mainstem river section to reach the Lower Granite tailrace and 2) the corresponding adult returns.

Our adult return estimates were based on assumptions for a range (low to high) of potential smolt-to-adult returns from smolts arriving at Lower Granite Reservoir from each of the potential production areas. We had to make assumptions on potential smolt survival as smolts migrated through the various reservoirs and free-flowing sections or were transported around some reaches. The estimates also involved assumptions of adult survival from the mouth of the Columbia River to the production areas. We compared the estimates of adult returns (low and high smolt-to-adult returns) with estimates of escapement (low and high required escapement) that would be needed to maintain the subbasin smolt production estimates. Estimates of required escapement involved assumptions regarding egg-to-smolt survival, fecundity, and pre-spawn mortality. Although we did not evaluate all subbasins or every potential scenario, we present and discuss a range of alternatives that cover the requisite factors and considerations for any reintroduction alternative. In this analysis, we did not consider the specific actions necessary in each subbasin for reintroduction to succeed—actions such as irrigation screening and construction of bypass or collection facilities within the subbasins. We also did not consider predation and other mortality factors that could occur within the subbasin.

Under both sets of required escapement assumptions and for the estimates of what would be considered low smolt-to-adult return levels, none of the potential reintroduction scenarios we analyzed (Scenarios 1−9A, most specifying various combinations of drawdown, bypass or collection facilities, or transport between Hells Canyon and C.J. Strike dams) allowed any of the species in any of the production areas to return at sufficient levels to maintain production potential. Even under assumptions of a free-flowing river for smolt passage to the head of Lower Granite Dam, returns were not high enough using the low smolt-to-adult return estimates. Low smolt-to-adult return assumptions are representative of conditions prevalent in the early 1990s.

Under the high smolt-to-adult return assumptions, representing average conditions prevalent in the 1960s before Lower Granite Dam construction, spring chinook salmon returned at levels that would meet or exceed the low required escapement set of assumptions in Pine and Eagle creeks and the Wildhorse and Bruneau rivers (under transport assumptions) under one or more of our reintroduction scenarios. However, none of the basins exceeded the high required escapement assumptions. Steelhead returns just met required escapement levels in Pine Creek only under the low required escapement assumptions and only under the survival estimates for the free-flowing river scenario. Under Reintroduction Scenario 2, which allows for upstream passage of adults at Hells Canyon and Oxbow dams, return levels were within 10% of the low required escapement for the Wildhorse River and Pine and Indian creeks. Fall chinook did not return at high enough levels to the Walters Ferry reach under any of the sets of assumptions, and they only approached the level required under the low required escapement assumptions under the free-flowing river scenario. However, under the collection and transport options at Swan Falls and C.J. Strike dams (Scenario 6A), fall chinook survival exceeded that under free-flowing conditions. Under the high smolt-to-adult return estimates, fall chinook met or exceeded survival levels required under the low required escapement set of assumptions.

Under the low smolt-to-adult return assumptions, the number of smolts that could be produced by the estimated escapement was well below the production area potential. To achieve required adult levels, a high proportion of smolts arriving at Lower Granite Dam would be, by necessity, of hatchery origin. For example, Scenario 5A, which allows passage of adults at Brownlee Dam

with collection facilities at Brownlee Dam, had the highest survival rate of spring chinook smolts in the Weiser River arriving at Lower Granite Dam. However, under the low smolt-to-adult return and low required escapement assumptions, approximately 47% of the smolts would need to be of hatchery origin. An additional number of smolts would be required to supply enough extra adult returns to maintain the hatchery program and maintain natural spawning in the basin at full production. Using the high smolt-to-adult return and low required escapement assumptions, 17% of the smolts arriving at Lower Granite Dam would need to be of hatchery origin, plus additional smolts would be necessary to provide enough adults to maintain the hatchery program.

Reintroducing fall chinook in the Walters Ferry reach would require a more extensive hatchery program than would reintroducing spring chinook in the Weiser River. Under Scenario 5A, approximately 80% of the smolts arriving at the Lower Granite Dam tailrace would need to be of hatchery origin under the low smolt-to-adult return and low required escapement assumptions. Under the high smolt-to-adult return and low required escapement assumptions, approximately 58% of the smolts would need to be of hatchery origin to maintain adult returns high enough to maintain basin production. Additional smolts would be required to retain enough adults to maintain the hatchery program. The number of adults required for the hatchery program would depend on whether smolts were released for in-river passage or held on site for acclimation and then transported to the tailrace of Hells Canyon Dam.

Challenges for the Future

Clearly, the issue of reintroduction raises many uncertainties. Reintroduction for the purposes of recovery of the salmon and steelhead listed under the Endangered Species Act does not appear feasible unless very significant societal commitment develops for ecosystem recovery. Also, unless average smolt-to-adult returns downstream of the HCC improve substantially, reintroduction with the goal of self-sustenance is quite infeasible. The same factors that limit anadromous fish downstream of the HCC would also limit success of reintroduction upstream of the HCC. Even with substantial increases in smolt-to-adult returns, most of the reintroduction scenarios that we examined would not permit self-sustaining populations of anadromous fish to develop in many subbasins.

Very significant steps toward ecosystem recovery need to occur upstream of the HCC. Such ecosystem recovery should be an immediate priority even before reintroduction is pursued. We suggest that primary action should be directed at protecting and maintaining the remaining strongholds. Secondarily, we suggest recovering and enhancing the areas that have the greatest potential for at least partial recovery. Many of these necessary actions go beyond the scope of IPC and of relicensing the HCC; they would involve a large group of societal interests and commitments. These actions should include efforts to increase escapements in habitats for all anadromous fish downstream of the HCC.

The viability of native resident fish populations upstream of the HCC depends on ecosystem recovery. Many of the more immediate actions that would be required to recover native fish would also be needed before reintroduction of anadromous fish could succeed. In the short term, we have much to learn regarding factors that would affect successful reintroduction. Our assumptions about tributary and mainstem habitats, production potential, survival through

reservoirs and free-flowing sections, and incubation survival in the mainstem Snake River all shape our decisions on feasibility of reintroducing anadromous salmonids. Future study should address the uncertainties in conjunction with implementing measures to recover native salmonids and their habitat in basins such as Pine and Indian creeks. Studies about intragravel conditions in mainstem production areas could continue in conjunction with measures implemented in the ongoing total maximum daily load process to improve water quality in the mainstem Snake River.