4.0 FACTORS CONTRIBUTING TO DECLINES IN SALMON AND STEELHEAD RUNS IN THE UPPER COLUMBIA BASIN BEFORE THEIR TOTAL DESTRUCTION BY GRAND COULEE DAM.

Requirements necessary for maintenance of salmon runs in the Columbia Basin were succinctly outlined by Craig and Hacker (1940):

> *"At first glance it appears that all that is necessary for the continued maintenance of the fishery is proper regulation of the [catch] so that sufficient spawners escape to the upper tributaries each year to produce offspring numerous enough to provide adequate catches and spawning escapements for the future. But no matter how large the escapement, the returns from that escapement will not be satisfactory unless the spawners had free access to [adequate spawning and rearing habitat], and in downstream passage their offspring can migrate safely to the sea without the hazards [associated with irrigation diversions and hydroelectric projects]."*

Livingston Stone (1884) speculated about factors that govern the total run size and harvest and provided the first record of density dependent stock regulatory factors and basis of the stock/recruitment model:

> *"Such enormous quanties of salmon taken from a river [by commercial harvest] must ultimately endanger the productiveness of it. However, the stock of a salmon river is not diminished in proportion to the number of salmon taken from it because a compensating element of great weight comes into the picture. If salmon produced no more eggs every year than what are needed to keep the places of the parent fish filled, then the river's stock would be diminished in proportion the number of salmon harvested. However, the parent salmon produce 3000 times as many eggs as needed to replace themselves."*

It follows that if the adult spawning population level remains relatively stable from year to year there must be a high rate of mortality of juveniles and adults due to competition for limited resources. More of the offspring from individual spawners would survive if fewer adults spawn than if many adults survive to spawn insofar as competition would be reduced. This mechanism is referred to as density dependent compensatory mortality and its significance is that, provided the adult population is not below the minimum size to produce enough fry to fully occupy all the available rearing habitat, the size of the juvenile population is essentially independent of the size of the spawning population and, therefore, is relatively constant over time. This also means that the surplus adults can be harvested without affecting the future run size.

Ricker (1954) and Beverton and Holt (1957) developed this theory into the stock recruitment/maximum sustained yield model. In their model the term "stock" refers to the level of spawning escapement required to produce a certain level of recruitment. The term "recruit" refers to the number of fish that reach a size where they can either be harvested in the commercial fishery or survive to spawning. At most stock sizes the number of recruits produced exceeds the number required to replace the stock by a wide margin. These "extra" recruits could then be harvested in the commercial fishery.

Ricker and Beverton and Holt pointed out that if more adult fish survive to spawn than are required to produce maximum recruitment an exceptionally large number of offspring would be produced, which, in competing with each other for limited resources, would reduce the resource base such that fewer offspring would be able to survive (i.e., fewer recruits). Fig. 4.1 illustrates this point. Fewer recruits in the area of the curve to the right of the point of maximum recruitment show that if the number of adults exceeds the number providing maximum recruitment, the recruitment actually declines.

From this model Ricker and Beverton and Holt were able to calculate the stock level which would provide the maximum harvest (yield) to the fishery. If the appropriate escapement was provided this harvest could be sustained indefinitely (Fig. 4.1). The Stock Recruitment Model assumes: (1) density dependent compensatory mortality is the dominant regulator of the population; (2) the environment must remain relatively constant so that density independent regulatory factors (e.g., enviromental fluctuations that reduce the amount of useable habitat for juveniles and sub-adults and therefore, the size of the juveniles or sub-adults population) does not come into play; (3) one target stock; (4) semelparous reproduction (i.e., spawns only once); and (5) maximum sustained yield is the objective. This model has provided the basis for management of the Columbia Basin salmon and steelhead runs. This indicates that salmon and steelhead stocks are resilient and can easily recover from a temporary reduction caused, for example, by overfishing or fluctuating oceanic environment. In technical terminology salmonids are "r-selected" species.

In view of these considerations it is clear that the following types of factors can have pronounced effects on regulating the total run size:

(1) Factors that reduce the number of adult spawners below the escapment level needed to produce enough fingerlings to saturate the available rearing habitat such as over harvest due to inadequete harvest management regulations oceanic environmental conditions (e.g., El Nino) or other factors, such as hydropower that contributes to mortality of adults;

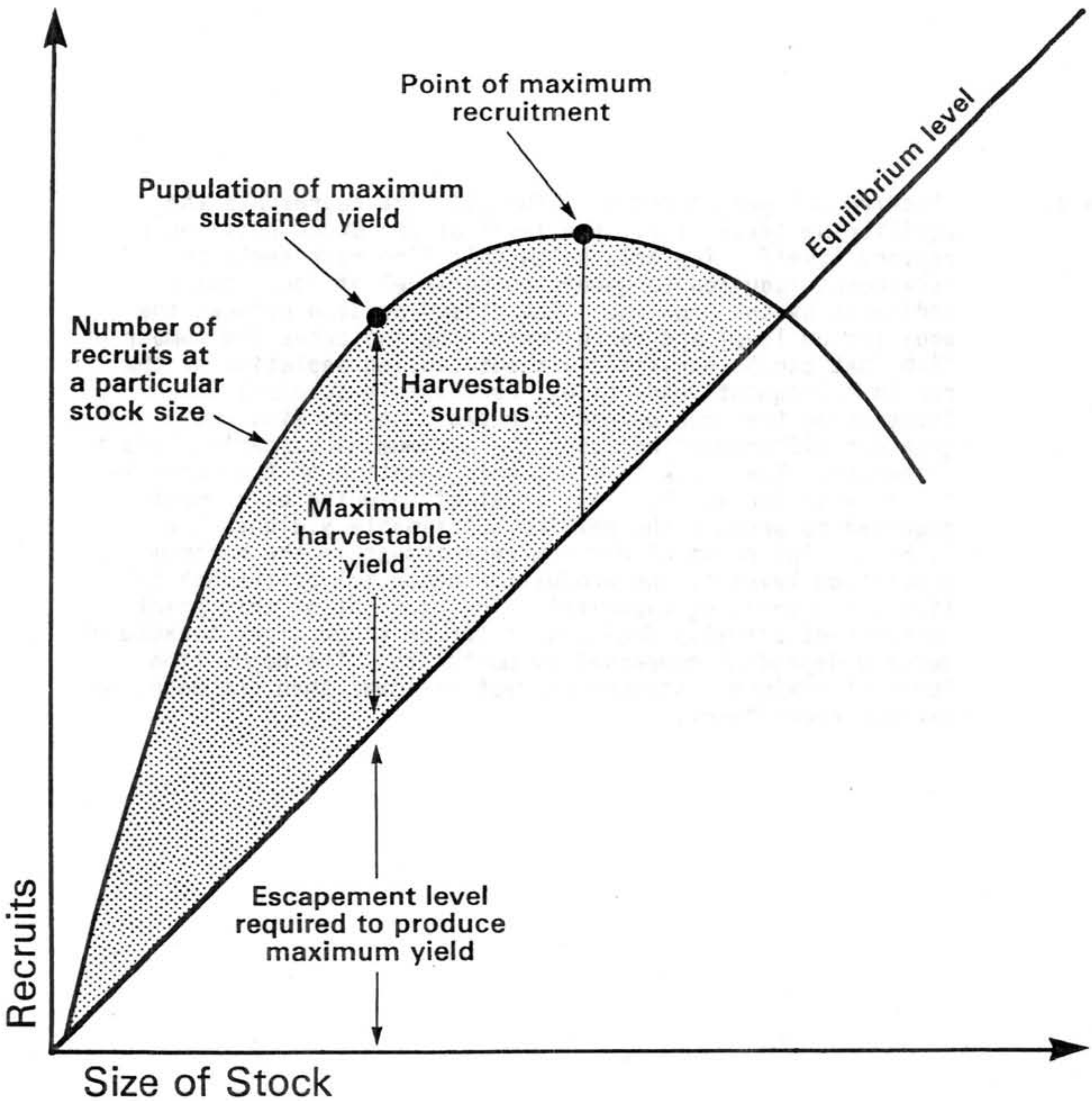
(2) Factors that block access of fish to former spawning areas such as hdroelctric or irrigation dams;

(3) Factors that interfere with the ability or motivation of adult fish to reach their spawning ground such as hydroelectric and irrigation dams;

(4) Factors that alter the capability of spawning and rearing habitat for producing juveniles such as inundations by dams, destruction of redds by increased sedimentation from logging, mining and farming, dewatering of redds by irrigation or hydropower, and pollution caused by municipal sewage or industrial development;

(5) Factors that cause mortality of smolts during the downstream migration such as passage mortality, via turbines and nitrogen supersaturation, at hydroelectric dams, and irrigation diversions;

Figure 4.1. Stock/recruitment function. The 45^{o} line represents the equilibrium level, i.e., the level of the stock required to replace itself. The area below this line represents the escapement required to generate the level of recruitment indicated by the arc line. The shaded portion between the equilibrium level and recruitment line indicates the number of fish that can be harvested without causing depletion of the run in subsequent years (i.e., harvestable surplus). Integrating the area between the two lines to find the greatest difference indicates the maximum harvestable yield to fishermen. The stock level at this location of the curve is the size of the stock, i.e., level of spawning escapement, required to produce the maximum sustainable yield to the fishery. The point of maximum recruitment is the maximum population level at the production potential of the habitat (i.e., the carrying capacity). To the right of this point recruitment actually declines at larger stock sizes because of density dependent compensatory mortality. The population level at maximum sustained harvest is lower than the point of maximum recruitment.


Point of maximum recruitment
Equilibrium level
Pupulation of maximum sustained yield
Number of recruits at a particular stock size
Harvestable surplus
Maximum harvestable yield
Escapement level required to produce maximum yield
Recruits
Size of Stock

(6) Factors that delay the time it takes for smolts to reach to ocean, thereby, decreasing salinity tolerance of the young salmon and increasing mortality when they enter the ocean;

(7) Natural environmental fluctuations that act as density independent regulatory factors during juvenile life history stages, e.g., droughts.

The most severe impacts on salmon and steelhead are those that are irreversible because such impacts cannot be corrected. Irreversible impacts include the loss of habitat caused by construction of high dams over which it is unfeasible to provide passage. Less severe impacts are those that are reversible (i.e., can be corrected) such as overfishing (Northwest Power Planning Council 1985).

The remainder of this section considers the relative contribution of these factors to the decline of the salmon and steelhead runs into the Upper Columbia Basin.

4.1 EVIDENCE FOR NATURAL FLUCTUATIONS IN THE CATCH AND RUN SIZE.

Historical records indicate that salmon and steelhead catch and run-size in the Columbia River System apparently experienced periodic fluctuations in abundance even before any major development occurred (Simms 1876, Drury 1968, Chance 1973). In 1826 there was no salmon harvest in the middle Columbia by late July and few salmon were harvested in the upper Columbia and Spokane River (Black 1826). The Tshimikain missionaries on the Spokane River reported that the run in 1843 failed (Drury 1968). Poor runs of salmon were experienced at Kettle Falls from 1826- 1829 according to John Work (1830). During those years some of the Kettle Falls tribe (Sxoielpi) starved to death (Heron and Kittson 1831). There are several historical and ethnographic reports of similar occurences throughout the Columbia Basin even in precontact times (reviewed by Chance 1973).

Rev. Eells, at the Tshimikain mission, in a letter to the Missionary Herald (1843) complained that salmon had been decreasing for several years before the collapse of the run in 1843. This was a temporary decline because later reports by Eells and Rev. Elkanah Walker in 1845-1848 and by Gov. Stevens railroad survey team in the 1860's indicate that large runs of salmon and steelhead were entering the Spokane River (see section 2.1.1.1).

The action of density independent regulatory factors, i.e., short-term climatic changes or forest fires could account for the periodic collapse of the fishery in precontact times and into the 19th century. In this connection it is interesting to note that the Hudson Bay Company officials reported an extreme drought from 1823-1825, four years preceding the reduced runs from 1826-1829, and that Rev. Eells and Rev. Walker recorded a drought in 1839- 1840, four years before the reduced run in 1843 (Drury 1968). One could speculate that the droughts led to a reduction in useable habitat or created conditions, such as high temperatures, which were responsible for increased mortality during the period of stream residence of the juvenile life history stages, leading to a reduced number of adults returning to spawn four years later.

These periodic fluctuations in abundance do not seem to be associated with long-term declines in the salmon runs because rebounds of runs to normal levels were subsequently reported. Moreover, these natural fluctuations have occurred several times with no apparent long-term effects. Rebounds are expected because salmonids are r-selected species.

Since natural fluctuations are reported it cannot be determined if the declines in upriver runs in the Spokane River and mainstem Columbia reported by Livingston Stone (1884), McDonald (1884) and Gilbert and Evermann (1895) represent long-term trends or short-term fluctuations. This is because they monitored the Upper Columbia Basin for only one or two years. These investigators attributed this reduction to a long-term decline caused by the development of the commercial fishery on the lower river. However, subsequent newspaper accounts--the only evidence that could be found--indicated that chinook runs into the Spokane River were increasing by the turn of the 20th century (Section 2.1.1.3), suggesting that Stone and Gilbert and Evermann may have observing a short-term fluctuation.

4.2 CATCH-VS-ESCAPMENT IN THE INDIAN SUBSISTENCE FISHERIES.

It is unlikely that the Indian subsistence fishery contributed significantly to the short-term fluctuations noted above by not allowing adequate spawning escapement (see Section 4.1).

For example, the Indians had traps stretched completely across the Spokane River at the confluence with the Columbia, Little Falls, and confluence of the Little Spokane River. However, the fact that the catches actually increased further up the river attests to the inability of these traps to catch all of the fish, i.e., escapement was high. Rev. Elkanah Walker confirms this: *"It is not uncommon for many to pass the weirs. These are taken if they have laid their eggs"* (Drury 1963).

Koch (1976) has noted that the Indians were dedicated in their conservation and this ethic was tied into their religion by allowing upstream escapement of salmon during the early portion of the run at the time they held their First Salmon Ceremony.

At Kettle Falls it was a common practice to let many salmon escape upstream of the falls so Indians living above Kettle Falls would have an adequate supply (see section 2.1.1.4 for details).

Deward Walker (pers. comm.) reported that Tommy Thompson, the modern equivalent of a salmon Chief at Celilo Falls, in 1949- 1955, by waving a flag, could stop the fishing in order to let salmon escape upstream. At other times, if he wanted to preserve the run for the fishermen at Celilo Falls, Chief Thompson would gaff a salmon and let its blood drip into the water, which caused salmon to stop their migration for a period of time and hold below the falls overnight until the fishing resumed the next day.

In summary, these observations suggest that the tribes actively and routinely practiced fish management.

4.3 EFFECTS OF SETTLEMENT; IMPACTS OF LOGGING, FARMING IRRIGATION, MINING, AND MUNICIPAL SEWAGE ON THE POTENTIAL OF THE HABITAT FOR PRODUCING SALMONIDS PRIOR TO 1947.

The effects of logging, farming, irrigation, mining and municipal sewage on salmon and steelhead runs was relatively minor in the upper Columbia above Grand Coulee compared to other portions of the Columbia Basin (U.S. Bureau of Reclamation 1947; U.S. Army Corps of Engineers 1948; Meinig 1968). In part this was because the mainstem above Grand Coulee, the Spokane/Coeur d'Alene River Basin, the Pend Orielle/Clark Fork River Basin, and the Kootenai River Basin were not occupied by white settlers until the 1880's and 1890's, whereas the lower Columbia River, Willamette Basin, Umatilla, Walla Walla, Yakima, Clearwater, and upper portions of the Snake Rivers were opened to settlement by the 1850's.

After the "Indian Uprising" had been put down in the 1850's, the settlement of the central portion of the Columbia Basin along the lower Snake, Yakima, Umatilla, John Day, Walla Walla, and Clearwater Rivers, occurred rapidly as stockmen and farmers scattered over this region (Meinig 1968).

From 1850-1900, the early developmental period in the Yakima Valley, the important factors which contributed to the rapid decline in the Yakima River salmon population included logging, irrigation and mining (Davidson 1953; Robertson 1957; Lavier 1976). The construction of irrigation diversion dams without fish ladders formed complete barriers to migration and *"diversion ditches led great numbers of smolts to perish in fields and orchards"* (Bryant and Parkhurst 1950). Periodic log drives down the main river and its tributaries tore up spawning areas (Davidson 1953, Robertson 1957). Mine wastes and hydraulic washings dumped sediment in the tributaries and mainstem (Robertson 1957).

Prior to 1880 about 160,000 salmon per year were caught by about 4000 Yakima, Klickitat and Priest Rapids Indians (Robertson 1957). By 1905, the salmon and steelhead populations had declined to about 10% of their former abundance and showed no signs of recovery (Spokesman Review, June 26, 1920; Lavier 1976). After 1905 evidence seems to indicate that the catch went down annually until about 1930 while the acres under irrigation increased from 121,000 to 203,000. Screening of irrigation canals and drainage ditches commenced in about 1930.

Similarly, at about the same period of time, runs on the John Day, Umatilla, Walla Walla and lower Snake Rivers (Craig and Hacker 1940; Fulton 1970), and on the Owyhee, Bruneau, Boise, Payette, Weiser, and Malheur on the upper Snake (Fulton 1970) were decimated by irrigation projects. Stober et al. (1979) concluded that anadromous fish runs were almost eliminated due to irrigation withdrawals and concomitant low flows. In the upper Snake tributaries, Fulton (1970) stated that no salmon runs had occurred in these rivers for many years and that the loss was due to irrigation.

The Clearwater and Salmon River Systems experienced heavy pressure from miners by 1880 which reduced the salmon and steelhead runs (Fulton 1980). The Clearwater and Walla Walla areas also began to produce timber and sawmills were constructed (Meinig 1968).

In the Snake River watershed in the early 1890's Gilbert and Evermann (1895) also reported, *"Great numbers [of chinook salmon] are annually killed through mere love of destruction. The advent of the salmon brings out from every town men and boys with pitchforks and other weapons, curious to see how many of these fish they can destroy. These locations in Idaho and eastern portions of Oregon are so remote from canneries that the people have no interest whatever in the preservation of the salmon."*

In contrast, settlement and its concomitant problems did not occur in the Upper Columbia Basin until much later. For example, no irrigation occurred in the Spokane Valley before 1900 (Stimson 1985).

Meinig (1968) states, *"The meteoric rise of Spokane Falls as surely the most remarkable phenomenon of its time in the interior. The falls of Spokane River was a fine site for mills and it was long assumed that a settlement would eventually arise there. But during the first twenty years of colonization it was a remote corner, well away from the main avenues and areas of development. Only as farmers began to move into the northern Palouse was a town initiated."* In 1880, 1890, 1910 the population was respectively 350, 20,000 and 104,402 people.

Meinig (1968) shows a map of settlement patterns of the Palouse district indicating considerable land claimed as of Dec. 31, 1880, but none on Latah (Hangman) Creek or north of Spangle except for the towns of Cheney, Spangle and Spokane. Expansion didn't take place until the coming of the railroads in 1884.

The major impact that occurred in the Upper Columbia Basin above Grand Coulee Dam prior to 1885 was gold and silver mining activity, which was concentrated around Kellogg, Idaho upstream from Lake Coeur d'Alene, (Meinig 1968) along the Clark Fork/Flathead Rivers, along the Kootenai River upstream from Kootenay Lake at Wild Horse Creek, and on the Moyie River (Graham 1945; Northcote 1972 and 1973; Lyman 1909). All three of the areas are outside of the salmon production areas of the Upper Columbia Basin, and each is separated from them by a large lake system -- respectively Coeur d'Alene Lake, Lake Pend Oreille, and Kootenay Lake.

Within the salmon production areas of the Upper Columbia Basin, the only reports of mining activity before 1939 were:

(1) Near the mouth of the Spokane River in 1876 where about *"76 Chinese and several white miners worked the gravel bars in the Columbia"* (Bohm and Holstine 1983). This activity apparently only lasted a few seasons; and

(2) On the Lower Pend Oreille River. On Sept. 5, 1859 John Palliser, at Fort Shepard, near the mouth of the Pend Oreille River, saw where miners had been working for gold, both on the Columbia and Pend Oreille Rivers (Spry 1968). J.W. Sullivan received orders from Palliser to explore the Pend Oreille and Kootenai River portions of the Columbia in Sept, 1859. He reports, *"Eighteen miles up the Pend Oreille River from where it empties into the Columbia we struck the mouth of the Salmo River. Gold miners on this river are contained to this small portion of the valley, and the miners are engaged in*

mining the flats and bars of the river only." Mr. Sullivian journeyed up the Salmo River its full length. From the description in this journal there were few miners and they were confined to the mouth (Spry 1968). Mr. Sullivan futher indicated that the miners were not able to sucessfully work this area because of the large volume of the flow in the river. A plan to divert water from the Pend Oreille into the Little Spokane River, so as to make placer mining easier, was considered but rejected. Apparently, low level mining activity occurred in this area only until about 1867 -- so it is unlikely that this activity could have affected salmon production over the long term.

Later hardrock mines were developed at the following locations:

(1) The mainstem of the Columbia near Northport, WA (LeRoi Mine) in the Late 1890's. This was closed by 1920;

(2) The Metaline District along the Pend Oreille River in 1906;

(3) The Coeur d'Alene mining district in the 1890's upstream from Lake Coeur d'Alene;

(4) The Kootenai mining district upstream from Kootenay Lake in about 1900 (Graham 1945; Northcote 1972, 1973); and

(5) The Midnite Uranium Mine on the Spokane Indian Reservation which was not discovered until 1952 (Ruby and Brown 1970).

Reports by the Army Corps of Engineers (1948) and the Bureau of Reclamation (1947) indicate that before 1900 timber harvesting, agriculture, and irrigation in the upper Columbia Basin were confined principally to Lake Coeur d'Alene, Palouse River, Lake Pend Oreille, and Kootenai River, i.e., outside of the salmon producing areas. For example, even as late as 1925 when a total of 331,600 acres was being irrigated in the upper Columbia Basin (above Grand Coulee), only 2580 acres were being irrigated in the salmon producing areas. In 1948/50 when 389,200 acres were under irrigaton in the upper Columbia Basin only 2600 acres were in salmon production areas. Presumably, since the principal effect of irrigation in the early days of development was the diversion of downstream migrating smolts onto agricultural fields, or dewatering of redds by irrigation withdrawls, the impact of irrigation on the upriver runs would have been minimal.

According to McDonald (1978) extensive timber harvesting and sawmill operations did not occur on the Spokane River until after completion of the hydroelectric dams on the Spokane River, which supplied power to operate the saws. Apparently only one sawmill, located in the city of Spokane, operated prior to this time. No records of floating logs down the Spokane River below Spokane Falls could be located before the water was backed up in reservoirs behind the dams. There is only one record of rafting logs down the mainstem Columbia between Kettle Falls and the mouth of the Spokane River (Bohm and Holstime 1983). No records were found for rafting logs on the lower Pend Oreille or lower Kootenai Rivers. Apparently, rafting logs was practically impossible on account of the steep gradient and numerous rapids and falls on these river reaches.

There are several detailed reports that directly answer questions about quality of the water and habitat of the upper mainstem Columbia and its tributaries for producing salmon and steelhead.

4.3.1 Spokane River.

Stone (1884) wrote an article for Transactions of the American Fisheries Society which stated, *"At the mouth of the Little Spokane River in Washington Territory, there is an excellent location for a hatching station where at least ten million eggs a year could be collected [requires 3000 adult females], if the statements made about the number of salmon coming up this river are true and if the canners now on the [Lower] Columbia leave enough [to reach the site]. Thousands and thousands of breeding salmon used to frequent this natural and favorite spawning ground."* Mr. Stone mentioned that when he visited the site in 1883 there were a few claims on the Little Spokane River but that they were not valuable; he saw only Indians and no white men. He did state the water quality was good enough for hatching salmon, and that *"the water supply may be safely depended upon in every respect,"* and *"the adjacent country is still in its primitive state."* The importance of this article is that it demonstates that as late as 1884 there had been no habitat degradation on this stream and that if any factor was culprit in declining salmon runs it was the downstream fishery.

In 1894, Gilbert and Evermann (1895) indicate that the Little Spokane had not changed much in its capability to produce salmon and steelhead and state that salmon, *"enter the Little Spokane in considerable numbers even yet, but much less abundantly than formerly. The dam at Dart's Mill (about 15 miles upstream) interferes with [but does not completely block] their further ascent and a fishway should be put in. Steelhead were abundant."* With the exception of Darts Mill, Gilbert and Evermann described the valley of the Little Spokane as being in pristine condition. The bottom was of coarse gravel in most places, and at the time *"an excellent salmon and trout stream as is fully evidenced by the great abundance of salmonid fishes which we found."*

There were a few problems with a sawmill on the Little Spokane River in 1897 but these were rapidly corrected as indicated in this newspaper article in the Spokesman Review:

- o Spokesman Review (November 5, 1897). *"Captain Downey, deputy fish commissioner and deputy game warden, has returned from a visit to the mill on the Little Spokane. He notified the mill proprietor that they must in five days stop throwing sawdust into the stream and must in 30 daysconstruct fishways over their dam to be in compliance with the state law. He reports that the mill proprietors are willing to comply with the law and will do so."*

In 1887 an inspector of the Interior Department met the Spokane Chiefs, and recommended that the land on both sides of the Spokane River from Spokane to Tum Tum be used as a reservation for the Upper and Middle Spokane (this was the area they occupied at the time), and the land between Tum Tum and the confluence of the Spokane River with the Columbia River be used as a reservation for the Lower Spokane (Curtis 1911). Commissioner Wright of the

Northwest Indian Commission, met with the Spokanes for two weeks in 1887 trying to get them to sign a cession agreement and move to the Coeur d'Alene reservation. Most of the Spokanes refused to go and requested land of the junction of the Little Spokane River and Peone Prairie. Eventually, the Spokane were settled on a two hundred and forty square mile reservation with the east bank of Chamokane Creek as the east boundary, the south shoreline of the Spokane River (i.e., the bed and both banks were located within the boundaries of the reservation) as the south boundary, the west bank of the Columbia River as the west boundary, and the 48th parallel as the north boundary (President Hayes, Executive Order, 1881) (Curtis 1911). Altogether, fewer than 100 of the Upper and Middle Spokanes moved to the Coeur d'Alene Reservation after 1887, and most of the Upper Spokanes remained in their territory from 1887 to 1908. The "surplus" land from the City of Spokane to Chamokane Creek was not opened to settlement until 1909, the year when the Upper and Middle Spokane were gathered on the Spokane Reservation (Curtis 1911). This information suggests that the area of the Spokane River between Spokane and the confluence with the Columbia River probably did not receive significant impacts from logging, mining, agriculture, etc., before 1909.

A hard rock metal industry, which consisted of mining (above Lake Coeur d'Alene), and smelting (in Spokane), developed after the hydroelectric dams were built along the Spokane River. Production was minimal until World War II, and it is unlikely that this industry affected anadromous fish populations.

By 1909 sewage from the City of Spokane was impacting the river immediately below the City of Spokane but it did not extend more then a few miles downstream from town (McDonald 1978). Sewage from Spokane became a concern after 1929, and a serious problem by 1940 (McDonald 1978). Sewage accumulated in the reservoir behind Long Lake Dam such that the reservoir acted as a great sewage lagoon with biological oxygen demands so high that the oxygen content of the water dropped from five parts per million to about zero or one parts per million. Release of deoxygonated hypolimnetic water from Long Lake Reservoir was reported to cause fish kills downstream in the 1960's (Ray Soltero, Limnologist, EWU Dept. of Biology, pers. comm.).

After 1895, as settlers began to occupy the northern sections of the Palouse in the Latah Creek Valley, it is likely that increased soil erosion and sedimentation occurred in this stream, which could have reduced salmon habitat. However, as pointed out in section 2.2.1.1, this stream ran muddy before any farming occurred in the area. Although salmon did run up this stream as far as Tekoa, WA it is unlikely that it was ever a major producer of salmon.

In 1911, Little Falls Dam located 28 miles upstream from the mouth, permanently blocked the salmon and steelhead from their principal spawning grounds in the Spokane River. The information presented here suggested that at the time Little Falls Dam was built, the capability of the habitat for producing salmon had not been significantly altered by logging, mining, irrigation, agriculture, or pollution. The sole purpose of Little Falls Dam was hydroelectic power production. In the absence of Little Falls Dam and other hydroelectric dams built on the Spokane River during this period, there is no reason to suspect that the habitat would not have continued to produce about as many salmon and steelhead as it had during the period from 1807-1890.

4.3.2 Mainstem Columbia from Grand Coulee to Kettle Falls.

Gilbert and Evermann (1895) state:

> *Salmon were abundant at Kettle Falls as late as 1878. Since then there has been a great decrease. They have been scarce since about 1882; since 1890 there have been scarcely any. The Meyers brothers say they have been almost unable to buy any salmon from the Indians for three years. Certain Indians with whom we talked at Kettle Falls said salmon were once very abundant there, but that very few were seen now. Other persons testified to the same effect."*

It should be noted that Gilbert and Evermann (1895) also reported *"an abundance of excellent water"* was present, indicating that poor water quality or habitat destruction were not factors affecting the fishery. Gilbert and Everman suggested that the declines in fish runs were related to commercial fishing in the lower portion of the Columbia.

In the Colville River, salmon spawned in the lower four miles of the river but were blocked at 80 foot high Meyer's Falls. In the period from 1925 to 1935 salmon were still spawning in this stream, even though an irrigation dam was located about two miles upstream from the mouth (Stan Morris, pers. comm.). Mr. Morris, a resident who grew up at Kettle Falls, also related that the fish were easily able to migrate past the dam and spawn below Meyers Falls because the dam extended to an island and only blocked half the channel. He reported seeing 10 to 20 pairs of chinook salmon spawning in a 1/8th mile section below Meyers Falls.

Salmon spawned in the lower 25 miles of the Kettle River (Bryant and Parkhurst 1950). Smelters are reported to have run slag into this river and killed off many fish at times, but salmon persisted spawning in the river until the building of Grand Coulee Dam (Bryant and Parkhurst 1950).

Lt. Symons, and his topographical assistant, Mr. Downing canoed down the Columbia for the purpose of charting navigation corridors for steamboats in 1881 (Symons 1882). Lewis R. Freeman (1921) made a canoe trip down the Columbia in 1920 and compared his log to that of Lt. Symons. He reports, that for the mainstem in the Upper Columbia region from the Canadian border to the Okanogan River, *"I may state that it was only rare that we found the distances arrived at by Lt. Symons and Mr. Downing to be greatly at variance with those established by later surveys. In the matter of bars, rapids, currents, channels and similar things, there appeard to have been astonishingly little change in the four decades that had elapsed since he had made his observations."* This might suggest that the human activities between the period 1880 and 1920, such as mining and logging did not significantly alter the mainstem Columbia in terms of spawning habitat for salmonids.

Chapman (1940) reported about 1500 chinook salmon spawning in the mainstem Columbia below Kettle Falls in 1937. Fulton and Laird (no date) in about 1967 conducted a detailed habitat analysis of tributaries of Lake Roosevelt from Grand Coulee to Kettle Falls, including egg incubation tests within the tributaries. They make scant mention of adverse impacts of logging, mining, pollution, or irrigation. Almost all of the tributaries had water quality and habitat capable of producing salmonids except for tributaries with hydroelectric dams, e.g., the mainstem Spokane River, indicating that even by 1967 this area had not received any significant developments. In part this is due to the majority of the shoreline being contained in the Colville and Spokane Indian Reservations.

The following article, published in the Spokesman Review on May 24, 1912, indicates the situation on the San Poil River,

> *"The salmon run up the San Poil River spring is not equal to what it was at this time last year. The entire catch from the San Poil in the vicinity will not average more than 75 chinook salmon a day, as against about 300 a day at this time a year ago. The cause of the light run this year is attributed to the fact that the large eddy at the mouth of the San Poil, where the salmon rest before beginning the long swim up the strong current, is being dynamited by white men, who, it is reported on good authority, a few nights ago killed no less than 500 salmon at the mouth of the San Poil by a single charge of dynamite, out of which number it is said, those who committed the unlawful act secured no more than 15 fish, the remainder being carried to the bottom of the deep pool."*

Collectively, these accounts indicate that relatively few isolated incidents may have impacted spawning of adult salmon in the upper Columbia mainstem and tributaries, but, generally as late as the 1920's and 1930's little long-term alteration of the potential of the habitat for producing salmon had occurred.

4.3.3 Pend Oreille River.

Stone (1885) reported that a *"white fur trader lives at Seniakwateen Falls [Albeni Falls on the Pend Oreille River] but I am informed that there is not another white settler along the whole course of the River from this point to its mouth."* Smith (1985) states *"Because of the Kalispel's geographic isolation and the absence of significant gold finds in their country, encroachment by the whites came later. The town of Spokane Falls was already well established before any important movement of whites into Kalispel Territory occurred. Only the coming of the railroads triggered it and even then the public entry into Kalispel lands was further delayed."*

In 1870, Winans in his report to the Northwest Indian Commission, reported 403-420 Indians living on both sides of the river at Usk. Up to 1890 only twenty homestead patents in present Pend Oreille County, Washington had been approved, none of these in the Cusick-Usk area, which was not surveyed until 1891-92 and, consequently, not open to homesteading (Fahey 1983).

Throughout the distance from Lake Pend Oreille to the confluence with the Columbia, Gilbert and Evermann (1895) describe the Pend Oreille River as *"a beautiful, clear stream with a good strong current, and varying in width from 500 to 1000 feet. The water is clear and pure and cold -- an ideal trout stream."* Resident trout were abundant in the Pend Oreille River in the region of Cusick and Usk, and steelhead were abundant in the lower 20 miles of the river.

Reports by the Washington State Game Department from 1947- 1960 indicate that the habitat of the Pend Oreille River in Washington State was in almost pristine condition until Box Canyon Dam was built in 1952. No problems were reported relative to the Metaline Mining District.

4.3.4 Kootenai River

No information was located about the Kootenai River below Kootenay Lake, i.e., the anadromous salmon producing portion of the Kootenai River. In the Idaho Section of the Kootenai River, dyking of the river for flood control on agricultural lands was started in 1892 and continued sporadically with little success until the late 1920's. Over 68% of the area had been reclaimed by 1950 (Northcote 1973). Dyking could have restricted the rearing habitat of resident fish. Also, access of resident fish to and from spawning streams entering the Kootenai River between Bonners Ferry and Kootenay lake may have been seriously restricted by dyking. The magnitude of these effects are unknown (Northcote 1973). Periodically, a pulp mill and mines in British Columbia (upstream from Libby Dam) and Montana have dumped effluents in the river with toxic concentrations detected in the Idaho portion of the Kootenai River, but these events are episodic and not a permanent alteration of the habitat. Spawning and rearing habitat in Idaho were severely impacted by construction of Libby Dam in 1972, especially by the rapid water level fluctuations (as much as 4 ft in 12 hours) related to power peaking.

4.3.5 Salmon habitat in the Upper Columbia Basin circa 1909 and 1939

In summary, the potential of the habitat in the Upper Columbia Basin for producing salmon in 1909, when three dams for hydropower production were built on the Spokane River, and in 1939, when Grand Coulee blocked salmon, was not significantly different from the potential in 1807-1890. Logging, agriculture/irrigation, mining or urbanization/pollution had not seriously impacted the drainage. A similar conclusion was reached by The Northwest Power Planning Council (1985) staff in their Draft Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin. The Power Council staff concluded the following about the effects of logging, mining, agriculture/irrigation and urbanization/pollution on anadromous fish populations in the Upper Columbia Basin:

- *"It is doubtful that logging practices in the Upper Columbia area have had any discernable effects on anadromous fish"*

- *"Although considerable mining and degradation occurred in streams of the Upper Columbia River area, there wereminimal effects on anadromous fish because [the bulk of this activity was outside the major salmon production areas]."*

- *"The dominant irrigation areas in the Upper Columbia include the Clark Fork, Bitterroot and Flathead irrigation districts, however, salmon and steelhead have never used these areas."*

- *"Urbanization/[pollution] in the Upper Columbia area has been largely confined to development along the Spokane and Coeur d'Alene River drainages [and principally outside of the* *major salmon production areas in the upper part of the basin]."*

The Power Council's Issue Paper concluded, in a section entitled *"activities Detrimental to Salmon and Steelhead,"* that *"the Upper Columbia River area has not been strongly affected by logging and less by agriculture and irrigation than other subregions. The major detrimental impacts have resulted from dam construction, including that associated with hydropower generation."*

4.4 THE COMMERCIAL FISHERY IN THE LOWER COLUMBIA: EFFECTS ON UPRIVER SALMON AND STEELHEAD PRODUCTION.

Since the habitat remained intact (Section 4.3), and obviously the runs in the Upper Basin had declined by the 1920's and 1930's (Sections 2.1.1.3 and 2.1.1.6) the only other factors that could have accounted for the declines were the commercial fishery and operation of hydroelectric dams. In the early 1880's approximately 17 fish wheels were operated on the lower Columbia. One wheel reportedly caught as many as 50,000 pounds (about 3,000 fish) in one day, but 20,000 pounds (about 1,300 fish) was the average (The West Shore 1888). Additionally, over 400 miles of gill nets were strung across the mouth of the Columbia. A number of investigators (e.g., Stone 1885; McDonald 1894; Gilbert and Evermann 1895; Craig and Hacker 1940; Fulton 1968, 1970; Chapman et al. 1983 to name a few) felt that the commercial fisheries located from the mouth to Celilo Falls intercepted the upriver runs and point to these fisheries as the principal culprit in causing declines in the upriver runs. McDonald (1894) says this plainly:

> *"There is no reason to doubt -- indeed, the fact is beyond question -- that the number of (chinook) salmon now reaching the headwaters of the Columbia Basin is insignificant in comparison with the number which some years ago annually visited and spawned in these waters. It is further apparent that this decrease is not to be attributed to either the contraction of the area accessible to them or to changed conditions in the waters which would deter the salmon from entering them. We must look to the great commercial fisheries prosecuted in the lower river for an explanation of this decrease, which portends inevitable disaster to these fisheries if permitted to continue. The relations of the decreased number of salmon in the headwaters to development of the commercial fisheries is brought about in a very instructive way by an analysis of the salmon canning industry from 1866 to 1893. After 1866 each succeeding year operations were extended until reaching their culmination in 1884 [when 40.3 million pounds of salmon were harvested]. From this time on the catch declined, reaching its lowest point in 1889 [20.6 million pounds]. Up to 1888, practically the entire pack consisted of king or chinook salmon and the fishing season did not extend beyond the first of August. In 1889 the packers began canning bluebacks and steelheads to make up the deficiency in the supply and extended their operations to the first of September."*

Gilbert and Evermann (1895) reported that the Spokane River below the [Spokane] Falls *"was formerly an important [chinook] salmon stream and* *[chinook] salmon are rarely seen there now"* but, *"the Steelhead still occur in considerable numbers in the Spokane."* The steelhead continued to be abundant in the Spokane River until about 1910 (See section 2.1.1.3).

Gilbert and Evermann (1895) also noted that chinook abundance at Kettle Falls had dropped markedly but steelhead were abundant in the Lower Pend Oreille River in 1894.

These are extremely significant observations because the chinook salmon was the target species of the commercial fishery during the 1880's. Very few steelhead were taken. Gilbert and Evermann's 1895 observations of the difference in abundance of the two species in the Spokane River in 1892 and 1893 demonstrate that (1) the upriver habitat had not been altered significantly by human-caused factors (because steelhead were as abundant as in former years) and (2) places the cause of the decline of chinook squarely on the downriver commercial fisheries (because the targeted commercial species -- the chinook -- was less abundant, whereas a non-targeted species -- the steelhead -- experienced no reduction in abundance). After the period during which Gilbert and Evermann made their observation, chinook apparently increased in abundance (see sections 2.1.1.3 and 2.1.1.6).

From the information presented above it is clear that after about 1880 the Upper Columbia Basin periodically suffered reduced salmon runs because the commercial fishing in the lower portions of the river. H.J. Vaux, Jr. (1976), a professor of Natural Resource Economics at the University of California--Riverside, points out *"these losses must be regarded as temporary in nature, since cessation of commercial over-fishing of the Columbia River at any time during this period could have restored the [upriver] salmon runs to levels where no losses would have been sustained by the upriver Indian fisheries."* Koch (1976) stated *"even though salmon and steelhead losses [in the upper Basin resulted from the development of the downriver commercial fishery], the resilience of their populations has been noted, and with proper controls [placed on] the commercial fishery the fishery resource [in the Upper Columbia Basin] could potentially have been restored had Grand Coulee Dam not eliminated approximately 1,140 linear miles of spawning and rearing areas."*

There were great fluctuations in the commercial catch in the lower river between 1864 and 1940, but trends are difficult to see. This fluctuating catch may be caused by a number of factors, including: (1) natural fluctuation in production rates (see section 4.1); (2) reduced fishing pressure caused by socioeconomic factors such as market price commercial fishermen received; and (3) overharvest in preceding years. In order to evaluate the contribution of the commercial fishery to the decline in run size, a trend analysis was performed on the total catch and chinook salmon catch. This simple approach weighs a series of data points from catch records over time using least squares methodology and uses them to plot a regression line that represents the trend in the catch over time. A slope of 0 would indicate that the catch was stable over time. A positive slope value would indicate that the catch was increasing over time. A negative slope value would indicate that the catch was decreasing over time. Another way to think about this is that if the fishery were harvesting at the maximum sustained yield the slope would be near zero, if it was exceeding the maximum sustainable yield the fishery would be declining and the slope would be less than zero. Projecting the regression line into the future provides an idea of what the catch would be like each year in the future if it continued to increase or decrease at the same rate, i.e., if the factors that controlled the past catch remained constant.

To separate the effects of commercial fishing above the maximum sustained yield from the effects of hydropower on causing reductions in the catch, the trends with and without hydropower were calculated. This was accomplished by plotting three regression lines based on catch from: (1) 1872 to 1933 (when the first mainstem dam at Rock Island was completed and the construction of Bonneville and Grand Coulee Dams was underway); (2) 1872 to 1941 (after Bonneville and Grand Coulee were operational); and (3) 1872 to 1983. The first line represents the trend controlling the trend, and the second and third lines shows the trend with the effects of hydropower added. When these lines are projected incrementally into the future, the difference between them represents the loss due to hydropower each year. Actually, the difference between the lines represents the loss due to hydropower plus other factors which are different before and after 1933 such as the extent of ocean harvest on Columbia River stocks.

Note that the first five years of the commercial fishery (1866 to 1871) were not included in this analysis because the catches were so low they would have led to a higher value for the slope and therefore a greater difference between the regression lines representing the trends with and without hydropower, i.e., greater hydropower loss. The catch data used for this analysis are from Northwest Power Planning Council (1985, Table A-1). The trend plots are presented in Fig. 4.2 (total catch) and 4.3 (chinook catch).

Results indicate that the trend for total catch was increasing before hydropower (1871 to 1933 slope = + 20.73; 1871 to 1941 slope = +9.47), suggesting that the fishery had not reached the maximum sustainable yield. When hydropower was added, the slope of the trend line became negative (1871 to 1983 slope = -17.15). The difference between the 1871 to 1941 and 1871 to 1983 trends in 1985 amounted to approximately 2.6 million fish. It should be emphasized that the 2.6 million fish does not represent the total hydropower related loss, only the loss to the commercial catch. It does not include the Indian subsistence catch or escapement. The Indian fishery suffered a loss of about an equivalent number of fish. (e.g., 644,000 above the block at Grand Coulee alone). The lost escapement on approximately 5 million fish would range between 3.3 million (if a 66% catch/escapement ratio were used) and 5 million (if a 50% catch/escapement ratio were used) for a total loss of 8.3 to 10 million fish.

The trend for the chinook catch was already decreasing before the effects of hydropower were added (1871 to 1933 slope = -5.61) however, with hydropower added it dropped at a substantially faster rate (1871 to 1941 slope = -8.26; 1871 to 1983 slope = -14.72). The difference between the 1871 to 1933 and 1871 to 1983 trends in 1985 amounted to approximately 800,000 chinook.

The trend line established for chinook salmon (Figure 4.3) likely does not accurately portray the trend for chinook catch because in the first 15 years of the fishery the chinook population was higher than the population that produces the maximum sustained harvest. In comparing the Indian subsistence catch (before 1850) to the modern (1930 to 1940) commercial catch, Craig and Hacker (1940) state:

Figure 4.2 Trend analysis for total commercial catch of salmonids in the Columbia River (includes some fish caught off the coast of Washington and Oregon).

Total Catch of Salmonids Since 1866
Thousands of Fish

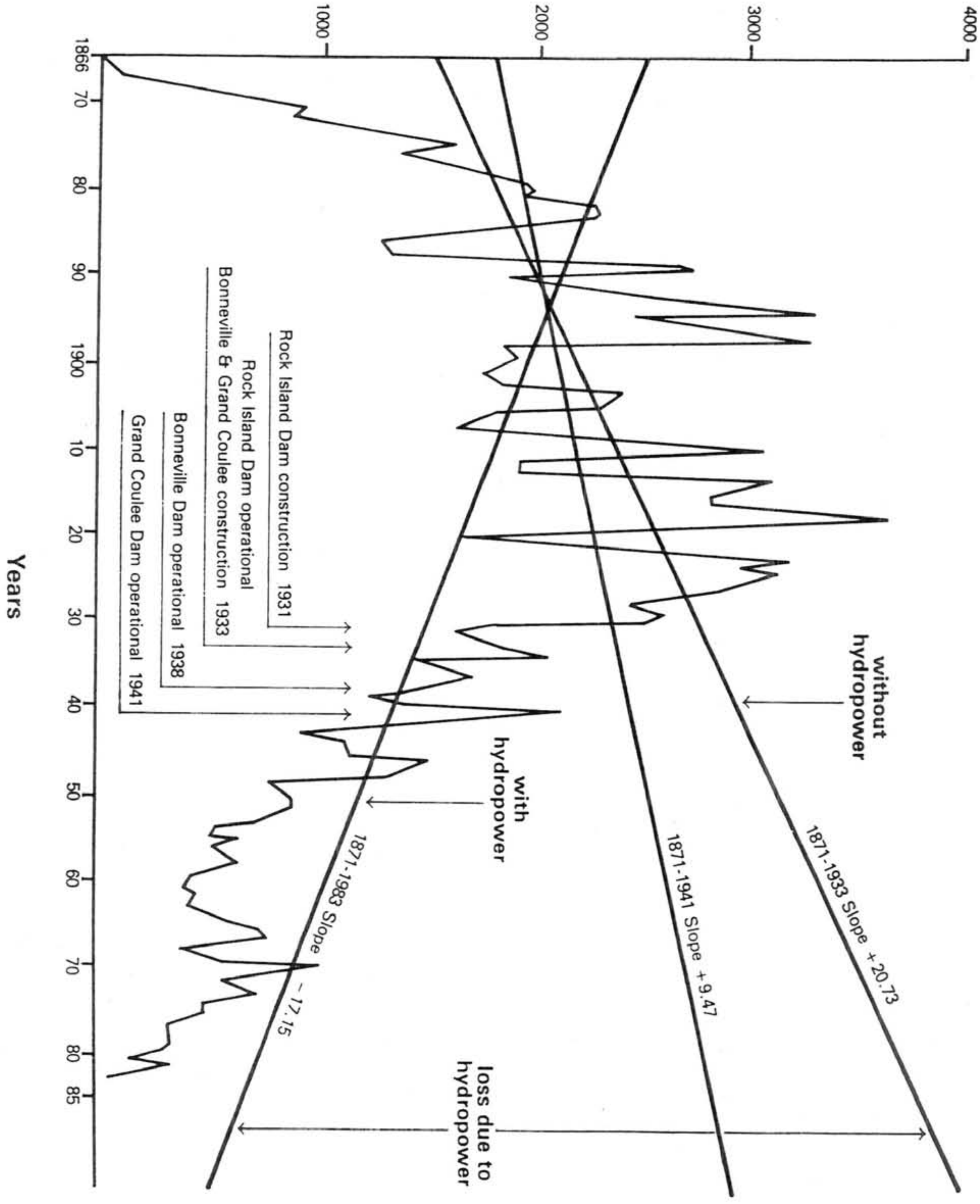
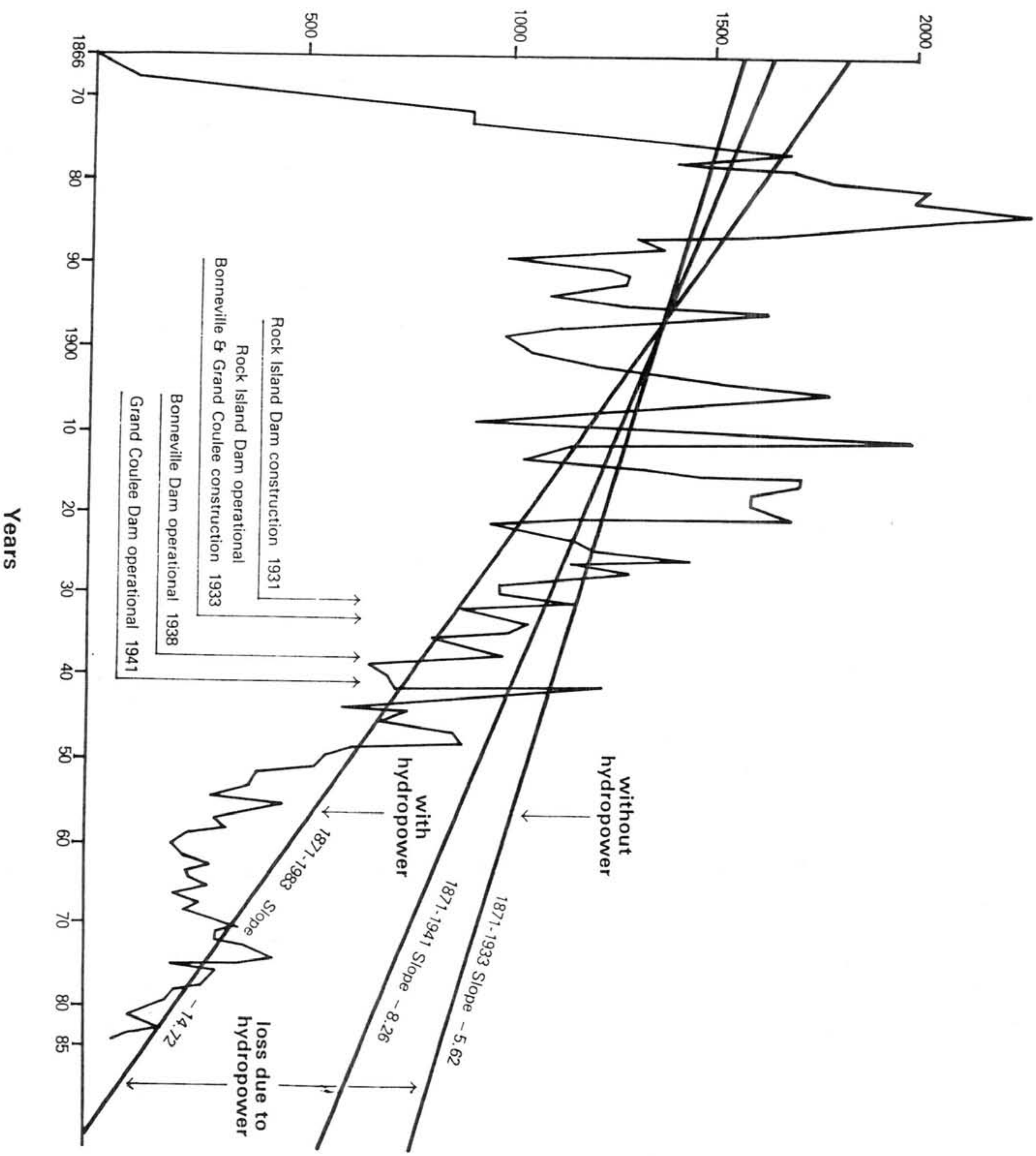


Figure 4.3 Trend analysis for commercial catch of chinook salmon in the Columbia River (includes some fish caught off the coast of Washington and Oregon).

Total Catch of Chinook Since 1866

Thousands of Fish



"Even though the primitive Indian catch might have been of comparable magnitude to the modern commercial catch, it did not represent as a great a proportional strain on the spawning population as its relationship to the present catch would indicate. This is true because it must be remembered that under present conditions many miles of spawning streams have been cut off by dams so that they are no longer available to the migratory fish, that irrigation diversion take an enormous toll of the young migrants when they are on their way to the sea, and that pollution and other changed conditions have made many streams less suitable for salmon. However, discontinuance of the primitive Indian catch because of the great decrease in the number of Indians may be one of the factors which helps to explain the ability of the Columbia River salmon to continue to produce a catch as large as they have, even under increasingly unfavorable conditions."

Craig and Hacker (1940) point out that from 1800 to 1865 the Indian populations of the Columbia Plateau were decimated by disease. Consequently, the fishing pressure on salmon decreased. The authors state:

"Between 1820 and 1865 the amount of salmon used by the white settlers did not equal the falling off of the Indian catch which was occasioned by the decrease in the Indian population. Therefore, it is not improbable that there was less fishing strain on the salmon populations of the Columbia during the period from about 1835 to 1865 than at any other time in their history. If this were the case, the salmon of the Columbia may have been more abundant during the few years immediately before the advent of the canning industry in 1866 than at any other time within our knowledge."

Hewes (1973) considered this *"evidence for a resting period; following the decline of native fishing, during which the stocks of certain species actually may have become more abundant than they had been for many previous centuries. Part of the early high productivity of the commercial fisheries might be attributable to the temporary existence of a fish surplus."*

Restating this thought in technical terms, at the time the commercial fishery commenced in 1866 the population level of the stock was near the level of maximum recruitment.[1] Since the size of the population at maximum sustained yield is less than at maximum recruitment, it is logical that the surplus suggested by Hewes existed.

Following this line of reasoning, the surplus should be subtracted from the chinook catch during the first years of the fishery to determine the trend relative to the maximum sustainable harvest. The magnitude of the surplus was estimated by recognizing that the Indian population had, by 1865, been reduced to approximately 1/4 of the precontact level (Stevens 1856). Since the total chinook catch during the precontact period was approximately 994,000 fish (see section 3.3), i.e, about 1/4 to 1/2 of the maximum

1. It is extremely unlikely that the spawning excapement exceeded the level which produces recuitment in the years preceding the commercial fishery because there is abundant evidence that the Indian fisheries still harvested a large number of salmon during the period 1897 to 1880 (i.e., 1 to 2 million fish -- see Sections 2.1 - 2.4).

(approximately 490,00 fish) would be a conservative estimate for the surplus. This number was then subtracted from the peak chinook catches from 1875 to 1885 (i.e., approximately two spawning cycles). A new set of regression lines was plotted from these data. The value of the slope during prehydro period was nearly zero (1871 to 1933 slope = +0.30), suggesting that the fishery was operating near the maximum sustainable level. With hydro added, the slope (1871 to 1941) was -3.39 and the slope (1871 to 1983) was -17.54. The difference between the 1871 to 1933 and 1871 to 1983 trends in 1985 was projected at approximately 1.1 million fish. Adding the loss to the Indian fishery and lost escapement provides a range in the estimate of a total loss of approximately 3.3 to 4 million chinooks.

This analysis indicates that although the commercial catch perhaps contributed to the temporary declines in abundance of salmon, it was not a significant factor in the long-term decline that began in the 1930's and has continued to the present time.[2] This analysis points to hydropower as the principal factor in causing the long-term downward trend. Other factors that were different after 1933 such as ocean harvest also could have contributed to the downward trend.

Fulton (1968) describes several factors that have contributed to the decline of salmon runs in the Columbia Basin including harvest management practices, sewage, logging, mining, irrigation, and dam construction, which reduced the size and capacity of spawning areas; and passage problems associated with development and operation of the Columbia River hydroelectric system. The latter factor was identified as a problem of particular importance because *"resolution of the problems of safely passing migrating salmonids -- particulary [smolts] -- has not kept pace with dam construction in the Columbia River drainage."* Destruction of spawning and rearing habitat by siltation and accumulation of debris from erosion caused by poor farming, mining, and logging practices is largely reversible. Losses due to overfishing can be reversed through changing harvest regulations. Irrigation loss can be reversed by screening diversions. In contrast, dams block and inundate habitat -- the effect is more permanent and cannot be readily reversed.

4.5 CONSTRUCTION AND OPERATION OF HYDROELECTRIC PROJECTS: EFFECTS ON SALMON. AND STEELHEAD RUNS INTO THE UPPER COLUMBIA BASIN.

4.5.1 Mechanisms of hydropower induced mortality.

The effects of hydropower on the salmon and steelhead resources of the Columbia River are related to the construction and operation of dams. A large volume of literature on this subject is available in reviewed journals.

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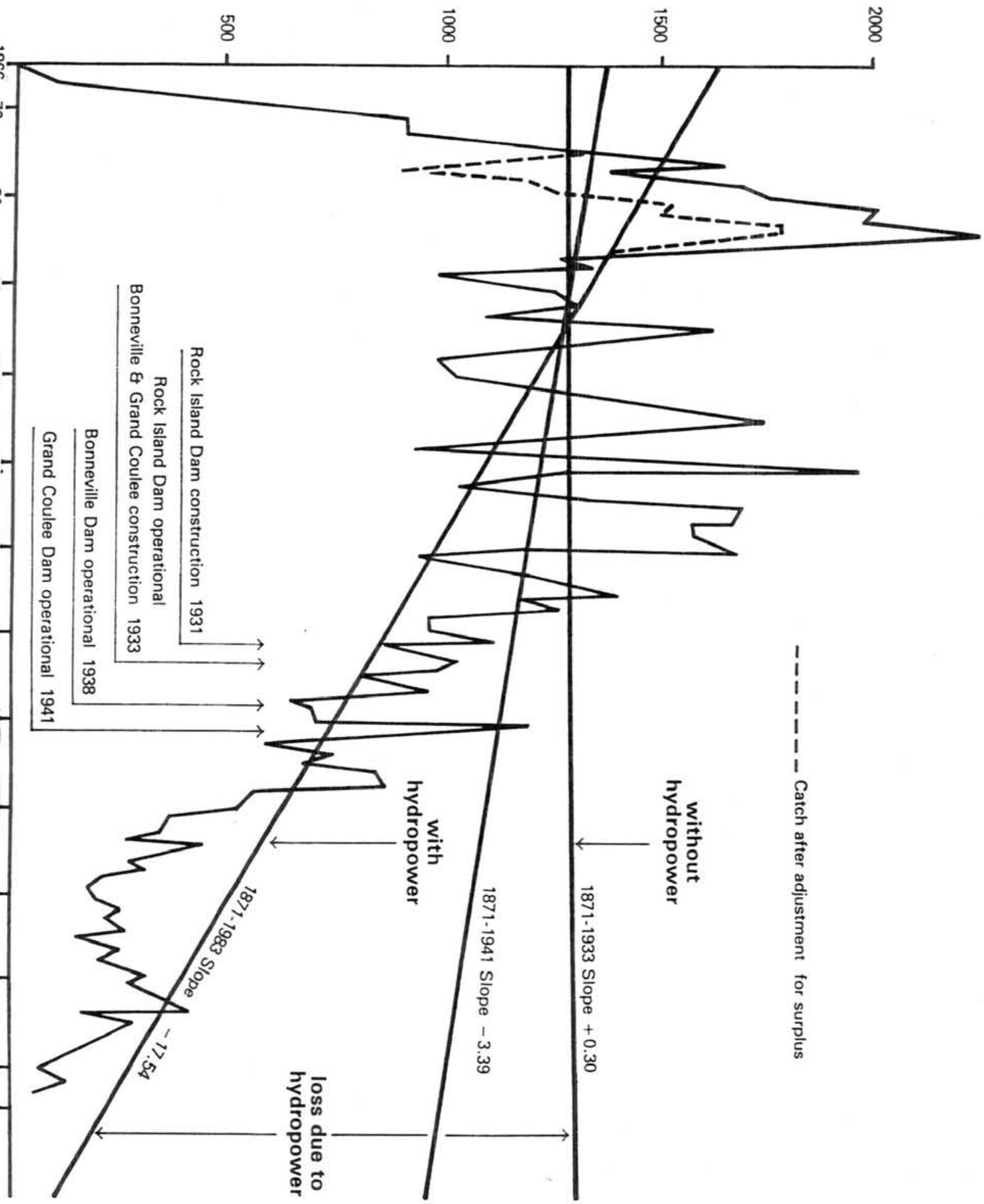
2. Note also that the catch to escapement ratios of 50% and 66% appear to be reasonable estimates in view of the number of years that the catch remained constant (about 50 years). If the catch to escapement ratio had been at 80 to 85% the declines in catch would have been observed much earlier and been more pronounced.

Figure 4.4 Trend analysis for commercial catch of chinook salmon in the Columbia River after subtracting the temporary surplus in 1875 - 1885 (includes some fish caught off the coast of Washington and Oregon).

Years

Total Catch of Chinook Since 1866
Thousands of Fish



Dam construction on the Columbia River has resulted in direct blockage and alteration of spawning habitat and delayed migration of adults and juveniles to remaining habitat. The first mainstem dam, Rock Island, became operational in 1933. According to Chaney (1978): *"By 1968 the entire mainstem Columbia River from the head of tidewater to the Canadian Border had been impounded behind a succession of dams except for a fifty-mile reach near Richland, Washington."* These dams inundated and eliminated hundreds of miles of mainstem salmon spawning habitat and, in addition, blocked thousand of miles of tributary spawning and rearing habitat (Fulton 1968, 1970; Thompson 1976).

Grand Coulee Dam alone blocked salmon and steelhead from over 1,140 linear miles of habitat in the upper Columbia River drainage (Chapman 1940; Fish and Hanavan 1948, Chaney and Perry 1976, Chaney 1978). The failure of fish passage facilities at Brownlee Dam on the middle reach of the Snake River terminated all fish passage into the Upper Snake system (Netboy 1980). Collectively, mainstem and tributary dams and their impoundments have eliminated nearly 2/3 of anadromous salmon and steelhead spawning habitat in the Columbia River Basin (BPA 1984) and flooded other spawning sites. The greatest loss has been in the Upper Basin. In addition to blockage and loss of habitat, dams and im-poundments have created vast changes in the environment of Columbia River salmonids. Free-flowing rivers with rapids and gravel bars for spawning and incubation have been replaced with a series of reservoirs and impoundments. Hundreds of miles of salmonid spawning habitat were flooded with the building of Columbia River Dams. John Day and McNary dams inundated 137 miles of important fall chinook spawning area in the mainstem Columbia River (NWPPC 1985).

The Bureau of Reclamation (1947) stated that *"many valuable [salmon] breeding areas have been totally eliminated by construction of dams wholly unprovided with fishways ... It is evident that a large part of the spawning and rearing areas originally available has either been completedly eliminated or so seriously reduced as to be useless. This reduction... has undoubtedly been an important factor in the reduction in salmon runs."* Stober et al. (1979) estimated that dam construction has reduced habitat to 44% of the habitat available before 1910, from 163,00 square miles to 72,800 square miles. This means that dam construction is responsible for at least 56% (approximately) of the reduction in run sizes plus ongoing operational losses in passing the remaining fish during the smolt migration and adult spawning migration.

Besides losses caused by permanent blockage of habitat, operational passage losses occur. For example, the U.S. Fish and Wildlife Service, by 1947, had made a study at Bonneville Dam and concluded that 15% of downstream migrants were killed, and possibly more as they attempted to pass downstream (Netboy 1958;1980). Wes Ebel, of the National Marine Fisheries Service, told the audience at the Salmon and Steelhead Symposium held in Vancouver, WA in March of 1976 that before the era of dam building, homing of adult chinook salmon in the Columbia River averaged 4% of the number of smolts migrating downstream. As the number of dams increased the percentage of returning adults decreased, especially after a large number of dams were constructed on the mainstem Columbia and Snake in the 1960's and 1970's. Returns from the 1972 year class were 0.8%, and from the 1973 year class 0.4%. Steelhead returns showed a similar trend, dropping from 5% in 1966 to 2.5% in 1969, 1% in 1972, and 0.3% in 1973.

The downstream migration of juveniles and upstream migration of adults have been delayed significantly due to the series of dams and impoundments on the Columbia and Snake Rivers (Schoning and Johnson 1956; French and Wahle 1964; Junge 1964; Major and Mighell 1966, 1967; Major and Paulik 1972; Park 1967; Davidson 1967; Raymond 1968, 1969; Park 1969; Becker 1970; Major and Paulik 1972; Raymond et al. 1974; Bentley and Raymond 1976; Collins 1976; Raymond 1979; Haynes and Gray 1980). An average impoundment delays juvenile salmonids around three days. Fish from the upper river were found to reach the estuary almost a month later than before the dams were built (Raymond 1979). The effects of cumulative delays and altered temperature regimes have resulted in high mortalities of juvenile and adult salmonids. (Schoeneman et al. 1955, 1961; Junge 1966; Raymond 1969; Raymond et al 1974; Ebel et al. 1975; Bell et al. 1976; Bentley and Raymond 1976; Ebel and Raymond 1976; Raymond 1979).

The effects of delays result in increased mortality from exposure to saturation of atmospheric gases (Ebel and Raymond 1976; Raymond 1979) in high flow years and increased mortality from turbines, high temperatures, predation and disease in low flow years (Bell et al. 1976; Raymond 1979). During low flow years, delays can result in the tendency of juveniles to hold- over in reservoir for extended periods before completing their migration. Some residualize, i.e., they remain in the reservoir or impoundment and never go to sea (Raymond 1974, 1979). While remaining in the reservoir, juvenile salmonids are susceptible to predation, disease, and lethal temperatures. The creation of reservoirs, it should be noted, favors predatory species such as squawfish which are now more abundant than they used to be in the Columbia River. These fish feed, in part, on downstream migrating smolts (Dennis Rondorf, USFWS, pers. comm.). It has also allowed for the introduction of predatory species such as walleye that are not native to the Columbia system.

Cummulative delays may affect smoltification. During smoltification, juvenile salmonids are motivated to migrate downstream and are physiologically capable of adjusting to a saltwater environment from a freshwater environment (reviewed by Hoar 1976; Hasler and Scholz 1983). Collins (1976) reported that smolts from the Salmon and Clearwater Rivers, in Idaho, reached the ocean within about 30 days before dams were constructed on the Columbia and Snake Rivers, whereas they took 78 days after the dams were constructed. Bonneville Power Administration (1984) summarizes the smolt problem succinctly: *"Dams slow spring flows by storing water in headwater reservoirs for power generation later in the year. Slow waters and large reservoir lakes could compromise the critical migration schedule. Smolts must reach the ocean within about 30 days of beginning their downstream migration or they will have difficulty adapting to saltwater."* Zaugg et al. (1972) and Hasler and Scholz (1983) showed that steelhead and coho smolts will revert to parr if they remain in freshwater longer than 30 to 45 days. Adams et al. (1975) and Hasler and Scholz (1983) demonstrated that saltwater survival drops to less than 20% for steelhead and coho that have reverted to parr. The problem of juvenile mortality when the fish enter the ocean can, thus, be traced back to hydropower.

Supersaturation of atmospheric gases (primarily nitrogen) in the Columbia and Snake Rivers and its effect on salmonids has been well documented (Westgard 1964; Pauley et al. 1966; Coutant and Genoway 1968; Beiningen and Ebel 1970; Coutant 1970; Ebel 1970; Beiningen and Ebel 1971;

Ricker 1972; Elling and Ebel 1973; May 1973; Meekin and Allen 1974; Meekin and Turner 1974; Smith 1974; Blahm et al. 1975; Gramer and McIntyre 1975; Dawley et al. 1975; Dell et al. 1975; Ebel et al. 1975; Bouck et al. 1976; Ebel and Raymond 1976; Nebeker et al. 1976; Nebeker and Brett 1976; Snyder et al. 1977; Nebeker et al. 1979; Raymond 1979; U.S. Army Corps of Engineers 1979; Bouck 1980; Fickeisen et al. 1980; Knittel et al. 1980; Montgomery and Becker 1980; and Stevens et al. 1980). Supersaturation of nitrogen was first recognized as a potential problem to anadromous fish in the Columbia River in 1965 when levels of 125 percent saturation were recorded. Ebel (1969) found that high levels of dissolved gases occurred from Grand Coulee Dam to Astoria during the spring and early summer when high flows occur. This study indicated that water plunging over spillways was the main cause of supersaturation and that little equilibration occurred in the reservoirs associated with the dams.

Losses of juvenile chinook and steelhead migrating from the Salmon River to the Dalles Dam have ranged from 40% to 95% since 1968. The proportion of this loss that can be attributed to exposure of fish to supersaturation of nitrogen ranges from zero in low-flow years (because turbine mortality kills the majority of the fish) as in 1973, to 80% in high flow years such as 1971 (Ebel and Raymond 1976).

The severity of gas bubble disease and its consequences depend on the level of supersaturation, the duration of exposure, water temperature, physical condition of the fish, and swimming depth of the fish. Mortality due to nitrogen supersaturation can be direct or indirect. Fish that undergo sublethal levels may be partially blinded and unable to spawn (Westgard 1964), suffer impaired swimming function (Schiewe 1974; Weber and Schiewe 1976; Newcombe 1975), and have secondary bacteria or fungus infections (Weitkamp 1976). Thin walled blood vessels in the eyes of smolts rupture easily. The eye humor fills with blood, clouding it and blocking light from the retina, leaving the fish blind. At nitrogen supersaturation levels of 115%, 13% of the survivors were blind in both eyes and 85% were blind in at least one eye (Collins 1976).

Gas bubble disease can also cause high mortality in adult salmonids. In 1968, at John Day Dam all water passed over the spillway before the turbines were installed. Dissolved nitrogen saturations of 123 - 143% downstream from the dam were produced. Concurrent problems with fish passage facilities caused a delay in migrating adult salmonids in the highly supersaturated water. An estimated 20,000 were lost (Beiningen and Ebel 1970). Meekin and Allen (1974) estimated that 6% to 60% of adult salmonids in the middle region of the Columbia River died between 1965 and 1970 due to nitrogen supersaturation.

Mainstem dams pose passage problems for juvenile and adult salmonids migrating to and from their remaining spawning habitat in the upper Columbia. Mortality rates among juveniles are especially high. Once the smolt has passed through the reservoir, it must negotiate the dam itself via the spillway or through the turbines. When juvenile salmonids pass through the power turbines they are subjected to a variety of conditions that can cause injury or death. Pressure changes, physical blows, and cavitation within each turbine are major causes of juvenile mortality, as well as moving turbine blades and shearing action of water (NWPPC 1985). Young salmonids may be stunned or disoriented as they move through the turbines, which increases their vulnerability to predators such as gulls and squawfish.

Mortalities at each dam differ with the amounts of water passing through the powerhouse and spillway, with the operating load, etc. (Schoeneman et al. 1961; Collins 1976). Losses at each mainstem dam have been estimated to be 15% to 20% (Chaney and Perry 1976; Chaney 1978). Mortalities of 30% have been recorded for juvenile coho salmon passing through turbines at Ice Harbor and Lower Monumental Dams when indirect mortality by predation was included (Long et al. 1968, 1975).

When predation is combined with turbine mortality the cumulative loss occurring to downstream migrants passing a series of dams can be significant. During the low flow years of 1973 and 1977 when many juveniles passed through turbines, cumulative losses of 95% and 99% were recorded for chinook salmon and steelhead populations from upper dams in the Snake River to the Dalles Dam (1973) and John Day Dam (1977) (Sim et al. 1978; Raymond 1979; NWPPC 1985). Junge (1980) has suggested that mortalities due to passage of a series of dams were exponential rather than additive. For upriver fish, cumulative juvenile passage mortality for nine dams is 77% (NWPPC 1985).

Fish passage facilities have been constructed at most dams to allow adult salmonids to migrate upstream to their spawning grounds. Some facilities have been poorly designed, others inadequately operated. Fish ladders may not attract fish and thus delay them in their upstream migration. After ascending a fish ladder, the salmonids in weakened condition may move back downstream -- fallback, which also delays their passage. Fallback has been observed at most dams on the Columbia River and is a serious problem at Bonneville Dam (Monan and Liscom 1971, 1973, 1974, 1975, 1976; Liscom et al. 1977, 1978, 1979; Gibson et al. 1979). The amount of spill was shown to determine the likelihood of fallback. During one season, a fallback rate of 63% occurred during a period of high flow (Monan and Liscom 1975).

One of problems caused by fallback is overcount which can result in count discrepancies between dams. Another problem is the added delay to upstream migrations as the fish seeks out a fishway and reascends the dam. Passage delays for adult salmon at an individual dam varies from 2-4 days (Van Hyning 1973). A series of such delays causes the salmon to lose valuable energy stores and reduces their motivation to migrate upstream.

Passage difficulties have resulted in prespawning mortality of adults and reduced success of late spawners (Meekin 1969). Prespawning mortality is estimated to be 5% per mainstem dam (NWPPC 85). Each mainstem dam is estimated to have a total average adult mortality of 15% (Chaney and Perry 1976; Chaney 1978; NWPPC 1985). Adult losses may also be cumulative.

Fish ladders were found to be important sites for infection with *Chondrococcus columnaris*, the causative agent of columnaris disease (Fujihara and Hungate 1971, 1972). *C. columnaris* disease and gas bubble disease may have a synergistic effect on mortality (Fujihara et al. 1971).

Within the last 10 years, Columbia and Snake River Dams have been utilized to provide power during peak demand in the Pacific Northwest (NWPPC

1985). Acute fluctuations in water levels are common during power-peaking activites. Significant losses of eggs and juvenile salmonids can be incurred during flow reductions due to dewatering of redds (Becker et al. 1982) and stranding or entrapment of juveniles in shorelines pools, gravel bars or side channels. Stranding observations on the Skagit River by Thompson (1970) indicated that large numbers of salmon fry can be killed by stranding under certain flow conditions. In a similar study, Phinney (1974) reported that during two days of test flow reductions, an estimated 272, 600 fry were stranded and killed. Observations in other areas revealed serious stranding problems during flow reductions (Bauersfeld 1977; Bauersfeld 1978a, 1978b; Graybill et al. 1979; Woodin 1984).

Other stranding effects include increased susceptibility to predation, lethal temperatures and dessication. Salmonids spawning under altered flow conditions were shown to construct abnormal or incomplete redds (Bauersfeld 1978a).

Reservoir fluctuations influence stream flows which in turn alter migration time. Temperatures regimes are altered in reservoirs, i.e., increased over what they were in the free flowing river. High temperatures can act as blocks that prevent the migration of salmonids. The appearance of a temperature block at the confluence of the Snake and Columbia Rivers was evident in 1967 and 1968, and was a probable cause of loss during high temperature-high flow year (Stuehrenberg et al. 1978; Liscom et al. 1979).

The following sections (Sections 4.5.2 - 4.5.4) expand on the effects of hydropower construction and operation in the Upper Columbia Basin on the mainstem and tributaries.

4.5.2 The Spokane River Dams.

The Spokane River was one of the first rivers in the northwest to be impacted by hydroelectric development. Spokane had streetlights before San Francisco or Portland (Meinig 1968).

In 1890, the Monroe Street Dam was built at Spokane Falls. This replaced a hydroelectric generating facility that was constructed at the falls in 1888. Post Falls Dam was operational in 1906. In 1909 construction was started on Little Falls Dam 28 mile above the mouth. This dam was 60 to 70 feet high and totally blocked salmon runs from the main spawning areas. Apparently, a wooden fish ladder was built when the dam was constructed. In any event, it was not operated after Long Lake Dam became operational. Little Falls Dam was completed in 1911. Nine Mile Falls Dam (60 feet high) was to built in 1909 about 19 miles farther upstream just above the mouth at the Little Spokane River. Long Lake Dam (175 feet high) four miles above Little Falls Dam was built in 1915. The primary purpose of all of these dams was hydroelectric power generation. Except for Post Falls, which also served an irrigation function, we have been unable to locate any information that states these dams were constructed for any purpose other than hydropower.

A number of investigators reported cessation of salmon and steelhead runs, as well as declines in resident fisheries, shortly after these dams were built. For example, Bryant and Parkhurst (1950) reported, *"By 1918 the chinook, coho and steelhead runs had practically disappeared from the* *river. Various residents have stated that there was also an extensive sport fishery on this river before the dams were built."* Fulton (1970) said that steelhead trout were *"numerous up until about 1915 (shortly after hydroelectric dams completely blocked upstream passage of adults), after which they completely disappeared."* Regarding former spawning areas of chinook salmon on the Spokane River, Fulton (1968) stated, *"Historically, salmon ascended this stream to Spokane Falls, about 80 km above the mouth. In 1909, Little Falls Dam blocked runs at river km 44. Subsequently other dams were built. Large runs spawned in this stream before hydroelectric developments, but only remnant runs were left by 1939."*

McDonald (1978), who actually lived on the Spokane River in the vicinity of these dams at the time they were built, wrote, *"When the Little Falls Dam was completed, it sounded the death knell of the salmon fishing which... was so important... to the Indians. No longer were they able to catch or spear fish at their accustomed grounds. [The blocked passage at Little Falls Dam] could have very well have been instrumental in the decline of salmon fishing in the entire Columbia drainage."*

McDonald (1978) further states,

> *"While the Nine Mile Dam [above the mouth of the Little Spokane River] prevented any further migration of salmon and steelhead beyond that point, the fishing in the river showed no noticeable change. The day of infamy came in 1910 when Little Falls Dam was completed, thus ending for all time the run of migratory fish. It was a sad day for the pioneers who had grown to depend on salmon as one of their staple foods, but for the Indians it was a catastrophy. Fortunately, the Indians, and whites as well, were able to catch salmon below Little Falls Dam [until Grand Coulee Dam was built]. Although the salmon were gone, the [resident] trout fishing seemed to be as good as ever and fabulous catches continued until 1914 when Long Lake Dam went on line."*

Mr. McDonald states that within a short time perch, sunfish and carp replaced trout as the principal fish in the Long Lake reservoir. By the 1930's bass were also being caught.

4.5.3 The Columbia Mainstem Dams.

Even before the permanent blockage by Grand Coulee Dam, Rock Island Dam severely impacted upriver salmon runs.

Koch (1976) stated,

> *"The first dams, Rock Island and Bonneville, initially had fish passage facilities that proved to be inefficient. They also presented supersaturated atmospheric gas problems, an unanticipated problem in the planning stages, to both up and downstream migrants. The dams also initiated delays and massive injuries to the upstream migrants. The fish often jump in vain at the face of the dams, or are delayed long enough in their search for the fishway that they do not have enough energy left to reach the spawning areas or are so injured that fungus or infection drains*

their energy supplies resulting in death prior to reaching the spawning areas."

It is reasonable to expect that these dams affected fish construction phase before they became operational. For the first three mainstem dams the year construction began and the year operation began are listed below:

	Year construction began	Year service started
Bonneville	1933	1938
Rock Island	1930	1933
Grand Coulee	1933	1941

Runs were partially blocked during construction. According to Grand Coulee project histories (1933-1939) for example, the fishway that was built at Grand Coulee Dam did not function properly all the time. Additionally, it is well known that blasting killed large numbers of adult and juvenile migrants. This is interesting in view of the fact that most people look at the years 1938-1939 for the initial effects of dams on the fish runs. Actually, they began impacting fish in the period of 1930- 1933. It is interesting to note that this is the period when the commercial catch began to decline precipitously.

In the original construction of Rock Island Dam two fishways were incorporated into the dam. The specifications for fish passage at Rock Island stated *"There shall be at least two fishways with a possibility of a third after study of the model of the dam"* (Bell 1937). Koch (1976) reported *"Unfortunately, the model was the real dam and need for a third fishway was from studying actual fishery losses. The noticeable loss to the fishery was quite apparent within two to three years after the dam was completed,"* and necessitated construction of the third fishway. Koch (1976) reported

> *"The fishing activities of the Indians at Kettle Falls offers conclusive evidence that Rock Island delayed the rate of migration of fish up the river. The Colville Indians have fished these waters since early times and the peak of the chinook salmon run was always about the same time -- August 1. However, after the construction of Rock Island Dam, chinooks reaching Kettle Falls were delayed until after August 20th, which could have significant adverse effects (Bell 1937)."*

At Kettle Falls, Indians caught 1000 salmon in 1930 and 1500 salmon in 1931, but in 1932, when Rock Island Dam was completed the Indians caught but 400 salmon. In 1933 the catch had dropped to 267 and, in 1934, to (Lemery 1938, Table 4.1). Lemery (1939) further states *"[these] facts show that the fishways are not working efficiently"* and that *the first dam (Rock Island) on the Columbia River presented a significant obstacle to fish runs in the Upper River."*

Table 4.1. Number of chinook salmon caught at Kettle Falls: 1929 - 1934 (Lemery 1938).

Before Rock Island		
Year	Catch	
1929	1,353	
1930	1,000	
1931	1,500	
Ave.	1,284	

After Rock Island	
Year	Catch
1932	400
1933	263
1934	134
Ave.	267

From Table 4.1 it can be seen that the effect of the dam was almost immediate and reduced the numbers taken at Kettle Falls to approximately one-fifth and the numbers were declining each year. Lemery (1938) documented a decline in the catch of chinook salmon in the Indian Fishery at Kettle Falls from an average of 1,284 for the three years immediately preceding operation of Rock Island Dam to 267 fish during the first three years after Rock Island Dam became operational. These data suggest that the early Rock Island Dam counts for chinook salmon should be multiplied by a factor of 4.8 for an accurate portrayal of the number of fish arriving at, but not passing, Rock Island at least until the third fish ladder was constructed. Presumably other species of salmonids would be similarly affected. This correction is made in Table 4.2. This should be considered a minimal estimate because construction of Rock Island Dam commenced in 1929. It is likely that the construction phase could have negatively influenced (i.e., reduced) fish runs. Therefore, Mr. Lemery's 1929 to 1931 counts (during construction) may already have been seriously depressed.

For proper interpretation of Rock Island counts, Calkins et al (1939) and Fish and Hanavan (1948) point out that it is important to notice that the counts for 1933 and 1934 covered a relatively shorter period compared to other years, i.e., in 1933 counting did not start until after the spring run of chinooks and steelhead had already passed over the dam, and was terminated before the late runs of chinook and steelhead passed over the dam. In 1936, counting was stopped at the end of August so that the late runs of these two species are not reported for this year either. This suggests that the corrected counts presented above should be higher (see footnote 2, Table 4.2). In 1951-1953 Rock Island Dam was modified by addition of six new generating units to the power house and increasing the height of the forebay by 12 ft. The left bank and middle fish ladders were modified to make fish passage easier but the right ladder was not. In 1954-1956 a study (French and Wahle 1965) was conducted to determine whether the loss or delay associated with the right bank ladder was greater than the modified ladders. Tagged fish were released below Rock Island Dam and counted at the three ladders. Fewer fish used the right ladder after 1953 than before 1953 and were delayed by 2-3 days. In the left and middle ladder the delay was .5 to 1 day less than before. This suggests that the Rock Island ladder may not have been functioning at the best efficiency through the early 1950's.

A tagging study was made to determine the accuracy of the counters. Fish were given tags and released below the dam and counted as they passed by the counting window. Counts were also made upstream at Tumwater Dam (Wenatchee River) and Zosel Dam (Okanogan River). Spawner Counts were made to determine how many fish actually reached spawning grounds. Upstream tag recoveries included both visual observation of the different colored and shaped tags by counters at fish ladders and actual recoveries. Counters were not aware of the type of tags being applied each day so as to provide a blind control. Specific examples of counter errors included: (1) mis-identification of species -- i.e., fish counters recorded as tagged species which had not been tagged; and (2) on several occasions more chinook salmon with tags were recovered on the spawning grounds upstream than had been counted at Rock Island Dam.

Because they were confronted with the apparent loss of many tagged fish at Rock Island Dam, French and Wahle (1965) also conducted a study at Bonneville Dam in 1954. Two hundred and ninety three chinook, sockeye and

Table 4.2. Actual and corrected Rock Island run size for years before the construction of the third fish ladder.[1]

	Year	Actual Rock Island count	Corrected Rock Island count
Chinook	1933[2]	5,668	27,206
Coho	1933	182	874
Sockeye	1933	40,737	195,537[3]
Steelhead	1933	1,055	5,064
Totals	1933	47,642	228,681
Chinook	1934[2]	6,482	31,114[2]
Coho	1934	69	331
Sockeye	1934	2,227	10,689[3]
Steelhead	1934	583	2,798
Totals	1934	9,361	44,932
Chinook	1935	16,310	78,288
Coho	1935	10	48
Sockeye	1935	14,013	67,262[3]
Steelhead	1935	5,412	25,978
Totals	1935	35,745	171,576
Chinook	1936	7,396	35,500
Coho	1936	---	---
Sockeye	1936	16,501	79,205[3]
Steelhead	1936	2,369	11,371
Totals	1936	26,266	126,077
Chinook	1937	5,133	24,638
Coho	1937	58	278
Sockeye	1937	15,087	72,416
Steelhead	1937	2,214	10,627
Totals	1937	22,492	107,962

1. Counters may have missed as many as half the fish passing through the fish ladder so it might be appropriate to increase these numbers by a factor of 2 (French and Wahle 1965).

2. The 1933 and 1934 counts did not include the early runs which contribute approximately 1/4 to 1/3 of the total run. If this correction were made, the corrected Rock Island count for chinook in 1933 should be multiplied by 2 (to account for the counters recording only half of the fish) and divided by .33. This yields a corrected Rock Island run size of chinooks in 1933 of 72,367 chinook.

3. The sockeye salmon were apparently not affected by the dam as severely as chinook salmon. The sockeye habits of seeking slower waters and eddies close to the shore allowed them to find the fish ladders much more easily (Koch 1976) so the corrected values for sockeye may be high.

steelhead were tagged at Bonneville Dam with a distinctive black and bright orange disc. Of these 63 were seen passing up the fish ladders at Bonneville and 75% of them were seen at points upstream. The Rock Island counters were alerted to be on special look out for the particular tag applied at Bonneville. Only 6 of these tags were reported by counters at Rock Island but 14 were recovered upstream from Rock Island Dam. In view of this example French and Wahle conclude: "It is undoubtedly true that the counters missed tagged fish--the counters only saw 42% of the fish that passed." In another experiment designed to test the magnitude of errors in counting, the error averaged 70.5% for chinook (range: 66.7 to 83.4%) and 3% for sockeye (range: 0-10.1%).

Dam counts also did not count all fish moving past fish ladders. At Bonneville Dam, for example, in 1938 actual counting did not begin until May 7th but partial counts were made before that time (Calkins et al. 1939):

	Calkins (1939)	Northwest Power Planning Council Figure (1985)
Chinook	277,189	271,799
Steelhead	120,373	107,003

Apparently, the Power Planning Councils (1985) count for Bonneville Dam does not include the period of partial counts.

Major and Paulik (1972) reported that the filling of Wanapum Reservoir in 1964 flooded the lower sections of the three fish ladders at Rock Island Dam, 61 km upstream from Wanapum Dam. To maintain fish passage under the new hydraulic conditions, the lower portions of the center and left bank ladder were rebuilt and a new sequence of spill patterns inaugurated. The effectiveness of these modifications was evaluated by comparing results from a series of tagging experiments conducted in 1964-65 on chinook salmon and sockeye salmon with the results of similar experiments in 1954-55 before Wanapum Dam was built. Three features -- travel time, the percentage of tagged fish observed, and the distribution of tagged fish by ladder -- were compared. These comparisons indicated fish passage over Rock Island improved substantially between 1954-55 and 1964-65. Tagged fish travelled over the dam in a shorter time (For chinook: 5.8 half days in 65 compared to 12.4 and 16.0 half days in 54/55; For sockeye: 3.8 and 3.3 days in 64/65 compared to 9.7 and 7.8 days in 54/55). Also, a higher percentage of the tagged groups were sighted passing over the dam in 64/65 (For chinook: 38% and 59% in 54/55 compared to 90% and 91% in 64/65; For sockeye: 67% and 79% in 54/55 compared to 91% and 94% in 64/65). These results indicate that at least until 1964/65 Rock Island Dam had problems in passing adults. In view of the information presented on comparative tag sightings it is likely that Rock Island formerly did not pass a significant number of fish even after construction of the third fish ladder.

Grand Coulee Dam permanently blocked fish runs from the Upper Columbia Basin. The mitigation plan designed by a Board of Consultants, composed of R.D. Calkins, W.F. Durand and W.H. Rich of Stanford University (Calkins et al. 1939) and referred to as the Grand Coulee Fish Maintenance Project, was to transfer the runs from above Grand Coulee Dam to the four tributaries immediately below the dam and to expand the resulting enlarged fish run in those streams to the full limit they would support. As the mitigation was all off site the, Upper Columbia Indian Tribes and Spokane area sports fishermen never received any compensation for the fish losses they suffered. Three hatcheries were included in the plan to supplement the runs of fish that were to be relocated. The four streams designated for relocation of the upper Columbia River fish were the Wenatchee, Entiat, Methow, and Okanogan rivers. The fish were trapped at Rock Island Dam and hauled by trucks to holding ponds and then released to the streams when ready to spawn (Grand Coulee Project History 1938-1944). These streams were selected for transplanted fish because they were historically excellent salmon-producing streams (Fish and Hanavan 1948). However, seven years after the relocation of fish, Fish and Hanavan (1948) stated:

> *"The relocation of fish runs occasioned by the construction of Grand Coulee Dam was an experimental operation on a vast scale. At the very outset, there was ample reason for doubting if the process of relocation, involving as it did the trapping, hauling, and impounding of adult salmon in large numbers, could be accomplished without at least a temporary decline in the production levels. As the program progressed, these doubts were increased by the substantial mortality of adult salmon, both in the hatchery holding ponds and in the more extensive natural holding areas.*

The U.S. Fish and Wildlife Service concluded in a report published in 1958 that *"despite several problems the relocation of Upper Columbia salmon and steelhead runs (transplanted to tributaries below Grand Coulee) in the years 1939-1947 to areas below Grand Coulee Dam was successful to a degree exceeding expectations."* They base this statement principally on the Rock Island Dam counts before and after the relocation project. Counts before the relocation project began typically ranged between 5000 to 10,000 chinook. After the relocation project, counts ran from 10,000 to 30,000. However, they did not consider that in the early years Rock Island Dam impaired passage of chinook salmon to a greater degree than in later years. If the corrected Rock Island counts (calculated above) are used, the counts before the relocation project range from above 24,000 to 78,000 fish. This would indicate that the runs to Rock Island actually declined after the relocation project.

This idea is reinforced by the following observations recorded by Koch (1976):

> *"Bryant and Parkhurst (1950) reported large chinook weighing from forty to sixty pounds historically migrating up the Columbia to spawn in the mainstem just below the outlet of Windermere Lake in British Columbia. Chapman (1943) reported large numbers of chinook spawning in the mainstem of the Columbia River below Kettle Falls in October, 1938. After the construction of Grand Coulee Dam these runs were then collected at Rock Island Dam for transplanting into the Wenatchee, Entiat, Methow, and Okanogan Rivers. However, the success of the transplant was far from complete because the large-sized fish are no longer present anywhere in the Columbia River."*

Since fish growth is linked to elements contained within the genetic program (Donaldson 1955, 1961; Hines 1976), the most likely explanation is that the transplants failed to become established and these genetic stocks are now extinct.

Three hatcheries were established for maintaining fish stocks in the Columbia below Grand Coulee on the Wenatchee, Entiat and Methow Rivers, and one was established at Ford to plant fish above Grand Coulee in Franklin D. Roosevelt Reservoir. The Ford trout hatchery stocked fish into the reservoir for approximately 2-3 years then stopped. No explanation was provided in the Grand Coulee project histories as to why stocking of the reservoir was stopped. The three salmon hatcheries met with extremely poor results and according to the Pacific Northwest Regional Commission (1976), " . . . *the hatcheries built to compensate for Grand Coulee failed to meet expectations.*"

Donald W. Moos, Director of the Washington State Department of Fisheries testified before the Senate and House Joint Public Works Appropriations Committee in May, 1975,

> *"Unfortunately, these hatcheries were plagued with numerous problems from the very beginning. The brood stock died before ripening, disease was rampant, fish food was costly and inadequate, sufficient water of proper temperatures was not available, and the hatcheries were never adequately funded. In short, these hatcheries never fulfilled their intended purpose, which was maintenance of the vast numbers of anadromous fish that had formerly spawned upstream of Grand Coulee Dam. By 1965, some salmon were still being reared and released, but the emphasis on production had changed to trout rearing."*

Meekin (1974) related that the Entiat Hatchery was converted to a trout hatchery, and that this hatchery raised trout for the Warm Springs Reservation in Oregon for a number of years. Again the Upper Columbia Tribes, whose fish these trout replaced, received no benefit.

These statements are borne out in the Grand Coulee project histories. For example the project history for 1941 (U.S. Bureau of Reclamation 1941) states that of 1422 fall steelhead transferred from Rock Island to Leavenworth, 560 died due to injury and fungal development. Of 1,071 spring steelhead, 755 died; and of 851 sockeye only 13 females survived. The 1942 project history stated that there were abnormal losses in all chinook, sockeye and steelhead. Problems were also noted with the survival of eggs. Given these sorts of problems it is unlikely that increases noted after the completion of the relocation project were actually related to the transfer of fish from the upper basin into the four tributaries. More likely the increase represents a natural fluctuation in the populations of fish native to these tributaries after a period of low abundance, and after some of the passage problems associated with early fish ladders had been fixed. This is the type of increase that could have also been expected in the upper basin above Grand Coulee had the dam not blocked salmon from this area.

4.5.4 Notes on the effects of dams on resident fish in the Upper Columbia Basin.

Some effects of the construction of the Spokane River Dams on the resident fish were noted in Sections 2.2.3 and 4.5.2. These dams severely damaged resident trout and whitefish.

Negative impacts of dam construction on resident fish in the Pend Oreille River have also occurred. The following is excerpted from a file of correspondence and fisheries statistics concerning the Pend Oreille River from about 1948 to 1985 that was located in the Washington Department of Game (WDG) Regional Office in Spokane, WA. The information in this file suggests that the Pend Oreille River at one time had a "blue ribbon" resident trout fishery. Coinciding with dam construction at the Albeni Falls, Box Canyon and Boundary projects, the trout declined and were replaced initially by squawfish. This occurred shortly after the construction of the dams. No decline in trout population was observed before their construction. More recently a large population of big (3-5 lb) largemouth bass has come into existence in the River, and the River is well known as one of the best spots in eastern Washington for catching large bass. The following excerpts, from information contained in the file, indicate how the Pend Oreille River has changed over time.

- May 15, 1949 letter from Don Earnest (WDG,Spokane) to Clarence Patuzke (WDG, Seattle). *"Rainbow in large numbers are being caught in the Pend Oreille River from fingerlings planted in 1946 and 1947. Most of these fish are now 17 to 18 inches in length. Many large fish are being taken. One rainbow had a dressed weight of 13 lbs 9 oz, length of 31 inches and girth of 20 inches. Such (good) stream survivals have not been found elsewhere. [Brown trout are also plentiful]."*

- October 1, 1952 letter from Don Earnest (WDG, Spokane) to Robert C. Meigs (WDG, Seattle) concerning potential impacts of Box Canyon Dam. *"From the damsite upstream for approximately 25 miles is found the majority of the riffle and fishable pool area of the entire Pend Oreille River. The elevation at Box Canyon is 1195 ft at low water (1943) and at Ruby 2023.5 -- a difference of 28.5 ft. The pool elevation of 2025 will inundate all the good riffle and pool area in the 25 miles of Box Canyon [including the section adjacent to the Kalispel Indian Reservation]. Fish populations of the Pend Oreille River are relatively heavy. Good populations of large rainbow, cutthroat and brown trout inhabit the riffle and pool areas principally. Whitefish are found in countless thousands throughout all riffle and pool areas...When Box Canyon Dam is built at least 75% of the best water in the Pend Oreille River will be destroyed as trout and whitefish habitat. The results of such impoundments are well illustrated in Roosevelt Lake. Prior to construction of Coulee Dam whitefish were very abundant. They are still (1952) below Coulee but only small remnants are found in Lake Roosevelt. Rainbow trout were found in all the faster water. At present the rainbow and cutthroat are restricted to the extreme upper portion of Roosevelt Lake where the river is still in relatively natural condition and good fishing is enjoyed only in this area."*

- Box Canyon Dam became operational in 1955.

- April 3, 1958, Metaline Falls Gazette. *"A 15 lb 8 oz rainbow caught in Pend Oreille River in the 1957 Field and Stream tournament. Also caught in this tournament were a 13 lb 9 oz rainbow, 9 lb 8 oz rainbow, 6 lb 8 oz rainbow and many large Dolly Varden."*

- In 1958 Don Earnest (WDG Spokane) felt that the river is *"a lost cause for trout and will be full of squawfish in a few years."* By 1961 the river was overrun with squawfish and few trout were being caught.

- July 17, 1972 Letter from L.G. Perry (USFWS Bureau of Sport Fish and Wildlife) to USDI (Portland). *"Box Canyon Reservoir . . . Formerly as the free-flowing Pend Oreille River, it provided a salmonid fishery of moderate to high value. Presently the reservoir supports primarily a spiny ray fishery that is largely unused."*

- April 19, 1973 Letter from R.R. Simmons (WDG) to Mr. Bob Bayless: *"Good fishing on the Pend Oreille River cannot be expected."*

- May 9, 1978 Letter from Ray Duff (WDG, Spokane) to Dave Gufler (WDG, Olympia). *"Box Canyon Dam was completed in 1955. Prior to impoundment, the free-flowing Pend Oreille River offered some fair trout angling, which according to our records, diminished shortly after completion of the dam. Most recently, the bass fishery has received considerable interest (from Spokane bass clubs). A primary concern to many has been the water fluctuation occurring during June, which is the peak spawning period for the Pend Oreille River bass population. Shallow flooded areas are essential for reproduction. Stable water levels would be helpful. To my knowledge, no efforts were made by the department to mitigate lost resources as a result of Box Canyon Dam construction. I believe Box Canyon Dam was built by the Pend Oreille County P.U.D. and Albeni Falls by U.S. Army Corps of Engineers. I further believe that neither impoundment has been used for flood control, only power generation."*

In these documents no other causes for fish declines are mentioned. Logging, mining, pollution, etc. are not mentioned as affecting the area between Box Canyon and Albeni Falls Dams. A mine was present at Metaline Falls, downstream from Box Canyon.

Creel census data collected from 1946 to 1985 by the Washington Department of Game clearly demonstrates a dramatic decline in the trout and whitefish fisheries of the Pend Oreille River coinciding with the operation of Box Canyon Dam in 1955. Before 1958, principal species caught were cutthroat trout averaging 10-14 inches, rainbow trout averaging 10-14 inches, whitefish averaging 12-14 inches and occasionally large brown trout. Within five years of completion of the dam, squawfish were the predominant fish in the catch and trout were rarely caught. During the past 10 years eurasian milfoil has become a problem in the Box Canyon Reservoir. Since this aquatic macrophyte does not grow well in free flowing water, the problem can be attributed to reservoir conditions caused by construction of Box Canyon Dam.

On the Kootenai River System, Duncan Dam, constructed on the Lardeau River on the North Arm of Kootenay Lake, was completed in 1967. Results of an enumeration program conducted in 1964 showed that over 4 million kokanee spawn in the Lardeau River, of which 2.8 million would be prevented from reaching their normal spawning areas by construction of Duncan Dam (Northcote 1973). Additionally, several hundred large Dolly Varden spawners migrated up the river annually before the dam was constructed.

Libby Dam in Montana has impacted the Kootenai River in Idaho. In Montana, some species of resident salmonids have acutally benefited from building of this dam. However, in Idaho it is generally recognized that the impacts are largely negative such as impeding the migration of sturgeon and large rainbow from Kootenay Lake to the Moyie and Yak Rivers and Kootenai Falls. Hydropower peaking also causes problem for Idaho fisheries. As pointed out in a preceding section (Section 2.4.3) Turney-High (1941), Schaeffer (1935, 1940), Brunton (1968), and Walker (1985) described how the Tribe had developed sophisticated resident slough fisheries, requiring weirs and traps, that were dependent on fluctuating water. At Bonners Ferry, for example, weirs were set up across sloughs, which filled with trapped fish during subsidence of annual spring flood. Regulated water flows for flood control after construction of dams are damaging to the conduct of this type of resident fishery. Although it can be argued that this loss could be attributed to the flood control aspect of the dam, it is important to remember that water stored from the spring flood is used for hydropower generation. One should also be cognizant that water stored in flood control impoundments firms up and produces power downstream (see section 5.1 for additional details). Therefore, a portion of this loss should be assigned to hydropower. In this connection it is also important to note that it is unlikely that the flood control dams would have been built without the associated benefits of hydropower production, because it was envisioned that hydropower revenues would pay for the cost of the dam.

At Lake Coeur d'Alene, flooding, caused by impoundment of the lake by Post Falls Dam, damaged some of the more important resident fishing sites on the Coeur d'Alene Reservation (See section 2.2.3 for details).