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

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Editor

Technical Report
Appendix E.3.1-2

Hells Canyon Complex
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Historical Abundance of Anadromous Fish Upstream of the Hells Canyon Complex

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Chapter 6

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1. INTRODUCTION

In this chapter, we provide two sets of estimates of historical anadromous fish productivity for the area upstream of the Hells Canyon Complex (HCC). The first set of estimates covers the predevelopment era of the late 1800s. The second set of estimates covers the latter half of the 1950s, prior to construction of the HCC.

2. PREDEVELOPMENT (LATTER HALF OF 1800S) ABUNDANCE OF ANADROMOUS FISH PRODUCED IN THE AREA UPSTREAM OF THE HCC

Three sources provide estimates of steelhead and salmon production in the Columbia River basin in the 1800s. The first source (Chapman 1986) estimated peak salmon and steelhead runs for a period of 40 years from 1880 to 1920. The second source (NPPC 1986) also estimated predevelopment run sizes. Both of these sources used peak catches in the latter part of the 1800s and estimated harvest rates to calculate peak runs. Finally, the third source (PFMC 1979) estimated predevelopment run sizes for salmon on the basis of freshwater habitat.

Interdecadal cycles in ocean productivity and survival influence estimates of historical runs. Pearcy (1996) discussed interdecadal and intradecadal fluctuations in ocean conditions as they influence salmon abundance. He noted that a cool, wet climatic regime leads to high ocean survival, while warm, dry conditions reduce survival. He also linked predator abundance to survival changes, pointing out that periods of poor upwelling and warm temperatures reduce the abundance of forage for predators and that reduced forage probably leads to increased predation on young salmon. Yet such periods may also reduce the abundance of predators and thereby improve salmon survival for several subsequent years (e.g., the period of exceptional salmon returns in the mid- to late 1980s evidenced in many stocks other than spring chinook). The point here is that ocean productivity and survival strongly influence the numbers of salmon and returning runs in any period. Therefore, all estimates of predevelopment runs depend on the ocean conditions that produced returns and catches.

Chapman (1986) estimated peak runs of chinook salmon as follows: 2.00 to 2.50 million summer chinook, 1.25 million fall chinook, and 0.50 to 0.59 million spring chinook. He estimated sockeye runs as 2.25 to 2.60 million, and steelhead runs as 0.45 to 0.55 million fish. He based the lower estimates on probable harvest rates of 80 to 85% for spring and summer chinook, 88% for fall chinook, and 85% for sockeye and steelhead. He based the higher estimates on optimum harvest rates[1] of 68% for spring and summer chinook, 88% for fall chinook, 73% for sockeye,

[1] "Optimum harvest rate" here means the rate that would be appropriate to support maximum sustained yield.

and 69% for steelhead. For simplicity, we will use the lower estimates of run size, inasmuch as overfishing was the norm in the lower Columbia River.

The Northwest Power Planning Council (NPPC 1986) estimated predevelopment run sizes on the basis of harvest rates of 50 to 67%, a range lower than the fishing rates posited by Chapman (1986). Because run size is estimated on the basis of $N = C/a$, where N = estimated run size, C = catch, and a = fishing mortality rate, a lower fishing rate results in a larger run estimate. If fishing had been conducted at rates as low as those posited by NPPC (1998), we must question why Columbia River runs dropped so precipitously, especially in the summer chinook that represented the heart of the fishery. Those fish used large tributaries and the main Columbia River, where settlement, mining, and agriculture could have little effect on habitat during the period of interest.

The Pacific Fishery Management Council (PFMC 1979)—using information developed by an environmental task force composed of representatives of the Washington Department of Fisheries, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game (IDFG), California Department of Fish and Game, National Marine Fisheries Service, and U.S. Fish and Wildlife Service—estimated predevelopment runs of 3.40 million chinook and 0.60 million sockeye. Those numbers can be compared with NPPC (1986) run estimates of 4.78 to 9.20 million chinook and 2.60 to 2.80 million sockeye. The PFMC (1979) did not estimate steelhead abundance. Compared with the habitat-based estimate of the PFMC (1979), the NPPC (1986) estimate was 1.4 to 2.7 times greater for chinook and 4.3 to 4.7 times greater for sockeye. We believe that the NPPC (1986) figures are substantial overestimates of predevelopment run sizes in the Columbia River.

2.1. Estimated Snake River Component of Anadromous Fish Runs

The PFMC (1979) estimated that the Snake River basin produced predevelopment runs of 1.40 million chinook and 0.15 million sockeye. The Snake River habitat thought to produce these fish amounted to 7,739 miles (mi) (12,455 kilometers [km]) of stream (chinook habitat)[2]. That habitat was about 65% of the total habitat available to chinook salmon in the Columbia River basin and 79% of the total stream miles, or kilometers, available upstream of the present Bonneville Dam (PFMC 1979).

The Snake River was thought to produce 58% of the total chinook produced upstream of the Bonneville Dam site, even though the river contained 79% of the available stream miles, or kilometers. We attribute this estimate to the relative availability of habitat suitable for ocean-annulus[3] chinook. Potential mainstem Snake River spawning habitat totaled about 990 km from

[2] A total of 1,716 mi (2,761 km) of habitat were listed for sockeye but were thought to be mostly migration corridor.

[3] Ocean-annulus fish are anadromous fish that complete their first annual growth in the ocean, while stream-annulus fish complete their first annual growth in fresh water.

the river mouth to Shoshone Falls, or 7.9% of the total stream kilometers in the Snake River basin. Potential mainstem spawning habitat in the Columbia River totaled about 1,700 km from Bonneville Dam to Lake Windermere, or 51% of the 3,357 km of basin habitat outside the Snake River. Fulton (1968:4) shows 1,932 km, but we reduced this by the 232-km distance from the Bonneville Dam site downstream to the mouth of the Columbia River. Also, the mainstem Wenatchee, Yakima, Methow, Okanogan, and Spokane rivers, and probably the John Day River, produced ocean-annulus chinook (Fulton 1968, Mullan et al. 1992). In the Snake River, ocean-annulus fish used only the mainstem Snake River and not its major tributaries (Fulton 1968). A greater proportion of habitable kilometers in the Snake River basin lay in smaller tributaries—used by stream-annulus chinook—encompassing smaller surface areas at high elevations. Therefore, we should expect that those habitat kilometers would have produced relatively fewer adult chinook salmon than the habitat in the Columbia River outside of the Snake River basin.

2.2. Apportionment of Snake River Chinook to Spring/Summer and Fall Components

One way to partition predevelopment chinook runs into stream- and ocean-annulus components is to allocate "fall chinook" to mainstem spawning areas. Using Chapman (1986), we would therefore apportion 36% of the estimated 1.25 million adult fall chinook to the Snake River and 64% to the Columbia River on the basis of mainstem spawning habitat (976 km in the Snake River and 1,715 km in the Columbia River). This apportionment places the Snake River contribution at about 453,000 fish (calculated as [976 km ÷ (976 km + 1,715 km)] × 1,250,000 fall chinook).

Following the same logic, we would partition the spring/summer chinook, estimated by Chapman (1986), based on the complementary habitat kilometers: 11,406 km in the Snake River (calculated as 12,382 km – 976 km) and 1,642 km in the Columbia River system outside the Snake River (calculated as 3,357 km – 1,715 km). Thus, 12.5% of the spring/summer chinook (stream-annulus) would originate from the Columbia River, and 87.5% from the Snake River basin. The resulting apportionment yields about 314,600 spring/summer chinook produced by the Columbia River and 2.20 million produced in the Snake River basin.

A similar exercise with the PFMC estimates (1979) cannot be completed directly because the PFMC did not separate chinook by run timing. Chapman (1986) estimated that 3.75 million chinook were produced by the Columbia River in predevelopment periods, while the PFMC (1979) estimated total chinook runs at 2.40 million fish. Chapman (1986) estimated the fall run component to be 33% of the chinook total. One-third of the PFMC (1979) chinook total would equal 0.80 million fish. Allocating that to the Snake River on the basis of mainstem habitat, we estimate that 36%, or 288,000 fish, would have used the Snake River. The remainder of the PFMC (1979) total chinook production would be 1.60 million spring/summer fish, of which 87.5%, or 1.40 million fish, could be allocated to the Snake River.

In summary, the foregoing exercises yield predevelopment Snake River contributions of 1.40 to 2.20 million spring/summer chinook and 288,000 to 450,000 fall chinook. We have not undertaken similar calculations incorporating the NPPC (1986) run estimates prepared from a basis of 50% exploitation rates. We consider the NPPC run estimates to be too high because of the unrealistically low exploitation rate used to derive them.

We checked predevelopment production by examining an IDFG report (1985) that estimated the stream miles available to anadromous fish in Idaho at that time as 5,322. The same report also listed stream miles then unavailable upstream of the HCC (2,109) and in the North Fork Clearwater River (627). However, the report did not include habitat in Salmon Falls Creek, Rock Creek, or small independent tributaries of the Snake River.[4] We can arbitrarily add 250 stream miles to the IDFG (1985) total to account for those omissions and therefore estimate that Idaho stream habitat for anadromous fish in the predevelopment period totaled 8,308 mi. However, if we add stream miles in Washington (Tucannon River, for example) and Oregon (Powder and Malheur rivers, for example), the predevelopment stream miles in the Snake River basin do not comport exactly with the PFMC (1979) estimate of 7,739 mi. We cannot resolve this difference, as the PFMC (1979) does not provide individual subbasin habitat miles for comparison with IDFG numbers (1985).

The IDFG (1992) used the NPPC presence/absence database to estimate smolt capacity of the Salmon River for spring/summer chinook at 11,381,176 fish. Presumably, this estimate would be higher if all habitat in the Salmon River basin ("effective"[5] basin size about 8,500 mi^2) were in predevelopment condition. If we expand the IDFG (1992) estimate of smolt output to the entire Snake River basin (incremental effective drainage sizes equal to about 41,338 mi^2 above HCC, 6,000 mi^2 in the Clearwater River, and 3,400 mi^2 in the Grande Ronde, Imnaha, and Tucannon river basins), the total capacity of the basin to produce smolts increases to about 80 million smolts. At smolt-to-adult returns (SAR) of 4 to 6%, this would produce 3.20 to 4.80 million spring/summer chinook adults. This number does not coincide with estimates by the PFMC (1979) or Chapman (1986).

We can compare the IDFG (1992) estimate of 11.40 million stream-annulus chinook smolts from the Salmon River at full seeding with the early 1960s output at Ice Harbor Dam of wild spring/summer chinook produced by the entire Snake River basin. Raymond (1979) reported output from the entire Snake River at Ice Harbor as about 2.56 million smolts. We can assume that seeding was adequate in the brood years that produced the smolts for which Raymond (1979) estimated yield, as noted elsewhere in our report. It appears that the IDFG (1992), using the NPPC presence/absence database, overestimated potential smolt yield from the Salmon River.

[4] Nor did IDFG (1985) list the Malad River, although Richards (1990) included it as having once produced salmon and steelhead. We concluded in Chapter 4 (Chandler and Chapman 2001a) that the Malad/Wood River did not support anadromous salmonids, with the possible exception of the 3-mi reach below Malad Falls.

[5] We assumed that "effective" drainage area consisted of that portion of the basin that lay upstream of the most-downstream limit of rearing by stream-annulus salmon.

2.3. Allocation of Spring/Summer Chinook and Fall Chinook to the Area Upstream of the HCC

The estimated predevelopment runs of 1.40 to 2.20 million spring/summer chinook and 288,000 to 450,000 fall chinook for the entire Snake River basin can be allocated to the area upstream of the HCC on the basis of drainage area or stream miles. For stream-annulus fish, the effective predevelopment drainage area of the Snake River can be estimated as 41,338 mi^2 upstream of the HCC and 35,300 mi^2 in the basin downstream of the HCC. The former estimate does not include the area upstream of Shoshone Falls, nor does it include the Malad and Wood rivers as "effective."

On the basis of ratios of effective area, the predevelopment yield of adults from areas upstream of the HCC equals 54% (41,338 ÷ 76,638 × 100) of the total number of spring/summer chinook produced by the entire Snake River basin. That percentage equates to 0.76 to 1.19 million spring/summer chinook. One might argue that the habitat in the Snake River above Hells Canyon is less desirable than that in the Salmon and Clearwater rivers because the Snake River tributaries between Hells Canyon and Shoshone Falls drain areas that receive less precipitation. However, higher aquatic productivity may have partially offset that factor. For example, conductivity, a measure of dissolved salts, was probably higher in the upper Snake River and tributaries than in the Clearwater River and tributaries.

For fall chinook, we consider the allocation to be more problematic. Using stream distance alone (397 km downstream of the HCC and 593 km upstream), one would allocate about 60% of the production of ocean-annulus fish, or 172,800 to 270,000, to the area upstream of the HCC. Fall chinook once spawned from near the Ice Harbor Dam site to as far upstream as Shoshone Falls. The allocation based on distance alone may be reasonable. On the other hand, river gradient between the Salmon River and Weiser was steeper and perhaps offered less habitat for spawning than did the main Snake River downstream of the Salmon River and upstream of Weiser. Pirtle (1954) used various indicators to estimate that 50% of Snake River fall chinook spawned in that portion of the Snake River upstream of the Boise River.

2.4. Allocation of Steelhead to the Area Upstream of the HCC

No reasonably straightforward system is available for calculating numbers of steelhead produced by portions of the Columbia River basin. As one approximation, Chapman's (1986) estimate of 450,000 to 555,000 steelhead in peak runs to the Columbia River may be partitioned on the basis of drainage size. The Snake River basin upstream of Hells Canyon covers 73,300 mi^2, and the Columbia River basin upstream of the mouth contains 258,000 mi^2. Thus, one might expect the area upstream of Hells Canyon to produce 28% of the steelhead in the Columbia River basin, or 126,000 to 155,000 adults at the mouth of the Columbia River. This number of adults may be an overestimate, as the area upstream of Hells Canyon includes 17,180 mi^2 upstream of

Shoshone Falls and 3,000 mi^2 in the Malad River/Wood River basin unavailable to steelhead.[6] The upstream area also includes a relatively dry portion of the Columbia River basin.

A second approximation might be developed from an estimated ratio of steelhead to salmon numbers, especially to stream-annulus salmon. That ratio could be estimated from Chapman (Table 3 in Chapman 1986) as about 0.18 by dividing 449,000 by 2,500,000. Using 0.65 to 1.03 million as the estimate for spring/summer chinook produced upstream of the HCC site, one might thus calculate a similar estimate of 117,000 to 185,000 fish.

The error potential in either of these crude approximations is large. If one simply multiplies the predevelopment "effective" drainage basin size of 41,338 mi^2 upstream of Hells Canyon by 91 smolts per square mile (see section 2 in Chapter 7 [Chapman and Chandler 2001b] on yield of effective drainage areas and also Buckman 1990), yielding 3.76 million smolts, and assumes an SAR of 4 to 6%, one would calculate an adult return to the Columbia River mouth of about 150,470 to 225,700 fish.

2.5. Allocation of Sockeye Runs to the Area Upstream of the HCC

Sockeye production in the area upstream of the HCC was confined to the Payette Lakes area. Evermann (1896) reported reconnaissance of the area by T. M. Williams in summer and fall 1895. Williams provided information indicating that sockeye used neither Upper Payette nor Little Payette lakes. The surface area of Big Payette Lake totaled about 5,000 acres.[7]

Sockeye runs to the North Fork Payette River and to Big Payette Lake ended in the mid-1920s when construction of Black Canyon Dam permanently blocked anadromous runs. No statistics are available for the adult sockeye run or for smolt output.

The simplest way to estimate sockeye runs contributed by Big Payette Lake is to calculate its fraction of total surface area among sockeye lakes in the Columbia River basin and then to multiply that fraction by the estimated total run size in some time period of interest. Revising Mullan's information (Table 1 in Mullan 1986:3) by using the correct surface area of Big Payette Lake, and omitting Little Payette and Upper Payette surface areas, we find that the total area of sockeye lakes in the basin equaled about 226,350 acres. Thus, Big Payette Lake made up 2.21% of the sockeye rearing area available in the predevelopment era.

Chapman (1986) estimated runs of 2.25 to 2.60 million sockeye. These numbers would translate to pristine run sizes of about 49,700 to 57,400 fish. The PFMC (1979) estimated sockeye runs to the Columbia River of only 650,000 fish. If that estimate is used, the Payette contribution would be calculated as about 14,400 fish. The PFMC (1979) estimated that 23% of the sockeye runs to

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[6] On the other hand, steelhead in the upper Columbia River also could not reach much of the Spokane, Chelan, Okanogan, Pend Oreille, Clark Fork, and Kootenai river basins.

[7] Mullan (1986) erred in reporting a surface area for Big Payette Lake of 1,000 acres.

the Columbia River originated in the Snake River. Snake River habitat area (from Mullan 1986, as adjusted above) would total about 10,222 acres. The PFMC proportional contribution would thus have 4.5% of the lake surface area in the Columbia River basin contribute 23% of the sockeye. That scenario seems unlikely in light of the probable higher productivities of the lakes in the Okanogan River system, which made up 8.5% of the Columbia River basin.

The available information does not permit a productivity-adjusted proportionalization of sockeye runs. Such an adjustment might, with sufficient data, use a morphoedaphic index.

2.6. Best Estimates

In summary, we recommend that predevelopment adult returns to the Columbia River of fish produced upstream of the HCC site be estimated as follows:

	Run estimate	
Species/Race	**Low**	**High**
Spring/summer chinook	760,000	1,190,000
Fall chinook	172,800	270,000
Steelhead	117,000	225,700
Sockeye	14,400	57,400
Pacific lamprey	No data	No data
Total salmon and steelhead	1,064,200	1,743,100

Of course, adult salmon and steelhead that arrived at the mouth of the Columbia River did not all return to a point in Hells Canyon. Marine mammals, Native American anglers, and natural mortality reduced the returning cohorts. Therefore, escapement to the natal habitat was considerably less than the return to the Columbia River.

Estimates of run size based on peak-period catches in the late 1800s may or may not indicate average runs over multiple decades. If productivity of freshwater and marine environments was in either a high or low cycle relative to a long-term average, one would accordingly over- or underestimate predevelopment runs.

3. Mid-1950s Abundance of Anadromous Fish Produced Upstream of the HCC

In this section, we provide estimates of adult salmon and steelhead abundance in the 1950s, before the HCC affected returning brood years. We rely mostly on escapements at Brownlee and Oxbow fish traps in the period 1957–1960. We also offer estimates of adult abundance at the mouth of the Columbia River and as recruits to the exploitable phase (age) at sea. The latter two estimates necessarily involve several assumptions.

Empirical information on adult escapements, such as redd counts or trapping data, provide one basis for estimating productivity of given basins or subbasins. Although we lack such information on predevelopment fish abundance in the area of the HCC, we have estimates and fish counts at HCC trap facilities in the 1950s. These data do not necessarily indicate what the Snake River basin upstream of the HCC could have produced if habitat and harvest management were improved.

Adult escapements, adjusted with information on downriver harvests and estimated losses caused by dams on the migration route, do provide useful information on mid-1950s fish abundance. They thus offer an empirical baseline level for pre-HCC populations.

In adjusting numbers to provide approximate estimates for fish numbers at various adult stages and points in the migration route, we used an interdam loss of 5% per project (Chapman et al. 1991). Interdam losses may have been higher in some years at some dams, but available data do not support year-specific estimates. Fishing rates were obtained from the Oregon and Washington departments of fish and wildlife (ODFW/WDFW 1998).

3.1. Fall Chinook

3.1.1. Escapements Past the Site of Brownlee Dam in the Late 1950s

Richards (1973) estimated the number of fall chinook reaching the area upstream of Hells Canyon to be 2,695 before the Celilo Falls inundation (pre-1957) and 14,944 for the period 1957–1959 before the effects of the Brownlee Dam began to appear in adult returns (the first affected year would be 1960, from the outmigration of 1958). The mean of 4,981 for the three years 1957-1959 does not necessarily constitute maximum production of fall chinook from the area. Rather, it only constitutes escapement at whatever environmental saturation produced and then subsequently survived in the ocean and river to return to the Hells Canyon area. Natural mortality and fisheries at sea, both sport and commercial, reduced ocean recruits.[8] Sport and commercial fisheries in the Columbia River, mostly in zones 1 through 5 in the period 1957−1962, further reduced fish numbers. Natural mortality and some dam-caused mortality acted on survivors. Escapements as estimated by Richards (1973) constitute survivors of all of these sources of mortality.

3.1.2. Outages of the Electrical Barrier in 1957

The electrical barrier that guided chinook salmon into the Brownlee trap, so they could be moved above the construction site, suffered outages from August through October 1957. To examine the maximum possible effects of the outages on the 1957 fall chinook count, we tabulated all recorded outages from August 6 to October 19, the main period of fall chinook migration in Hells Canyon. No subsequent outages were reported. For each day in which an outage occurred,

[8] We did not adjust ocean recruit numbers to reflect natural mortality at sea between the exploitable age and the arrival of survivors at the mouth of the Columbia River.

we tabulated the chinook count in the trap. Next, we calculated the total count that might have been missed, assuming that passage during hours of outage on a given day would equal that during the same number of hours of electrode operation. The estimated outage count totaled 3,020 fish. If we expanded the count by the hours of outage, the total fall chinook count in 1957 would be estimated as 18,180 instead of 15,160. Unfortunately, we cannot determine whether any fish that might have passed the inoperative electrodes 1) died between the barrier and the Brownlee diversion tunnel, 2) dropped back through the barrier and subsequently entered the trap, or 3) dropped back and never entered the trap. It is even conceivable, though unlikely, that adults passing the inoperative barrier managed to pass through the diversion tunnel. Outages that occurred during daylight hours potentially would allow more adults to pass than would nighttime outages. However, outages for some days were recorded by total hours of outage and not by the times those outages occurred. We calculated the maximum outage adjustment to be 19.9%.

Later, the Oregon Fish Commission (1958a) estimated that 20,000 fall chinook would have been upstream of Brownlee Dam. They did so on the basis of "questionable passage conditions of tunnel and partial block causing fish normally destined for above Brownlee to drop back down river." However, they did not offer any data to support either tunnel passage or drop-back.

Dividing the Brownlee trap count by the September McNary (on the Columbia River) count provides a check on both the possibility of fish escaping through the tunnel and the "partial block" hypothesis. In 1957, that ratio was 0.31; in 1958 (based on complete trapping and including "Oxbow Incident" kill[9]), it was 0.215. On the basis of these ratios alone, it seems unlikely that many fall chinook escaped through the tunnel in 1957. However, the Snake River redd count as a fraction of known fish passage in the two years offers another check. Redd counts were 2,622 and 955, respectively, for 1957 and 1958. Thus, the ratios would be 2,622/15,160 = 0.17 for 1957 and 955/14,697 = 0.065 for 1958. The same ratio occurred in 1959 (718/11825 = 0.061); in 1960, the ratio was 0.132. The relatively high ratio in 1957 could be used to support a hypothesis of some tunnel passage by fall chinook.

Comparing these checks neither supports nor refutes the contention that some escapement occurred through the tunnel. If we concluded anything, it would be that some escapement did occur there. If we adjust for periods when the electric barrier was inoperative in 1957, the number of fish arriving at the barrier could be as high as 18,180, and the redd/escapement ratio becomes 0.14. This adjustment may not help clarify much, if anything, because we cannot determine the fate of the estimated 3,020 additional fish. They may not have existed; they may

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[9] The "Oxbow Incident" occurred during construction of the Oxbow dam and powerhouse. The main concrete wall at the fish trap failed, and the diversion tunnel and dam had to be dewatered for repairs. This forced breaching of the coffer dam on September 3, 1958, sending the river flow over the coffer dam and through the oxbow. The upstream migration of fall chinook and some summer steelhead was underway while workers repaired the damaged facility. This meant that adults entered the oxbow. Most could not pass the high-velocity flows at the breached coffer dam and so were trapped in the oxbow when the river once again was diverted through the diversion tunnel. Many adults failed to find their way downstream out of the oxbow as the water level there dropped. The adults stranded in the oxbow began to suffer from oxygen deprivation. Despite efforts to salvage fish, several thousand salmon and steelhead perished. The official estimate was 3,497 fall chinook and 771 steelhead. The kill made up about 20% of the adult fall chinook run that arrived at Oxbow trap, and 15% of the steelhead run for the 1958–59 brood (see Chapter 2 [Chapman 2001]).

have passed the barrier and died while trying to surmount the tunnel; they may have dropped back to spawn in the river downstream; or they may have dropped back and been trapped, and thus been included in the actual trap count.

Forrest Hauck, as noted in Exhibit 48 of IPC hearings, calculated adult salmon numbers based on percentages of adults in carcass recoveries in the main Snake River in 1957, 1958, and 1959. The proportions of adults were, respectively, 0.68, 0.86, and 0.50. These proportions would make available spawner adults number 10,182; 12,107; and 5,880. Female ratios in adult numbers were 0.41, 0.43, and 0.54. Therefore, female numbers would be 4,154; 5,158; and 3,152. With these numbers, we can recalculate the ratio of redds to estimated females as 0.630, 0.185, and 0.228 for the respective years. These data tend to support escapement through the tunnel in 1957.

In the final analysis, we find that the preceding information is inconclusive. We cannot exclude the possibility that some fish passed through the tunnel. If we assume that the electric barrier captured 100% of migrating adults when it operated, fish may have passed only during outages. That number may have equaled up to 3,020 fish, derived from proportioning outage periods to counts during operating periods, as we noted earlier. We found no evidence that the electric barrier forced fish to drop back and spawn in the Snake River downstream of the barrier.

3.1.3. Fall Chinook Escapements at the Oxbow Dam Site and Run Size

One option in estimating fish abundance would adjust escapements for inriver fishing and interdam loss. To do this, we lumped dams and fisheries in Zone 6 temporally. Hence, the following adjustments will be approximate; that is, a fish cannot be killed twice. However, we see this source of error as negligible in light of the probable accuracy of various estimates. Numbers shown here do not include fish destined to spawn between Hells Canyon Dam and Oxbow Dam.

Between the 1957 and 1958 trap counts, adults that would have spawned in the 14 mi of Snake River between the Oxbow trap and Brownlee Dam augmented trap counts. Richards (1959) identifies 24 redds in 1958 between Brownlee Dam and the site of the future Oxbow Dam. However, the so-called “Oxbow Incident” influenced numbers of spawning adults because the cofferdam was breached to allow adults to escape from the oxbow. Some fish passed to the river segment between the Brownlee Dam and Oxbow site, while trucks hauled others to a point upstream of Brownlee Dam. Thus, we regard the 1958 redd count in the Oxbow–Brownlee Reach as unrepresentative.

In 1959, no redd count was made between Brownlee Dam and the site of the future Oxbow Dam. However, 87 redds were counted in the 7-mi stretch between the Oxbow site and IPC’s “Interstate Bridge,” just downstream of Pine Creek. This number converts to about 12 redds per mile. Using the ratio of the redd count in 1959 upstream of Brownlee Dam (Haas 1965) to the number of adults that passed the HCC (ratio = 0.061), one can estimate 16 fall chinook in the escapement for each redd observed in 1959. This number converts to 192 escapees per mile from the Oxbow site to the Hells Canyon site. However, Brownlee Reservoir likely improved transparency of the Snake River (Haas 1965). Thus, we suspect the ratio of escapees to redds would decrease.

In the period 1960–1962, aerial counters observed 77, 59, and 67 redds, respectively, between Oxbow Dam and Interstate Bridge, an average of 68 redds.[10] The average ratio of redds to escapees upstream of Brownlee Dam in those years equaled 0.16, calculated from Richards (1960, 1961, 1962); this ratio converts to 6 escapees for each observed redd. Thus, in the 7 mi of river included in redd counts, about 58 fall chinook per mile used the reach between Oxbow Dam and Interstate Bridge. If we apply this figure to the mileage between Oxbow and Brownlee dams, we can estimate that we should augment the Brownlee trap count for 1957 by 699 fish to index the Brownlee count to the Oxbow trap.

Alternatively, Hells Canyon escapements could be multiplied by a "production factor" to estimate total recruits before ocean fishing began. Haas (1973) estimated a harvest-to-escapement ratio of 6:1 for the collective fisheries on Snake River fall chinook. Using that ratio, we can calculate that 15,177 escaping chinook at Hells Canyon represented 91,064 fish in the catch and a total "run" (catch + escapement) of 106,241 fish. The ratio of harvest to escapement varied to some degree from year to year as shown in Table 1.

3.1.4. Allocation of Escapements of Fall Chinook to Tributaries and River Reaches

Pirtle (1954, 1957) used aerial surveys of known spawning areas to estimate escapements to various areas and to prorate, or proportion, the McNary Dam count into various surveyed streams. He distributed the McNary Dam counts of 1954–1956. His allocations (Pirtle 1957) were as follows:

Roza Dam	Rock Island Dam	Ringold–Rock Island	Marsing–Swan Falls
0.22%	15.92%	41.43%	42.43%

We question these estimates for two reasons. First, we regard as inaccurate the aerial surveys of spawning areas between Ringold and Rock Island Dam and in the Snake River downstream of Hells Canyon to the mouth. An observer in an aircraft can see redds to a maximum depth of about 8 ft. However, Chapman et al. (1985) found that chinook salmon spawned at depths of over 30 ft in the Columbia River (Hanford Reach). Groves and Chandler (1999) used underwater video to observe deep spawning of fall chinook (to at least 22 ft) in the Snake River downstream of the HCC. In the spawning ground survey of 2000, a redd was found at a depth of 27 ft (Idaho Power Company, unpublished information). Trap catches in 1954 and 1955 at Central Ferry (near Ice Harbor) of very small chinook salmon fry (Mains and Smith 1964) show that chinook spawned in the lower Snake River. They very likely spawned in deep water throughout the lower Snake River wherever they found suitable gravel and water velocities. Turbidity worsened

[10] We assumed that fall chinook spawning in this river reach were free of influence of the HCC in the years noted.

conditions for aerial surveys there. Therefore, we do not regard the allocations by Pirtle (1954, 1957) to be accurate depictions of the distribution of fall chinook spawning.

Secondly, a check is available on the estimates. Fall chinook were tagged at McNary Dam in 1957 for upstream recovery (Haas 1965). Table 2 lists recoveries at the Brownlee trap. Only 25% of the tagged fish were recovered at the Brownlee trap. Fall chinook salmon destined to spawn in the Snake River upstream of Hells Canyon passed no dams between McNary Dam and Brownlee trap, no commercial fishery harvested them, and sport catch was negligible.[11] Some fish may have fallen back across McNary Dam and suffered mortality, but we discount that loss because fallback tends to be less for fish destined for far-upriver spawning areas than for fish produced near the dam studied for fallback data (Chapman et al. 1994). Fallback at McNary Dam in 1982 equaled only 5% for fall chinook (Liscom and Stuehrenberg 1983).

Even if we adjust the recovery percentage by a factor of 20% to account for a combination of barrier outage and mortality between McNary and Hells Canyon dams, the adjusted recoveries at the Brownlee trap would amount to only 30% of the numbers of fish tagged at McNary Dam. Deep-water spawning, spawning in Hells Canyon downstream of Brownlee Dam, and unobserved spawning in the lower Snake River could account for the difference between this 30% and Pirtle's (1957) allocation of 42%. One might infer from the data that only about 12% of fall chinook that spawned in the Snake River did so in the reach between the HCC and the mouth of the Snake River. This inference leads to an estimate that about 70% of Snake River fall chinook spawned upstream of the HCC. However, this inference should be regarded with caution.

3.1.5. Escapements and Run Size Downstream of the Site of Hells Canyon Dam

In 1961, the consolidated testimony of the fish and game agencies[12] produced escapement estimates of 25,000 fall chinook upstream of Oxbow Dam and an estimated 55 fish per mile that used the 22 mi between Oxbow Dam and the site of the future Hells Canyon Dam. From these figures, Haas (1965) estimated that this 22-mi reach could support 1,210 fall chinook spawners. However, Haas (1965:67) provides one indication that the latter estimate might be too high in part of this reach. In 1960, aerial counters observed 77 redds in the 7 mi, or 11 redds per mile, between Oxbow Dam and Interstate Bridge, and they observed 33 redds in the 15 mi, or 2.2 redds per mile, between Interstate Bridge and the Hells Canyon Dam site. Hence, we reexamined the escapement data, applying information for 1960 to the data for the years 1957−1959, with some adjustments for varied escapements. Table 3 shows our results.

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[11] In a statewide fishing harvest survey for 1960, Bjornn (1961) recorded no catch of salmon or steelhead for Idaho anglers who fished in the Snake River above or below the HCC.

[12] States of Idaho, Oregon, and Washington at the Pacific Northwest Power Company–Washington Public Power Supply System hearing before the Federal Power Commission.

The data shown in Table 3 still lack an estimate of redds in the area downstream of the Oxbow Dam site for 1957. We assumed that the redd count would fluctuate in proportion to escapement at the Oxbow trap in the years before 1960. With this assumption we took the number of redds found 7 mi below the Oxbow Dam site (Table 3, column [3]), divided that number by the fish count at Oxbow (Table 3, column [2]), and found the average of this ratio for the years 1958 and 1959. This average equaled 6.76×10^{-3}. We therefore estimated that, in 1957, there were 107 redds in the 7-mi stretch downstream of the Oxbow Dam site. We can apply the ratio in column [5] of Table 3 (0.43) to these estimated 107 redds to yield an estimated 46 redds in the reach from Interstate Bridge to the site of the future Hells Canyon Dam.

Finally, we used an estimate of 6 fall chinook per redd to estimate the numbers of adults escaping into the Hells Canyon–Oxbow Reach in 1957–1959 (Table 4).

The average of the figures (total escapement) in the final column of Table 4 equals 868, which is comparable to the agency-derived estimate of 1,210. Hence, we used the latter figure to obtain a final estimate of 16,387 fall chinook escaping at the Hells Canyon Dam site.

We can add the estimated escapements between the Hells Canyon Dam site and the Oxbow trap to our earlier estimates of escapement at the Oxbow trap and then adjust accordingly the arrivals at the Columbia River mouth and the recruits to the exploitable phase. The 16,387 escapees estimated to arrive at the Hells Canyon Dam site would translate to 29,936 fish in the run at the Columbia River mouth and 149,682 recruits to the exploitable phase, attributable to the Snake River upstream of Hells Canyon Dam.

3.1.6. Spring/Summer Chinook

Table 5 shows numbers extant at the time Brownlee Dam was completed and for two subsequent years, referenced to the Oxbow Dam site. The trap count in 1958 (761 fish) at the Brownlee electrical barrier did not include fish produced in Wildhorse River[13], whereas the trap counts for 1959 and 1960 incorporate fish from that source.

Alternatively, one could use the 3:1 catch-to-escapement ratio offered by Haas (1973) for collective spring/summer chinook fisheries (ocean and inriver). That procedure yields an estimated 4,671 fish in the catch, plus 1,557 in the escapement, or a “run” of 6,228.

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[13] The spring chinook count in 1958 occurred at the Brownlee diversion trap, upstream of the confluence of the Wildhorse and Snake rivers. To adjust the trap count in 1958 to account for fish that entered Wildhorse River, we examined Bell (1961), who operated a trap for downstream migrants in the 1959–1960 juvenile migration year. He estimated total smolt yield for spring chinook juveniles of the 1958 brood year as 1,110. We assumed egg-to-smolt survival equaled about 4%, which we converted to an egg potential of 27,750. Assuming that each female spring chinook contained 4,000 eggs, the potential represents 7 females. If we assume about 50% prespawning mortality, this number converts to 14 females and 14 males (assumed 50:50 sex ratio), or an escapement of 28 spring chinook to the Wildhorse River. That number should be added to the Brownlee trap count in 1958, yielding a total of 789 fish for 1958.

3.1.7. Allocation of Escapements of Spring/Summer Chinook to Tributaries

Pirtle (1957) allocated spring chinook at McNary Dam in 1954–1956 to various drainage components as follows:

Rock Island	Roza Dam	Yakima River Fisheries	Yakima River Spawn	Snake River Sport	Snake River Spawn
22.89%	1.35%	2.37%	0.49%	34.64%	38.28%

Thus, the total Snake River allocation would be 72.9%. "Snake River Sport" catch would largely take place in tributaries like Bear Valley Creek, the upper Salmon River, Middle Fork Salmon River, etc.[14] Pirtle (1957) then allocated Snake River fish as follows:

Tucannon River		Grande Ronde River		Imnaha River		Salmon River		Weiser River	
Sport	Spawn	Sport	Spawn	Sport	Spawn	Sport	Spawn	Sport	Spawn
0.28%	1.28%	0.14%	4.15%	0.05%	2.57%	33.38%	30.28%	0.77%	NA

Thus, areas below the HCC would account for 72.13% of the Snake River allocation of 72.9%, or 52.58%, leaving 20.32% allocable to the area upstream of the Imnaha River. Spring chinook counts at McNary Dam for 1954–1956 averaged 28,666 (jacks and adults combined). The maximum count in 1954 was 52,000 fish. Fishing in zones 1 through 6 strongly influenced these counts. Hence, fishing rates also influence the allocation of fish numbers at McNary Dam to given spawning areas.

Later, the Oregon Fish Commission (1958a) estimated, based on McNary Dam escapements for the period 1954–1957, that the Snake River spring/summer chinook spawning run amounted to 169,000 fish, of which 7,500 were allocated to the area upstream of Brownlee Dam, 200 to Wildhorse River, and 300 to Pine Creek.

Later, in 1961, the consolidated testimony of the state fish and game agencies of Idaho, Oregon, and Washington at a hearing of the Pacific Northwest Power Company–Washington Public Power Supply System before the Federal Power Commission produced escapement estimates of 6,500 spring chinook above Oxbow Dam (including the Wildhorse River) and 300 spring chinook in Pine Creek.

Earlier in this chapter, we tabulated the HCC count of spring chinook in 1958–1960 and adjusted the mean count of 1,557 upward to account for interdam losses and fishing. We estimated mean

[14] The allocations were only as accurate as information on total sport catches and redd counts. Factors such as non-response bias in sport catch estimates and inaccurate or incomplete redd counts would affect the allocations. However, we believe these potential sources of error for spring chinook are probably less important than the error for fall chinook caused by incomplete assessment of redd numbers and distribution.

arrivals of spring chinook at the mouth of the Columbia River as 4,098 and recruits to the exploitable phase at sea as 4,553. These estimates include fish destined to enter Wildhorse River. Adding 300 fish estimated to enter Pine Creek[15] would increase the HCC numbers by 888 fish at the mouth of the Columbia River and 987 fish reaching the exploitable phase at sea. Thus, the total spring chinook count for the HCC would rise to 1,857, arrivals at the mouth of the Columbia River would rise to 4,986, and recruits to the exploitable phase at sea would increase to 5,540.

3.2. Steelhead

Table 6 reflects steelhead conditions when Brownlee and Oxbow dams were constructed. The number of steelhead counted for the 1958 trap year did not include fish produced in Wildhorse River. We therefore adjusted this number as explained in the second footnote to the table. The numbers for the 1959 trap year include adults produced as smolts in Wildhorse River. We did not attempt to adjust numbers of steelhead that arrived in the 1958 trap year to account for the fall 1957 outages of the electrical barrier at the Brownlee diversion tunnel. This is because we found such effort for fall chinook inconclusive, as noted earlier in this chapter.

Inasmuch as steelhead were not harvested at sea, we adjusted only for the inriver fishery.

3.2.1. Allocation of Escapements of Steelhead to Tributaries

The Oregon Fish Commission (1958), on the basis of allocations of McNary-extrapolated escapements, estimated that 117,000 steelhead used the Snake River basin. Of these, 15,000 were assigned to the area upstream of Brownlee Dam, 1,000 to the Wildhorse River, 2,750 to Pine Creek, and 1,000 to Indian Creek. Another 50 fish were estimated to use “small tributaries” between the Hells Canyon Dam site and Oxbow Dam.

Later, in 1961, the consolidated testimony of the fish and game agencies of Idaho, Oregon, and Washington at a hearing of the Pacific Northwest Power Company–Washington Public Power Supply System before the Federal Power Commission produced escapement estimates deflated to 6,000 steelhead upstream of Oxbow Dam (including the Wildhorse River) and 3,750 steelhead between Hells Canyon Dam and Oxbow Dam.

This latter estimate comports reasonably well with the maximum trap-year escapements of 5,185 and 5,092 at HCC traps from 1958 onward. Table 7 shows brood-year counts at Hells Canyon trapping facilities.

Steelhead estimates for the period 1958–1968 (before hatchery intervention affected counts) include 1) trap counts at Brownlee trap in the 1958 trap year and 2) trap counts at Oxbow trap from trap years 1959–1965. During this period, and before counts began at the Hells Canyon

[15] As noted in Chapter 8 (Chapman and Chandler 2001), we suspect that the habitat of Pine Creek may not be capable of yielding sufficient smolts to produce 300 mature spring chinook.

Dam site in 1965 (the 1966 trap year), the maximum steelhead count was 5,185. The increase from 1958 (Brownlee trap) to the 1959 and 1960 trap years (Oxbow trap) offers one indication that the Wildhorse River, whose escapement would be captured at the Oxbow trap, might have supported an escapement of 646 to 1,200 steelhead. However, as noted in a footnote in Table 6, we feel that 571 steelhead is an appropriate estimate for the Wildhorse River in the 1958 trap year.[16]

Comparing the counts in the 1966 and 1967 trap years, just after counting shifted to the Hells Canyon Dam site, with counts in 1963–1965 might suggest that approximately 3,735 steelhead were destined for Pine and Indian creeks. The 1967 trap year[17] included 1-ocean adult[18] survivors from the 1965 spring smolt outmigration and 2-ocean adults from the 1964 spring outmigration.[19] However, the last smolts that had access to the sea from Pine and Indian creeks would have migrated downstream in 1967. Hells Canyon Reservoir did not begin to fill until October 1967. Thus, we can legitimately consider the adult count in trap year 1968 to be reflective of production by Pine and Indian creeks because as it would include 1-ocean fish that migrated as smolts in spring 1966 and 2-ocean fish that migrated as smolts in spring 1965. Thus, we included the count of adults in the 1968 trap year before comparing Hells Canyon trap counts with the counts in the 1964 and 1965 trap years.[20] The trap count in the 1968 trap year, 1,593 steelhead, constitutes a maximum estimate of production from Indian and Pine Creeks for that year because it must have included some steelhead produced upstream of Oxbow Dam. However, inclusion of the full count for the 1968 steelhead trap year reduces the estimated production of Pine and Indian creeks to about 2,700 fish.

Were Pine and Indian creeks adequately seeded in the brood years that produced the counts in trap years 1966–1968 at the Hells Canyon trap? The current escapement goal at Lower Granite Dam is 30,000 wild/natural fish (ODFW/WDFW 1998). For the trap years 1966–1968, the Ice Harbor counts that included steelhead captured at the Hells Canyon trap were 62,566, 64,987, and 47,536, respectively. We suggest that these escapements would be sufficient to constitute full seeding[21] throughout the Snake River basin, including the Tucannon River, which lies between Ice Harbor and Lower Granite dams.

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[16] Ocean conditions, downriver fishing, and smolt yield from various streams in the area upstream of the Oxbow Dam site affected the 1959 and 1960 adult counts, as well as those of adjacent years. The data in Bell (1961) provide the only information specific to the Wildhorse River.

[17] "Trap year" indicates the year in which June 30 terminates the counting year for steelhead; the counting period begins the summer of the previous calendar year.

[18] A 1-ocean fish has spent one year in the ocean; a 2-ocean adult, two years.

[19] The 1967 trap year also included steelhead that had left Pine Creek as pre-smolts in the falls of 1963 and 1964.

[20] In spring 1966, hatchery operations took large numbers of steelhead eggs at the Oxbow trap for the first time (see Appendix 6 in Chapter 2 [Chapman 2001]). Egg take in 1965 equaled only 288,000; in 1966 it equaled 7.5 million.

[21] We assume that the escapement goals stated in ODFW/WDFW (1998) define seeding for maximum sustained yield (MSY) of adults, which in turn equates to MSY smolt output.

Earlier in this chapter, we adjusted upward the steelhead counts at the HCC in 1958 and 1959 to account for interdam mortality and inriver fishing. We thus adjusted the mean count of 4,834 to 10,515, which represents steelhead arrivals at the mouth of the Columbia River (and to the exploitable phase, in the absence of ocean fishing for steelhead). These estimates incorporate an escapement estimate of 571 fish for the Wildhorse River. The addition of 2,700 steelhead destined to enter Indian and Pine creeks would bring the total escapement to 7,534 and arrivals at the mouth of the Columbia River to 16,388.

3.2.2. Best Estimates

In conclusion, the following table presents our best estimates for numbers of fish produced upstream of the Hells Canyon Dam site and reaching various points in the Columbia and Snake rivers.

Species	Hells Canyon Complex	Columbia River Mouth	Ocean Recruits at Ocean Age 2
Fall chinook	16,387	29,936	149,682
Spring/summer chinook	1,857	4,986	5,540
Summer steelhead	7,534	16,388	16,388
Sockeye	0	0	0
Pacific lamprey	No data	No data	

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Table 1. Escapement of fall chinook past the site of Oxbow Dam, based on trap counts at Brownlee Dam (1957) and the Oxbow trap (1958 and 1959), with numbers adjusted to points downstream for mortality caused by dams and fisheries, and showing the estimated run at the mouth of the Columbia River and to the exploitable phase at sea.

		Adjusted Numbers				Estimated Numbers	
Trap Year	**Hells Canyon count[1]**	**Dams**	**Fishing Zone 6[2]**	**Dam**	**Fishing Zones 1–5[3]**	**Columbia River**	**Recruits[4]**
1957	15,859	2-17,572	17,858	1-18,798	35,874	35,874	—
1958	17,848	2-19,776	20,057	1-21,113	27,817	27,817	—
1959	11,825	2-13,102	13,182	1-13,875	19,487	19,487	—
Mean	**15,177**					**27,726**	**138,630**

[1] Includes fish killed in 1958 in the "Oxbow Incident." The Brownlee electric barrier (15,160) and trap lay about 12 mi upstream of the location of counts in 1958 and 1959 at the Oxbow trap. As noted in the text, we increased the actual Brownlee trap count of 15,160 by 699 fish to account for escapement between Brownlee Dam and the Oxbow trap site.

[2] Fishing rates in Zone 6 of the Columbia River calculated from ODFW/WDFW (1998:163) in 1957, 1958, and 1959 as 0.016, 0.014, and 0.006 respectively.

[3] Fishing rates in zones 1–5 of the Columbia River calculated from ODFW/WDFW (1998:163) in 1957, 1958, and 1959 as 0.476, 0.241, and 0.288, respectively.

[4] Assumes an ocean fishing rate of 0.80 (NPPC 1986).

Table 2. Numbers of fall chinook tagged at McNary Dam in 1957 and recovered at the Brownlee trap, as documented by Haas (1965).

Date tagged	Number Tagged	Number Recovered at the Brownlee trap	Percentage Recovered at the Brownlee trap
Aug. 25–31	187	18	9.6%
Sept. 1–7	265	55	20.8%
Sept. 8–14	467	157	33.6%
Sept. 15–21	170	49	28.8%
Sept. 22–28	55	12	21.8%
Totals	1,144	291	25.4%

Table 3. Escapement and redd counts for fall chinook, 1957–1960. Data for 1960, shown first and in italics, provide the only measure of relative distribution of redds in the Hells Canyon–Oxbow Reach of the Snake River.

Trap Year	**Count at McNary [1]**	**Count at Oxbow [2]**	**Redds 7 mi < Oxbow [3]**	**Redds 7–22 mi < Oxbow [4]**	**Ratio [4]/[3] [5]**	**Redds 7–22 mi < Oxbow [5]X[3] [6]**
1960	47,300	affected by the HCC	77	33	0.43	33
1957	70,600	15,859	no data	no data	—	no estimate
1958	97,500	17,848	110	no data	—	47
1959	55,700	11,825	87	no data	—	37

Table 4. Counts of redds and estimated escapement of fall chinook in the Snake River between the Oxbow and Hells Canyon dam sites.

Trap Year	**Redds 7 mi < Oxbow**	**Redds 7–22 mi < Oxbow**	**Escapement in 7 mi < Oxbow**	**Escapement in 7–22 mi < Oxbow**	**Total Escapement, Hells Canyon to Oxbow**
1957	107	46	642	276	918
1958	110	47	660	282	942
1959	87	37	522	222	744
Mean					**868**

Table 5. Spring/summer chinook escapement past the site of Oxbow Dam, based on trap counts at Brownlee Dam (1958) and the Oxbow trap (1959 and 1960), with numbers adjusted to points downstream for mortality caused by dams and fisheries, and showing the estimated run at the mouth of the Columbia River and to the exploitable phase at sea.

		Adjusted Numbers				Estimated Numbers	
Trap Year[1]	**Hells Canyon Count[2]**	**Dams**	**Fishing Rate, Zone 6[3]**	**Dam**	**Fishing Rate, Zones 1–5[4]**	**Columbia River**	**Ocean Recruits[5]**
1958	789 (761)	2-874	918	1-966	2,760	2,760	—
1959	1,250	2-1,385	1,399	1-1,472	3,590	3,590	—
1960	2,631	2-2,915	2,936	1-3,091	5,944	5,944	—
Mean	1,557					4,098	4,553

[1] Brownlee Reservoir began to fill on May 9, 1958. We assume that most spring/summer smolts had passed Brownlee Dam by then. For 2-ocean adults, the outmigration of 1958 would return in 1960. No count is available for adult spring/summer chinook at the Brownlee site in 1957, so we included years 1958–1960.

[2] The count for 1958 includes an estimated 28 spring chinook that entered Wildhorse River.

[3] We used ODFW/WDFW data (1998:145) to calculate Zone 6 fishing rates in 1958, 1959, and 1960 as 0.0047, 0.0098, and 0.0071 respectively.

[4] The first year that sport catch was estimated for the lower Columbia River was 1960. The catch rate for that year was 0.085. We used this rate, together with the commercial fishing rate, to estimate the total catch-related mortality rate in the lower Columbia River in 1958 and 1959. We used ODFW/WDFW data (1998:163) to calculate commercial fishing rates in zones 1–5 in 1958, 1959, and 1960 as 0.621, 0.554, and 0.439 respectively. We converted sport and commercial catch rates to instantaneous mortality coefficients, added the latter, and converted back to survival rate. Thus, the survival rates in Zones 1–5 in 1958, 1959, and 1960 were 0.35, 0.41, and 0.52 respectively.

[5] These figures assume a 0.10 ocean harvest rate (NPPC 1986, Mullan et al. 1992).

Table 6. Steelhead escapement past the site of Oxbow Dam, based on trap counts at Brownlee Dam (1958) and the Oxbow trap (1959), with numbers adjusted to points downstream for mortality caused by dams and fisheries, and showing the estimated run at the mouth of the Columbia River and to the exploitable phase of the sea.

			Adjusted Numbers			Estimated Numbers	
Trap Year[1]	Hells Canyon Count[2]	Dams	Fishing Rate, Zone 6[3]	Dam	Fishing Rate, Zones 1–5[4]	Columbia River	Ocean Recruits
1958	4,482 (3,911)	2-4,966	4,973	1-5,235	9,694	9,694	—
1959	5,185	2-5,745	5,923	1-6,235	11,336	11,336	—
Mean	4,834					10,515[5]	10,515[5]

1 Brownlee pool began to fill on May 9, 1958. Adult steelhead counts in trap years 1958 and 1959 would not have been affected by smolt passage through the pool. No spring counts of steelhead adults are available for trap year 1957 at Brownlee. We used trap years (trap year at the HCC consists of adults that returned to the Columbia River in the previous year) 1958 and 1959 for escapements. The brood in 1960 probably contained one-ocean fish affected by reservoir conditions in 1959, hence was not used.

2 Actual count at Brownlee diversion barrier shown in italics and parentheses. It did not include Wildhorse River escapement. Bell (1961) estimated total smolt output of the Wildhorse River as 11,577 in the 1959-60 migration year. We adjusted this smolt yield by using egg-smolt survival of 0.01, fecundity of 4,500, an assumed 1:1 sex ratio, and 10% prespawning mortality to arrive at an estimated parent escapement of 571 steelhead in Wildhorse River. We added 571 fish to the 1958 trap-year escapement of 3,911, arriving at an estimate of 4,482. This figure provides an escapement estimate for the 1958 trap year that comports with the count for the 1959 trap year at Oxbow trap, which included fish destined for the Wildhorse River. The 1959 count includes 771 steelhead killed in the Oxbow Incident.

3 Fishing rates calculated from ODFW/WDFW (1998, p. 202) in 1957 and 1958 (correspond to trap years 1958 and 1959 at the HCC) as 0.0014 and 0.03, respectively.

4 First year of estimation of sport catch in lower Columbia R. was 1964. Catch rate can be estimated as 0.10 for that year, based on lower Columbia sport catch only, related to “minimum run.” We applied the sport catch rate for 1964 to steelhead returning in 1957 and 1958. Commercial fishing rate in zones 1-5 calculated from ODFW/WDFW (1998, p. 202) in 1957 and 1958 as 0.40 and 0.38, respectively. We converted arithmetic fishing rates to instantaneous ones, added the latter, then converted to arithmetic survival in zones 1-5 in 1958 and 1959, respectively, of 0.54 and 0.55.

5 Minimum estimate because it does not include sport catch between Hells Canyon projects and mouth of Snake River, and probably does not include all sport catch in main Columbia River.

Table 7. Escapements of steelhead as counted at HCC traps in trap years 1958−1968. The trap year is the year in which steelhead spawn. For example, some fish of the 1958 trap year entered the trap in the fall or early winter of 1957 and some entered in the spring of 1958.

Trap Year	Escapement	Trap Site
1958	3,911	Brownlee electric barrier
1959	5,185	Oxbow
1960	4,557	Oxbow
1961	1,971	Oxbow
1962	1,798	Oxbow
1963	1,140	Oxbow
1964	806	Oxbow
1965	779	Oxbow
1966	4,195	Hells Canyon
1967	5,092	Hells Canyon
1968	1,593	Hells Canyon

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