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Recovery Issues for Threatened and Endangered Snake River salmon Technical Report 1 of 11

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HABITATS OF WEAK SALMON STOCKS OF THE SNAKE RIVER BASIN AND FEASIBLE RECOVERY MEASURES

Recovery Issues for Threatened and Endangered Snake River Salmon Technical Report 1 of 11

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EXECUTIVE SUMMARY

This report describes spawning aggregations of Snake River salmon listed under the Endangered Species Act, and numerical status of aggregations. It summarizes habitat quality and problems betwen the natal area and the open ocean. It reviews critical habitat designation, identifies mitigative measures and suggests monitoring and research.

Sockeye salmon of Redfish Lake now appear supported in part or wholly by a residual 0. nerka . Several hundred such fish were found in November 1992.

Fall chinook upstream from Lower Granite Dam differ from upper Columbia River fall chinook and from spring/summer chinook, but no evidence establishes that naturally-spawning fish between Lower Granite and Hells Canyon Dams differ genetically from Lyons Ferry fall chinook or from chinook that spawn between Lower Granite and Ice Harbor dams. Fall chinook upstream from Lower Granite Dam have declined in recent years to precarious status. Temperatures in tributaries to the Snake River may not favor establishment of fall chinook populations there. The lower Clearwater may offer an exception because of moderation by Dworshak outflow.

Spring and summer chinook differ from Snake River fall chinook and from all other groups of chinook salmon. Separation of the spring and summer groups does not appear biologically useful or appropriate, and we term them spring/summer chinook in this report. Inadequate information on discrete spawning aggregations exists to define possible evolutionarily significant units. Status of various index populations will help managers evaluate trends in diverse groups. Spring/summer chinook index groups increased after the low levels of the late 197Os, then declined after 1988, reflecting drought effects.

Habitat quality in the Snake River Basin has declined historically. Current quality does not permit maximum smolt production from escapements at Lower Granite Dam.

U.S. Forest Service and Bureau of Land Management allotment management plans do not meet the constraints of modem Forest Plan Standards and Guidelines or Land Use Plans, respectively. Major gains in salmon habitat quality in grazing areas require appropriate planning. With such planning, mitigation can permit cattle grazing. Mitigation will require changes in grazing intensity, pasture management, timing of grazing, and fencing as needed.

Irrigation water withdrawals reduce instream flows in the upper Salmon River, and in the Imnaha and Grande Ronde rivers. Some tributaries carry no flow by early summer. Irrigation return flows can deliver water of low quality to the receiving stream. They can reduce fish access to spawning, rearing, and overwintering areas.

Creative purchase of water rights, conservation, management of flood control rule curves, and use of hydro storage theoretically could add about two million acre-feet to the Snake River discharge downstream from Hells Canyon Dam. A more realistic estimate is that somewhat over one million acre-feet might be made available. The

lower amount could add about 4,500, 6,400, and 5,900cfs to the respective April, May, and June mean discharges at Clarkston, Washington, in an average flow year. Although the augmented flows would not approach demands by fish managers for 140,000 cfs, they offer potential for water budgeting for the smolt migration period. Effects of augmented flows from Hells Canyon Dam on juvenile fall chinook ecology are unknown.

Irrigation screening has never been evaluated to determine whether fish saved from death sufficiently offset loss of rearing downstream in ditches downstream from screens. Agencies have assumed benefits. Screens operate on about 200 of 220 irrigation diversions on the Salmon River upstream from the North Fork Salmon. Only one, on the Lemhi River, meets modem screen design criteria.

Timber harvest remains unevaluated in the Snake River Basin with respect to overall effects on salmon. Much uncertainty remains about response of salmonids to timber harvest. Rest Management Practices (BMPs) available today can prevent habitat damage. Some sensitive areas of gentle slope can support logging without damage. Some already-roaded areas can support zero-impact logging. Some unroaded areas can only be harvested with helicopters. Managers should not support logging or roading in sensitive soils, gradients, and aspects.

Mining damage has seriously damaged or eliminated fish production in some drainages. Damage will continue. Sudden failures of existing tailings ponds remain a threat.

Juvenile spring/summer chinook require substrate interstices or undercut banks for winter cover. Overwinter survival of juvenile chinook in the Snake River Basin has been lower than that in other Columbia Basin tributaries. Survival from fall to arrival in spring for Salmon River PIT tagged presmolts has ranged from 5 % to 31%. The latter estimate is derived only from recoveries at weirs in Crooked River and in the Upper Salmon. For data derived from recoveries at Lower Granite Dam or at the head of Lower Granite pool, overwinter survival has ranged from 5% to 14%. Thus, modelers must define “smolt” when they specify egg to smolt or parr to smolt survivals. Overwinter survival in other tributaries of the Columbia River have ranged from 16% to 52%. All overwinter survivals for the Snake River Basin derive from drought years, and may not reflect average water years.

Releases of hatchery salmon and steelhead upstream from Lower Granite Dam have reached 18 to 25 million smolts, while smolt abundance in the early 1960s equaled less than 6 million. Fifty to sixty percent of the “smolts” do not survive to reach Lower Granite Dam. PIT tag data demonstrate that an important portion of the mortality occurs before hatchery smolts reach Lower Granite pool. Presence of many millions of non-viable and viable hatchery smolts in the migration corridor, bypass systems, and transport vessels has unknown effects on weak wild stocks. Interactions of residualized steelhead and subyearling fall chinook are unknown.

Project mortality estimates in the migration corridor in the 1970s are likely inappropriate for presently-configured dams. They ranged from 15% to 45 % per project. PIT tag interrogations of fish tagged and released from the Snake River trap, together with estimated fish guidance efficiencies, can provide data for estimates of current project mortalities. We estimated average project losses of about 7% for the reach from turbine intakes at Lower Granite Dam to the bypass collection facility at McNary Dam. We estimated mortality in Lower Granite pool as 29%, and regard the loss estimate as reflective of lack of physiological readiness to migrate, in part. Tagged fish took a median of about 8 days to reach the dam, while actively migrating smolts should take but 3 or 4 days to pass the pool. We could not use PIT tag data to estimate survival downstream from **McNary** Dam.

Bypass systems can descale and injure or kill smolts. Delayed bypass effects can kill smolts. Carcass counts in bypass collection facilities cannot serve to assess total bypass-related mortality. Recent studies indict predation on concentrated streams of fish downstream from bypass outfalls as an important cause of mortality. Time and place of delivery of bypassed (or transported) smolts are critical.

Several workers consider the first few months after smolts arrive at the estuary as very important in affecting survival to adulthood, hence recruitment and escapement. Most spring/summer chinook from the Snake River arid sockeye from the Columbia River seem to turn north promptly after leaving the Columbia River. At least some individuals have used inshore areas as far north as Prince William Sound in Alaska. One sockeye, tagged about 500 miles south of Kodiak and about 1,500 miles northwest of Astoria, returned to the Columbia River. Most ocean-type chinook (e.g., Snake River fall chinook) probably do not disperse more than about 1,000 km into the sea, and tend to use inshore areas more. Several workers consider that a potential exists for ocean density dependence and species interactions that would reduce adult recruitment or size.

Low flows in recent years have reduced stream habitat quality for overwintering fish. Lack of snow bridging and grazingdepleted riparian cover have left stream areas open to the atmosphere. Survival of overwintering presmolts and incubating embryos were likely reduced. Low fall and spring flows concentrated predators and wild salmon prey. Low flows also concentrated wild and hatchery fish in the migration corridor. Drought-year flows in rearing and free-flowing river migration areas exacerbated mortalities, already high because of hydro-caused losses in the migration corridor.

The Columbia River estuary now provides less habitat than formerly. Storage reservoirs have much reduced river flows in spring and summer, and decreased turbidity. Massive hatchery releases, probably coupled with growth of exotic shad populations, have increased prey availability and provided areas where predators can find concentrated streams of prey.

We recommend that critical habitat designation for listed salmon include the spawning/rearing areas, entire migration corridor, estuary, and North Pacific Ocean. I included the marine environment because of potential for managers to manipulate salmon numbers and non-salmonids in ways that could reduce growth and survival of Snake River salmon. We recommend critical habitat designation for the Snake River Basin upstream from Hells Canyon Dam, the North Fork Clearwater River upstream from Dworshak Dam, and upper Columbia River storage reservoirs. All of these areas influence limnological conditions in the migration corridor used by ESA listed salmon.

We recommend extensive efforts to improve quality of habitats. We ask for accelerated purchase of water rights and creative water conservation. We suggest modernization and monitoring of irrigation screens. We recommend accelerated completion of modem allotment management plans for grazing. We recommend against construction of instream structures to improve habitat for salmon, believing that managers should emphasize land husbandry first. Worth of instream structures has not been demonstrated. We place high priority on environmentally safe mining and intensive monitoring and mitigation to protect streams from existing tailings and mine waste. We recommend application of stringent BMPs in timber sales and harvest.

We emphasize the importance of PL 92-500, the Clean Water Act, as a mitigative and enforcement tool. It can assist managers in efforts to protect and improve salmon habitat, but has not been used to full potential.

We suggest that major reductions in output of hatchery salmon and steelhead would could improve survival of wild fish. Numbers of hatchery fish released in the migration corridor have gotten out of hand. Over half do not reach Lower Granite Dam.

We recommend intensive and accelerated habitat monitoring, and improved monitoring of redd abundance in index areas so that managers will not rely on escapements at Lower Granite Dam to determine the status of spring/summer chinook.

We recommend cost:benefit analysis of the irrigation screening program, comprehensive evaluation of bypass-related mortality at hydro projects, and a new program to assess reach and project survivals with PIT tagged smolts. We suggest increased research on overwintering survival, intra- and inter-specific interactions in the migration corridor, and intensive work on survival of transported and non-transported subyearling fall chinook. We recommend intensive work on survival and homing of hatchery fish transported as smolts directly to transport barges or downstream from collector dams. We suggest research on estuarine ecology of salmon.

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1. INTRODUCTION

This report, prepared for S. P. Cramer and Associates, discusses critical habitat and possible corrective measures for habitat problems of fall chinook (Oncorhynchus tshawytscha) spring and summer chinook (also O. tshawytscha), and sockeye salmon (O. nerka) listed'under the Endangered Species Act. We describe spawning aggregations, so far as available research permits, and review numerical indices of the status of various aggregations. We summarize habitat quality and problems in natal areas and in the migration corridor to the sea. We review the definition and alternatives for designation of critical habitat for listed salmon. We identify mitigative or restorative measures. Finally, we suggest monitoring and research.

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2. REPRODUCTIVE UNITS

2.1 SOCKEYE SALMON

Sockeye salmon in the Snake River Basin once occupied Wallowa Lake, Payette lakes, and the Stanley Basin lakes including Redfish, Alturas, Stanley, Yellow Belly, and Pettit lakes (Bjornn et al. 1968, Chapman et al. 1990, Evermann and Meek 1896, and Evermann 1897). Sockeye may also have used Hell Roaring Lake and Warm Lake. The great distance of the Stanley Basin from Lake Wenatchee and Lake Osoyoos in the Columbia River system very likely isolated the Stanley Basin 0. nerka .

Irrigation dams extirpated sockeye runs to Wallowa and Payette lakes, although kokanee are common in both lakes. Irrigation withdrawals from Alturas Lake Creek extirpated sockeye in Alturas Lake in the early1900s, although residual sockeye may remain, as do kokanee. The Idaho Department of Fish and Game (IDFG) eliminated sockeye in Pettit, Yellow Belly, and Stanley Lakes in the 1955-1965 period, and constructed permanent barriers to their reentry. Outlet barriers at Warm Lake probably eliminated any sockeye use (T. Welsh, personal communication). Only Redfish Lake remained accessible to sockeye.

Sunbeam Dam, built in 1909-1910, denied all anadromous fish access to the upper Salmon River Basin for at least 10 years (IDFG 1920). Although a fish ladder was built at the dam in 1919, fish passage remained unlikely until the early 1930s (Chapman et al. 1990, Locke 1929). Hauck (1955) reported sockeye reestablishment in Redfish Lake by the early 1950s.

Cramer (1990) chronicled events leading to the extinction of sockeye at Wallowa

Lake. Heavy exploitation probably began in 1880, soon followed by use of unscreened irrigation diversions. Hatchery racks were installed downstream, intercepting sockeye runs. Finally, a dam was constructed to store water in the lake. The run was considered extinct by 1905.

The origin of sockeye that reestablished themselves in Redfish Lake remains uncertain. Possible genetic sources include residual sockeye or kokanee. Sockeye spawn in October (Bjomn et al. 1968) in lake shoals, and kokanee in August and September in Fishhook Creek (Brannon et al. 1992), an inlet to Redfish Lake. Recent surveys by snorkelers located a few 0. nerka in Redfish Lake that had the appearance and later maturation timing of beach-spawning sockeye (Shiewe 1993). A residual sockeye population may have founded the sockeye of Redfish Lake after the 1920s. Other founder explanations, such as continued passage at Sunbeam Dam or perpetuation of sockeye by stream-rearing sockeye downstream from Sunbeam Dam for several generations, remain too difficult to accept (Chapman et al. 1990).

Brannon et al. (1992) offered data that suggested that more than one deme of kokanee exists in Redfish Lake. Welsh (1991) summarized the kokanee stocking history of Redfish Lake, and discussed origins of the October beach-spawning sockeye that Bjomn et al. (1968) noted:

> *"Redfish Lake received periodic stockings of kokanee from unknown sources until 1945 or perhaps later. The fish stocking records from 1946 to 1950 are missing from the Idaho Department of Fish and Game library. In 1962, Redfish Lake was stocked with 43,251 late spawning kokanee from North Idaho. Fishhook Creek was stocked with 50,344 early spawning kokanee from an unknown source in 1971 (Bowler 19%). However, the Fishhook Creek stocking is listed as Anderson Ranch Reservoir stock in Hall-Griswold (19%). The Anderson Ranch stock originated from Island Park, North Idaho and British Columbia kokanee stocked in Anderson Ranch Reservoir between 1964 and 1967.. . . Early reports (late 1800s) of sockeye salmon spawning in Fishhook Creek all indicate mid-August spawning time.. . . Reports from the post-Sunbeam Dam era (1940s-1950s) all indicate October spawning in Redfish Lake, mostly along the east shore at Sockeye Campground. It seems implausible that the early settlers and miners would have overlooked thousands of sockeye salmon spawning in shallow water in Redfish Lake in October. Obviously, the early spawning sockeye salmon stock was lost in the Stanley Basin lakes and replaced with October shoal spawners.... . The late spawning sockeye salmon must have evolved from the various stockings of kokanee (or perhaps sockeye salmon) fry from 1921 into the 1950s."*

Landlocked salmon were placed in Stanley Basin lakes, including Redfish Lake, as early as 1921 (IDFG 1924). The last two sentences of the foregoing quote may require some modification. Schiewe (1993) states that genetic data gathered from kokanee and adult sockeye in 1991 argue against the kokanee origin of Redfish Lake sockeye. A sample of kokanee that spawn in Fishhook Creek differed from a sample of outmigrants from the lake. A gene pool other than that in Fishhook Creek must have produced the 1991 migrants. Schiewe (1993) notes that in November, 1992, a number of 0. nerka were found that appear to represent a residual sockeye population. The population may consist of a few hundred individuals, based on very cursory surveys. The degree to which late-spawning kokanee from introductions may have contributed to the residual group of fish is unknown.

Brannon et al. (1992) reported that Redfish Lake sockeye in the late 1800s spawned in Fishhook Creek. They stated that it is likely the present kokanee population in Fishhook Creek offers the best representatives of the former Fishhook Creek sockeye population, which apparently spawned in August at the same time as kokanee. The extent to which introduced kokanee genes altered the Fishhook gene pool is unknown. Wardens planted exotic kokanee in Fishhook Creek in the early 1920s.

Differing from resident 0. nerka in Idaho lakes, Wallowa Lake kokanee do not have anadromous tendencies. Irrigation ditch traps that fished during 1948-1988 captured no sockeye smolts in the Wallowa River. No adult sockeye have been sighted in the Wallowa River since 1903 (Cramer 1990). However, many adult kokanee move into the Wallowa River in fall, and spawn in irrigation canals and in the river, in the Lostine River, and in Bear Creek. One spawning kokanee was observed in the Wenaha River.

2.2 FALL CHINOOK

Fall chinook once spawned in the lower Tucannon River (D. Park, personal communication), and in the entire Snake River from near Ice Harbor damsite to near Twin Falls, Idaho. Mainstem Snake River reservoirs now cover areas formerly used for spawning in the lower Snake River. Hells Canyon Dam blocks fall chinook passage to upriver areas. The reach from the head of Lower Granite pool to Hells Canyon Dam remains accessible for spawning. Fall chinook probably spawn in tailraces of some or all Snake River dams. A few fall chinook spawn in some years in the lower Grande Ronde and Imnaha Rivers. Genetic composition is unknown.

Thompson and Haas (1960) recorded populations of October spawning chinook in the Grande Ronde Basin. Field surveys were made 1964- 1970 in some areas where these fish were reported and no redds or fish were observed (Witty 1964-1970). October spawning would fall between timing of late summer chinook and early fall chinook. Planning for the Northeast Oregon Hatchery Program (NEOH) has included facilities and a management plan for October spawning chinook. A major question to be answered is whether the listing of Snake River chinook under ESA would allow the reintroduction of October spawning chinook into the Grande Ronde Basin. The Nez Perce Tribe plans to ask this question in a Grande Ronde Basin genetic risk assessment under the auspices of NEOH (D. Bryson, NPT, personal communication).

Fall chinook of the Snake River differ genetically from those of the upper Columbia River (Utter 1982, Bugert et al. 1990). The difference is relatively small in comparison to the difference between Snake River spring/summer groups and fall chinook.

Research has offered no evidence to date that naturally-spawning fall chinook in the area upstream from Lower Granite pool differ genetically from the fall chinook population cultured at Lyons Ferry Hatchery, or from any tailrace-spawning fall chinook in the lower Snake River. However, until electrophoretic or DNA samples become available, one must entertain the possibility that the Lower Granite to Hells Canyon population differs from all other Snake River groups.

2.3 SPRING AND SUMMER CHINOOK

As noted above, wild Snake River spring/summer chinook, and in fact hatchery spring/summer chinook, differ genetically from Snake River fall chinook, and from all other groups of chinook salmon. They have high frequencies of the same common alleles, and low heterozygosities relative to most other populations of chinook (Utter et al. 1989, Winans 1989).

The Idaho Department of Fish and Game lists Idaho streams "identified as being used for spawning by salmon and/or steelhead" with separate lists for the two species. Salmon spawning stream segments totaled 373, and the list appears to include many streams that do not support salmon spawners. Examples include tributaries upstream from the falls on the Little Salmon River, which lie downstream from New Meadows. Other streams that would not support spawning include Bumtlog, Trapper, and Riordan Creeks on lower Johnson Creek. The list does not assist in defining reproductive units.

Waples et al. (1991) concluded that summer chinook salmon in the drainage are genetically most similar to spring chinook salmon and that upper Columbia River summer chinook (ocean annulus) are more similar to upper Columbia River fall chinook than to Snake River summer chinook (stream annulus). Waples et al. could not determine whether spring and summer chinook from the same stream are more closely related to each other than to fish of the same run timing in other drainages. "Summer" chinook of the South Fork Salmon River did not differ significantly from "spring"chinook in other large drainages with respect to spawning time.

In 1962, the IDFG began investigating the differences between stocks of chinook in the upper and lower Salmon River drainages (Ortman and Richards 1965, Bjomn et al. 1963). They used timing of arrival of adult fish in Idaho streams, coupled with tagging in the lower Columbia River, to class early arrivals as spring chinook and late ones as summer chinook. Before 1962, the spawning ground reports referred to the runs of chinook salmon in the Salmon and Weiser River drainages as "spring chinook" (Richards and Gebhards 1959).

Bits of information from marking studies indicate that both spring and summer run chinook use the Grande Ronde and Imnaha basins. Low water flows caused by irrigation diversions may restrict summer run passage in some tributary streams of the Grande Ronde such as Bear and Catherine creeks. There is no information to indicate that spring and summer chinook spawn in different areas of any stream.

The IDFG spring and summer designations appear to have little biological merit. They may lead to lay misinformation by picturing less complexity in the spectrum of reproductive units than actually exists. The NMFS seems justified in combining spring and summer chinook at Lower Granite Dam (LGR) into one group for Endangered Species Act (ESA) listing. Writings (e.g., Mallet 1974) have tended to cement the arbitrary separation:

"Spring chinook salmon enter the Columbia River in late March, April, and May and spawn in August and early September. Summer chinook salmon enter the mouth of the Columbia River in June and July and spawn in September. Spring and summer chinook eggs hatch in December and fry emerge from the gravel in February and March. .

In fact, "spring"chinook continue to spawn in the Lemhi River in mid-September. "Summer" chinook in Stolle Meadows begin to spawn August 15. The normal peak of both "spring" and "summer" chinook fry emergence centers around the first week of May. The colder high tributaries require an earlier onset of spawning than do the warmer, somewhat lower ones. Early-migrating chinook spawn higher in the Snake River Basin than do later-migrating chinook.

One may infer, or at least speculate about, the degree of colonization and reproductive isolation of tributary spawners by examining the movements of newly-emerged chinook fry in early work on re-introductions of chinook to barren areas of the Clearwater River (Welsh 1962). In the absence of indigenous chinook, the only fry present in the Selway River originated from the egg plantings in Bear Creek and the upper Selway River. That work revealed that emerging salmon fry from eggs planted in Bear Creek and the upper Selway River migrated downstream as far as Selway Falls for summer rearing (40 miles). Subyearlings in Bear Creek also migrated upstream a mile or two from the egg planting site. When adults from the planted eggs returned, some spawned in Moose Creek, where IDFG did not plant eggs. Spawners either derived from fry that moved downstream a total of 14 miles (3 in Bear Creek and 11 in the Selway River), then upstream 3 miles to the prime spawning areas on Moose Creek, or they strayed to Moose Creek. A review by Chapman et al. (1991) found a high degree of homing in spring chinook. Spawning chinook in Moose Creek likely had reared there as juveniles.

From the Selway studies, one should probably infer that naturally-spawned or wild chinook fry move upstream to some degree, but can drift downstream many miles. If that inference is correct, some of the emergent salmon fry from Stolle Meadows on the South Fork Salmon River would rear far downstream in the Poverty area. Some fry from upper Big Creek (a "spring chinook" area) would rear in lower Big Creek (a "summer chinook" zone). Chinook from the upper Salmon River would probably rear as far down as Clayton, a "summer chinook" area.

Channel gradient and water velocity may dictate the magnitude of downstream movement. Degree of intraspecific interaction may influence it. In steep streams, fry that emerge at dusk may easily drift downstream 20 to 30 miles in one night. In flat-gradient streams during summer, fry may move two or three miles upstream from the emergence area. In flat streams, or in years of small spring discharges, fry may move downstream but short distances.

Downstream drift of newly-emerged fry in the Middle Fork Salmon River to the extent of movements in the Selway River (Welsh 1962) could place juveniles from, say, Sulphur Creek (RM 94.5), in the Middle Fork Salmon River downstream from, or in the lower end of, Pistol Creek (RM 74) or Rapid River (RM 78) or Marble Creek (RM 63). Marsh Creek (RM 106.5) fish could easily drift to Sulphur Creek, or move upstream into

Bear Valley Creek. Fish from Loon Creek (RM45.5) could drift to Camas Creek (RM 35) and Big Creek (RM 18). Fish from the upper Imnaha River could rear in the middle or lower reaches of the river. Where fry rear for extended periods, perhaps to late fall, in water of another tributary, either upstream from the mouth or in the tributary plume, one must ask whether those fry wilI return to the natal stream or to the rearing stream. Work on reintroduction of chinook to the Selway drainage would suggest that some, at least, likely spawn out of the natal stream.

Upstream colonization can occur quickly. For at least 10 years, chinook salmon could not pass Sunbeam Dam (IDFG 1920). The chinook that formerly spawned upstream in Alturas Lake Creek, the headwaters of the Salmon River, Valley Creek, Champion and Fourth of July creeks, Pole Creek, Frenchman Creek, etc., had to spawn downstream from Sunbeam Dam, either in the main Salmon River or in tributaries. Once they could pass Sunbeam Darn (probably sometime in the 192Os), they recolonized the upper Salmon River very quickly (W. Platts, personal communication).

Salmon can shift "traditional" spawning areas to some degree. Blocked salmon at Sawtooth weir responded by using portions of the Salmon River downstream from the weir. W. Platts (personal communication) states that areas now used by these fish received little attention from spawners before construction of the weir.

These behavior patterns help explain recolonization of streams after severe fire, and may help to explain the apparently small differences in electrophoretic patterns of chinook. They raise the question: *"what is a 'more or less reproductively isolated' unit?"*

Would "summer" chinook of lower Big Creek use "spring" chinook areas of upper Big Creek if all "spring" chinook disappeared suddenly from upper Big Creek? Assuming fish escape to lower Big Creek, we think that colonization of upper Big Creek would occur rapidly, perhaps within ten years. Upstream movement of fry from lower Big Creek, and subsequent rearing to the pre-smolt stage would play a role. Although chinook inherit their spawning timing, we suspect that in the group of "summer" chinook, some will spawn relatively early, hence could use more upstream zones with adaptive timing. Among the "summer" chinook with relatively late spawning time, a few will stray upstream into upper Big Creek. Their progeny may emerge somewhat later than they should, yet some early-emerging ones will survive to return to the natal area. Within a few generations, timing of spawning in the poppulation of upper Big Creek may again tune to the appropriate emergence time.

The foregoing speculation leads us to suggest that we should expect very small, perhaps undetectable, differences in the electrophoretic or DNA analysis of "spring" and "summer" chinook from the same tributary (e.g.,Big Creek, Loon Creek, Imnaha River, Camas Creek). We also suggest that one should not view reproductive isolation, as envisioned in the ESA, as very definitive between geographically adjacent tributaries within, say, the Middle Fork Salmon River. If we desire to subdivide the Lower Granite spring/summer chinook ESU, we may find that we can define no more discrete Evolutionarily Significant Units (ESUs) than, for example, Imnaha River, South Fork Salmon River, Secesh/Lake Creek, Johnson Creek, upper Middle Fork, and lower Middle Fork. On the other hand, Allendorf (1991) pointed out that samples from two tributaries of the South Fork Salmon River (Johnson Creek and Secesh River) had genetic variation at 11 loci. Allendorf emphasized that these data demonstrate the importance of recognizing the existence of independent population segments within the aggregated ESU. While not disagreeing with Allendorf, we note that the Secesh River and Johnson Creek lie separated by about 13 miles of the relatively warm East Fork of the South Fork, and that the main South Fork Salmon at the Secesh River mouth is probably too warm for summer rearing. Thus, this area differs from the Middle Fork Salmon or upper Selway, which more likely would support summer rearing by chinook in their main stems; fish that drifted long distances from upstream.

PIT-tagged wild chinook from various tributaries arrive with somewhat different timing at Lower Granite Dam (Chapman et al. 1991). This may argue at least for genetically different reproductive units in different drainages. It may also reflect environmental influences, such as tributary temperatures.

In any event, we may never have sufficient information to designate all potential ESUs for stream-annulus chinook in the Snake River Basin. This does not imply that managers should evaluate the performance of the Lower Granite stream-annulus ESU on the basis of escapements for aggregated Snake River wild fish. Managers will need to use index areas to assess the status of disaggregated portions of the Lower Granite ESU. This will help ensure that unknown discrete groups have opportunities to express their genetic potential.

It is also possible that electrophoretic and DNA evaluations will prove our speculation incorrect. Those assessments may find that many reproductively-isolated groups exist. They may, however, not define all such units in the Snake River Basin, so that managers will still have to rely upon the status of index populations to protect unknown ESUs.

Designation of stream-annulus chinook as “spring” and “summer” does not seem useful or appropriate. We refer in this report to “spring/summer chinook,” conforming to the NMFS ESU designation.

3. STATUS OF REPRODUCTIVE UNITS

3.1 SOCKEYE SALMON

Sockeye passage at Ice Harbor Dam has varied widely, but declined sharply after 1976 (Figure 1). Only four adults returned to Redfish outlet trap in 1991 and one in 1992. The IDFG incorporated these adults in a culture program rather than permitting them to spawn naturally.

While Snake River sockeye declined sharply, Columbia River sockeye have sustained themselves (Figures 2 and 3). Snake River sockeye pass 8 dams, Wenatchee River sockeye pass 7, and Okanogan sockeye transit 9 projects (Figure 4). One cannot definitively explain why. Several possible hypotheses could provide useful clues. The Columbia River carries about one-fourth to one-third as many yearling or older hatchery smolts as does the Snake River. Fishery agencies release ten-fold more steelhead from Snake River hatcheries than from mid-Columbia River hatcheries upstream from Priest Rapids Dam. The flow of the Columbia River in spring substantially exceeds that in the Snake River. Fish deflection screens, vertical barrier screens, and bypasses are not present in the Columbia upstream from the mouth of the Snake River, but were present in the two uppermost Snake River dams during the rapid decline of the Snake River sockeye. Sockeye suffer more damage in bypass systems than do other spring migrants. Reservoir volumes in the Snake River exceed those in the Columbia River. Finally, sockeye of the Stanley Basin may have originated from residual sockeye after the 1920s, while Columbia River sockeye have had continuous access to the sea and to their natal areas. Residual 0. nerka may not contain genes as viable as Columbia River nerka for the rigors of anadromy. Some or all of the foregoing factors, or variants of them, may explain the demise of Snake River sockeye.

3.2 FALL CHINOOK

Fall chinook passage, as counted at Ice Harbor Dam, declined from 1968 to 1976, remained low but stable through 1985, then increased slightly (Figure 5), likely in response to stimulation from Lyons Ferry Hatchery and straying from the Umatilla and Columbia Rivers (Chapman et al. 1991). Adult counts at Lower Granite Dam, available since 1975, have ranged from about 350 to 1,000, and for the most recent five years averaged about 600 fish (Figure 5). High harvest rates certainly reduce the escapement across Lower Granite Dam and subsequent redd counts. In the late 1980s, ocean harvest equaled about 35 % and river harvests took 44-63% of the inriver run, thus total harvest took nearly 75% of adult recruits (Chapman et al. 1991). Rates have declined to perhaps 60% in the last year or two. This is the only listed Snake River salmon with high harvest rates.

Hatchery fish from Lyons Ferry and upriver bright fall chinook from Umatilla and the Hanford Reach have contributed to the escapement at Lower Granite Dam. They may or may not have spawned in areas separate from wild spawners, if any of the latter can be said to exist as a reproductive unit. Some estimates have indicated that less than 50% of the run has consisted of naturally-produced fall chinook. Radio-tagged fall chinook in the Snake River wander and fall back across dams after they pass fishways (Mendel et al. 1992). Fallback may be as high as 50%. We do not know if the behavior of radio-tagged fish typifies that of wild fall chinook (if, indeed, wild fish can be said to persist discrete from Lyons Ferry fall chinook). The results illustrate that dam counts in the Snake River do not provide accurate information on either interdam losses or escapement. They may help explain the high adult:redd ratio assessed from knowledge of numbers of fish that pass LGR and redd surveys. Finally, they may indicate that the numbers of naturally-spawned or wild fall chinook estimated for the LGR escapement are too high.

Snake River fall chinook salmon spawn from Hells Canyon Dam to the head of Lower Granite pool. Capture of newly-emerged chinook fry in downstream pools supports the opinion that adults spawn in the tailraces of one or more mainstem Snake River dams. The pre-dam population of fall chinook salmon spawned from near the mouth of the Snake River to Hells Canyon and upstream in the Snake River as far as Twin Falls. Spawning was widespread in the lower Snake River (see Mains and Smith

1964, BCF 1960) [1], so the necessary substrate was present. Upriver bright fall chinook in the Columbia River spawn in depths over 30 feet where velocities and substrate permit (A. Giorgi, personal communication, Chapman et al. 1985, Swan et al. 1988). Tailraces should provide suitable velocities for some distance downstream from the dams from which they issue.

A few fall chinook salmon have spawned from time to time in the lower Clearwater, Imnaha, and Grande Ronde Rivers. The contribution of this spawning to brood-year recruitment has not been demonstrated. Data in Amsberg et al. (1992) suggest that the use of the lower Clearwater River by fall chinook salmon may have increased recently, possibly because of the higher water temperatures of Dworshak Dam releases (Amsberg et al. 1992). Stray fall chinook from areas other than the reach upstream from LGR may contribute to the increase. Historical information does not support presence of a fall chinook run to the main Clearwater River. Fall chinook may conceivably have used Potlatch Creek [2].

The reason for inability of fall chinook to colonize the lower reaches of the Salmon, Clearwater (pre-Dworshak Dam), Grande Ronde, and Imnaha rivers may involve temperatures. The Snake River accumulates temperature units for emergence earlier than do the other streams (see Connor et al. 1992). It also did not and does not suffer the severe icing and breakup that occurred in some years in the other rivers.

Early emergence of fall chinook in the Snake would permit subyearlings to grow rapidly enough to reach the largest possible size before temperatures in the main Snake River became too high. Early emergence and rapid growth would also permit Snake River fall chinook to enter the sea at large size. Connor et al. (1992) showed that juvenile fall chinook move away from nearshore areas as they reach a threshold size, probably near 80-90 mm. This size somewhat exceeds the size at which fall chinook appear to depart from the Hanford Reach (see Chapman et al. 1991). The juveniles reach Lower Granite Dam at large size, mostly over 110 mm (mean size 127 mm). This size is similar to that of fall chinook subyearlings as they cross McNary Dam in late July and early August. Growth in the first pool encountered appears important in the life history of subyearling chinook under present river configuration. In pristine times, that growth would have occurred in the free-flowing river between natal areas and the estuary.

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[1]. The Bureau of Commercial Fisheries (BCF) memo indicates that in 1957, redds and spawning fish were seen between river miles 13.5 and 31.0,and in 1958 spawning fish were seen at river miles 7 and 18.5. The memo notes low visibility made redd counts difficult.

[2]. A Lewiston Tribune article of November 18,1903 notes that recent heavy rains had raised the level of the Potlatch, allowing “the usual belated run of dog salmon to make their appearance....” Early literature sometimes refers to sexually mature or spawned-out fall chinook as “dog salmon.” The fish in the Potlatch may also have consisted of coho salmon.

3.3 SPRING/SUMMER CHINOOK

Redd counts in spawning grounds for wild spring/summer chinook indicate low escapements in the Salmon River (Figures 6 and 7), Imnaha River (Figure 8), and Grande Ronde River (Figure 9). The ODFW, Nez Perce Tribe (NPT), and Umatilla tribes have conducted index and extended spring/summer chinook counts since 1986 to calculate total spawning populations and peak spawning time and compare these data with past and present index counts in the Grande Ronde and Imnaha basins. Results of these counts have not been published.

Straying by Carson and Rapid River hatchery stocks released in the Grande Ronde Basin has influenced spawning ground survey results (Figure 9). Outplanting adult and juvenile hatchery stock may also increase spawning by hatchery fish in the wild. Straying and outplants have affected redd counts in most spawning survey areas since the Lookingglass Hatchery program began in 1982. The Oregon Department of Fish and Wildlife (ODFW) has special concerns about straying of hatchery fish into the Minam and Wenaha rivers because the agency has designated these streams for wild fish only. The ODFW has requested approval and funding to construct weirs to prevent straying of unwanted fish into these streams.

Redd counting in reasonably consistent index areas extends historically to 1957, although methods have not always remained the same (Chapman et al. 1991). The few counts before that date (see Welsh et al. 1965) cannot compare directly to post-1957 counts (P. Hassemer, IDFG, personal communication).

Examination of individual index counts for various stocks yields some interesting information. For "summer" chinook, the highest counts in several index areas (Figures 10-16) occurred in 1957, the year in which The Dalles Dam pool flooded Celilo Falls. The fisheries at Celilo tended to take summer and fall chinook more than the earlier-migrating spring chinook because fisherman access and efficiency increased as flows dropped. For a few index areas, high counts occurred in other years in the 1957-1961 post-Celilo period, before other fisheries intensified (see WDF/ODFW 1992, Table 29). Summer chinook redd counts for wild fish indices in total reached lows late in the 1970s, then rebounded from the lows from 1980 to 1988 (Figure 7) until they began to show effects of the extended drought that began in the 1987 water year.

Redd counts in index areas for wild spring chinook in the Middle Fork Salmon River (Figures 17-21) were highest in the early 1960s, then dropped to their lowest levels about 1980. They rebounded to 1988, then decreased as drought effects appeared. Recent counts in total have remained low and relatively stable. The IDFG may have undercounted spring chinook spawners in 1992 because the count may have occurred before the peak of spawning. G. Matthews (National Marine Fisheries Service (NMFS), personal communication) felt that spawning was later than usual because of warm summer water temperatures. Some streams with historical stocking with hatchery-produced chinook have enjoyed better recent redd counts (Figure 10,22,23), while others have not (Figure 24).

The IDFG counts of parr in late summer in index areas in streams that produce spring/summer chinook reflect escapement declines (Figures 25-29). They also indicate habitat degradation in some streams, e.g.,Bear Valley Creek (Rich et al. 1992).

Chamberlain Creek, a wilderness stream exposed to no commodity production uses, held more chinook parr than other Salmon River tributaries (Figure 29). The bleak trends in parr abundance reflect the combined effects of conditions in the migration corridor and drought in rearing areas.

4. QUALITY OF SPAWNING AND REARING HABITAT

4.1 HISTORICAL CHANGE

Historical records occasionally offer useful measures of how habitat quality changed over time. Sedell and Everest (1990) examined past and present data on habitat quality. They relied on systematic inventories between 1936 and 1942, as conducted by the U.S. Bureau of Fisheries (now the National Marine Fisheries Service); inventories that documented stream habitat conditions for salmon before mainstem dam construction on the Snake and Columbia rivers.

Sedell and Everest (1990) evaluated post-1987 surveys of stream reaches surveyed a half-century ago, using the same techniques as the earlier surveys. The old survey defined large pools as greater than or equal to 3 feet in depth and having an area greater than or equal to 25 square yards. The old surveys also included adult chinook resting pools as shallow as 2.5 feet, if the pools met the area criterion. Sedell and Everest excluded such shallow pools from the old survey data. For recent surveys, Sedell and Everest (1990) included pools that equaled or exceeded 2.5 feet depth and that covered 25 square yards. Thus, the comparative data tended to reduce historical pool abundance and increase present pool abundance.

For the Middle Fork Salmon River, a watershed with substantial wilderness components but some grazing and timber harvest in the upper portions, Sedell and Everest (1990) examined data for Marsh Creek, Rapid River, and Elk Creek. The lower half of Marsh Creek, now bordered by small willows and grasses, lost 50% of its large pools over 50 years. The upper half, bordered by tall willows, had a 50% increase in pools. Thus, the reach did not change overall. Rapid River, draining wilderness areas, lost about 10% of its pools, possibly because fires burned over 40% of the basin in recent years. Elk Creek, tributary to Bear Valley Creek and subjected to multiple use, lost over 40% of its large pools over 50 years.

Pool habitats in the Grande Ronde River system declined sharply over 50 years. The main Grande Ronde River lost about 67% of pool volumes, Catherine Creek lost 75 % Beaver Creek - 85% Meadow Creek - 26%, McCoy Creek 85 % and Sheep Creek lost 53 %. Sedell and Everest (1990) blamed road construction, stream rehabilitation after floods, dredge mining, and agricultural and forest practices. They stated that the greatest losses occurred in streams with grazing as the dominant land use.

Throughout the Blue Mountains, land managers sacrificed riparian meadows to use the large acreages of surrounding forest range for grazing, and left riparian habitats in a depleted state (Skovlin et al. 1977). Claire and Storch evaluated grazing exclosures in Camp Creek, a Blue Mountain stream. They demonstrated that game fish made up only 24% of the total fish population outside the exclosure and 77% inside. Stream morphology outside exclosures did not favor salmonid use. Kauffman and Krueger (1984), and Kauffman (1988) noted that poor livestock and forest practices have damaged the riparian areas of watersheds in Eastern Oregon.

D. W. Kelley and Associates (1982) interviewed long-term residents of the Tucannon River Basin. These individuals stated that many deep pools, formed by log jams or large boulders, formerly were present in the Tucannon River, and that the floods of 1964-65 washed the jams and boulders away. The Kelley group noted that only 4% of the length of the Tucannon River consisted of pools, and considered the lack of pools as a major constraint to juvenile rearing habitat and to production.

Williams et al. (1987) state: *"Observations in the Joseph Creek and upper Grande Ronde River drainage . . . . . indicate optimum rearing areas for summer steelhead and spring chinook are limited in large portions of these drainages by degradation of riparian and instream habitats. Several factors have contributed to this habitat degradation.. . . . . including cattle grazing, farming practices, timber harvest practices, road construction and stream channelization.. . .*

Historical degradation of stream habitats in the subbasins used by listed salmon should surprise no one. Only natural events and some man-caused burning affected watersheds before the arrival of non-Indians. Steam and internal combustion engines permitted man to alter the face of the land rapidly, and commodity demand promoted intensive timber harvest, mining, and heavy grazing.

4.2 PRESENT *CONDITION*

The Idaho Department of Fish and Game (IDFG 1992) classes rearing habitat for Salmon River spring chinook as 56% (stream miles) and 47% (stream area) poor or fair. For summer chinook, the quality estimates equaled *58%* (stream miles) and 66% (stream area) fair or poor. The ratings as fair or poor reflect habitat degradation and natural physical features such as gradient.

Platts and Chapman (1992) summarized their estimates of the status of chinook salmon spawning and rearing habitat in the Salmon River drainage. They concluded that 68% of Salmon River habitat should fall in the poor or fair category. Subbasin plans for the Salmon, Grande Ronde, Imnaha, and Tucannon rivers, prepared under the auspices of Northwest Power Planning Council (NPPC), frequently note habitat degradation associated with livestock grazing, timber harvest and roads, mining, and irrigation water withdrawals and return-water quality.

The Bureau of Reclamation (1981) reports that about 360 degraded stream-miles have been identified in the Grande Ronde Basin. The Umatilla Tribes (CTUIR 1984) produced a "Working Paper" that identifies habitat problems by type and stream and recommends improvement measures for the Grande Ronde and Imnaha basins. The BPA has funded stream habitat work for the Grande Ronde Basin and results of this work are published in annual reports produced by the USFS and ODFW.

The draft charter for the Grande Ronde Model Watershed Program, lists the following facts:

(1) over 80% of the anadromous fish habitat in the area is considered to be in a degraded condition;
(2) estimated numbers of spring chinook spawners in the Grande Ronde sub-basin have dropped from 12,200 in 1957 to less than 400 in 1989;
(3) water quality is documented by several agencies to be severely impaired by both sedimentation and thermal problems and the Oregon Department of Environmental Quality lists the basin as being of limited water quality;
(4) riparian habitat is in a moderate to severely degraded state in many areas through the watershed;
(5) large pool habitat in the mainstem of the Grande Ronde River and Catherine Creek has declined by 73% since 1941;
(6) spring flooding of down-stream areas and farmland occurs every few years.

5. LIVESTOCK GRAZING

Grazing-caused degradation of riverine-riparian habitats used by ESA-listed spring/summer chinook salmon began in the late nineteenth century (Platts 1990). Recently, Bauer (1989) listed livestock grazing as the most significant pollutant source associated with hydrologic changes in streams. The GAO (1989) estimated that 60% of all BLM grazing allotments presently are in unsatisfactory condition. A similar finding would result for U.S. Forest Service allotments. Most spring/summer chinook spawn and rear in streams with grazed watersheds that lack appropriate protective management (Platts and Nelson 1985a). W. Platts (personal communication) estimates that streams in meadows subjected to cattle grazing average at least 35% lower ability to produce juvenile salmon.

The Sawtooth National Recreation Area (SNRA), in the upper Salmon River, yields 28% of the wild salmon produced in Idaho (Peek and Gebhardt 1981). The U.S. Forest Service EIS, which evaluated the Stanley Basin grazing allotment, reported that current livestock management does not contribute to the desired future condition of anadromous fish habitat. The Stanley Basin draft allotment management plan stated that 46 of the 70 stream miles in the allotment had unstable streambanks and accelerated sediment production from livestock grazing. The draft plan would reduce grazing by 66%. The EIS estimated that smolt production will increase by an estimated potential of 331,000 each year after livestock grazing is rationalized, with a potential fishery enhancement of $1,854,0OO.

Of 2 1 streams studied in the upper Salmon and upper Middle Fork Salmon, 18 had “marginal” or unsuitable habitat for salmon spawning and rearing (OEA Research 1986). The Little Salmon River near New Meadows, and Sand Creek, a tributary to Johnson Creek in the South Fork Salmon River drainage, offer examples of grazing-damaged streams in the Salmon River Basin outside the upper Salmon and Middle Fork

Salmon. Livestock have widely degraded riverine-riparian systems in the Grande Ronde River Basin (Beschta et al. 1991). Sheep Creek, in the Grande Ronde Basin, reflects the effects of heavy grazing by sheep before 1900, and cattle since. Excessive livestock grazing has extensively damaged riparian zones on the upper Grande Ronde River (Beschta et al. 1991), Catherine Creek, Joseph Creek, and the Wallowa River (PNPPC 1989). Overgrazing has reduced bank stability in Imnaha River tributaries, including Little Sheep, Big Sheep, and Camp Creek, as well as parts of the mainstem Imnaha River (USFS 1981).

A USFS briefing paper (Pacific Northwest Region) lists five ranger districts on the Wallowa Whitman National Forest with resource damage. The paper estimated that 423,500 acres had "basic resource damage" and 210,100 acres had "other resource damage." "Basic resource damage" means that one or more of the following four conditions, in the wording of the USFS, exist @livestock use on the allotment is or has been a major factor that contributed to the condition.

1. Maximum summer water temperatures are elevated above State Standards or other approved criteria on Stream Management Unit (SMU) class I or II streams and this is largely due to the loss of shade-producing vegetation in the allotment.

2. Less than 80% of the total miles of SMU class I and II streams are in a stable condition (60% for class III and 50% for class IV streams) where this is largely due to the loss of stabilizing streambank vegetation.

3. Gully development is of sufficient size to lower the seasonally saturated zone and change the plant community type is occurring.

4. Soil condition rating on 25% or more of key areas is rated poor or very poor.

Improper livestock grazing practices can affect all four components of the stream-riparian system -- the channel, the streambanks, the water column, and the in-stream and bordering vegetation. Livestock usually graze riparian areas more heavily than the adjacent uplands (Platts and Nelson 1985b). Most current range management plans do not require different grazing strategies on the riparian and upland zones. Aggregated management of riparian areas with dissimilar vegetative communities of the uplands does not adequately protect riparian zones or account for their unique fishery and wildlife values.

5.1 U.S. FOREST SERVICE

The following table, based on 1992 Forest Service data, summarizes the distribution of National Forest livestock grazing within and/or affecting anadromous fish habitat in the Salmon River drainage. Data in this table differ from data used in "The Economic Impact on the Forest Sector of Critical Habitat Delineation for Columbia River Basin Salmon" by the NMFS/Pacific Northwest Research Station. The NMFS/PNW paper analyzed "ridge-to-ridge" impacts that affect critical migration/spawning/rearing habitats. Our data include grazing allotments that "contain or affect" anadromous fishery habitat. We summarized these data from raw data in the Forest Service RAMIS computer data base where NMFS/PNW data were received from the Forests in summarized form. Additionally, Forests' responses evolved under questioning by both the USFS/PNW authors and data gatherers of Don Chapman Consultants, Inc.

All National Forest Land and Resource Management Plans in the Salmon River drainage predate anadromous fish ESA listings. Thus, while Forest Plan Standards & Guides offer laudable goals, they very probably do not require management that would lead to delisting of the species. The present report relied on Forest determinations or our assumption that allotments scheduled for updating and/or with AMPS that predate Forest Plans do not fulfill Forest Plan Standards and Guides and do affect anadromous fisheries.

Work to bring grazing allotment management up to Forest Plan standards (Table 2) requires that 95 % of AMPS be updated by 1995. The Forest Service will not meet this schedule. Manpower shortages, funding problems, personnel transfers, permittee appeals, and other factors conspire to extend AMP update schedules. Forest Service examples include unattained early 1980s directives in Region 4 to have AMPS for all allotments by 1990, the delay in the Sawtooth National Forest in implementing the Stanley Basin Allotment Plan, and the delayed Bear Valley AMP in the Boise National Forest. Knowledgeable Region 4 range specialists indicate that very substantial grazing reductions may be needed on some allotments to obtain a "No Effect" determination for listed species. Permittees will strongly resist such reductions, further delaying progress toward improved land husbandry.

Table 3, based on 1992 BLM data, summarizes the distribution of Bureau of Land Management (BLM) livestock grazing within and/or affecting anadromous fish habitat in the Salmon River drainage, which includes portions of the Couer d'Alene and the Salmon Districts.

The two Salmon River BLM districts lack allotment monitoring data to permit managers to determine if their AMPS meet either mandated Land Use Plan (LUP) criteria and/or negatively affect anadromous fisheries -- i.e., the districts do not know what their grazing does to listed salmon. Table 4 suggests the workload involved to bring Salmon River BLM grazing up to LUP criteria and anadromous fish needs.

Federal agencies combined administer over 2.7 million acres of grazing that affects Salmon River anadromous fish habitat. This area produces 155,399 AUM of grazing. Valued at the 1991 Idaho rate of $11.59/AUM (USDA Agricultural Statistics Board), this grazing use has an annual value of $1801,074.

By calculations of the federal agencies, 112 to 140 of their grazing allotment management plans need revision to current standards. This comprises 77% to 96% of the federal grazing allotments with or affecting anadromous fisheries in the Salmon River drainage. Even at an assumed bare minimum cost of $40,000 for each AMP, the

Table 1. Distribution of grazing by animal type and amount. AUM means animal unit month.

National Forest	Allotments			Acres		
	cattle	sheep	horse	cattle	sheep	AUMs
Nez Perce NF (Rl)	11	3	-	292,228	110,664	29,527
Boise NF (R4)	4	-	1	189,609	-	10,178
Challis NF (R4)	14	3	-	296,828	60,746	20,718
Payette NF (R4)	4	22	-	68,039	299,936	16,688
Salmon NF (R4)	24	-	1	681,822	-	28,985
Sawtooth NF (R4)	21	9	-	255,752	104,110	23,090
Totals	78	37	2	1,784,278	575,456	129,186

Table 2. AMPS requiring updates, by National Forest, and USFS schedules for updates.

National Forest	AMPS Meeting For. Plan	AMPS not meeting For. Plan	Forests' Schedule of AMP Updates by Year			
			FY92	FY93	FY94	FY94+
Nez Perce NF (Rl)	1	13	2	5	3	44
Boise NF (R4)	0	5	1	1	2	1
Challis NF (R4)	3	14	6	5	1	6
Payette NF (R4)	1	25	10	3	3	9
Salmon NF (R4)	1	24	11	7	4	1
Sawtooth NF (R4)	0	30	Sawtooth NF has no schedule			
Totals	6	111	30+	21+	13+	21+

Table 3. Distribution and amount of grazing in BLM districts in the Salmon River drainage.

BLM District	Allotments			Acres		
	cattle	sheep	horse	cattle	sheep	AUMs
Couer d'Alene	8	2	0	13,343	13,516	1,322
Salmon	19	0	0	386,494	0	24,891
Totals	27	2	0	399,837	13,516	26,213

Table 4. Workload to bring Salmon River BLM grazing to Land Use Plan (LUP) criteria.

BLM District	AMPS Meeting LUP [3]	AMPS not Meeting LUP	District's Schedule of AMP Updates by year			
			FY92	FY93	FY94	FY94 +
Couer d'Alene	0-10	0-10	District has no schedule			
Salmon	O-18	1-19	2	4	6	3
Totals	O-28	l-29	2+	4+	6+	3+

revisions would cost $4,480,000 to $5,600,000. A more realistic assessment may be about $7,000,000 to $8,000,000. On small allotments it may be more cost-effective to retire the grazing permit.

On public lands the future lies in updating and implementing valid Allotment Management Plans. The USFS and the BLM have issued riparian policy statements, but budgetary restrictions, lack of skilled staff, failure to overcome political handicaps, and lack of agency commitment still stand in the way. The pace of improvement of chinook and steelhead (0. mykiss) streams depends on commitment.

The National Forest Management Act requires Management Plans for each National Forest. Each Plan guides land management for the Forest. Under a multiple use mandate, the Plan tries to "-- *serve the greatest good for the greatest number.* " Forest Plans establish multiple-use goals with desired future conditions, management prescriptions, and standards and guidelines for decision-making. Specific project activities such as grazing allotment management plans must meet both the letter and intent of the Forest Plan. While USFS managers have a legal mandate for multiple use,

[3]. Range, e.g.,0-10, indicates agency does not know if AMPs meet LUP or not.

they have historically subordinated fisheries to commodity uses of public lands. The USFS has strongly resisted changing this tradition. Recent letters from forest supervisors to the Chief of the USFS encouraged more balanced approaches to Forest Service resource management (Forest Supervisors of Regions 1,2,3, and 4 combined letter to Chief and open letter to the Chief from Region One Supervisors, both written in 1989).

Decision makers often over-study and delay actions on allotment management plans that demand obvious solutions even according to agency directions. Forest Plans of the USFS contract with the American public to manage public lands. Good plans identify long-term objectives, guidelines, and standards to protect the unique values of streams and riparian areas. They prohibit management practices with serious adverse effects on water quality and fish habitat.

The development of AMPs must cover four major requirements:

1. The USFS manual requires a plan for all grazing areas.

2. AMPs must comport with the Forest Land Management Plan and consider resources other than grazing.

3. The AMP sets "proper use criteria" for each unit of each grazing allotment. When grazing exceeds this use level, managers must move livestock out of the unit.

4. The USFS Manual states: "Where range improvements are not cost effective and management alone will not solve resource problems, aggressive livestock adjustment action must be taken" (FSM 2203.1[R4]).

An AMP requires one of these NEPA documents:

1. An EIS if planned grazing significantly affects the environment.

2. A finding of no significant impact.

3. A Categorical Exclusion.

Range management in the USFS requires that managers identify and evaluate fisheries indicator species and their habitat requirements as integral to the range analysis and allotment planning process. The USFS Range Manual (2200) and Handbook (FSH 2209) require involvement of permittees in the planning process. Planners must include fisheries input to the AMP to meet NEPA interdisciplinary requirements.

With recent listing of Snake River anadromous fish stocks as either threatened or endangered, the Forest Service and the BLM have attempted to accelerate efforts to better manage grazing of anadromous fish habitats. National Forests in the Salmon River drainage have plans to speed their revision of grazing allotment management plans, placing priority on those with anadromous habitat. As a result, habitat for resident fisheries may receive less attention and lower priority.

With appropriate planning, mitigation can permit cattle grazing on anadromous fish allotments. Protection of riparian zones by improved pasture management can actually increase meat production for permittees, e.g.,by encouraging livestock use of uplands (GAO 1989). Such improvements require changes in grazing intensity and timing in the riparian zone, and often investment in mitigation, such as fencing.

5.2 BUREAU OF LAND MANAGEMENT

Bureau of Land Management (BLM) grazing management has treated fisheries poorly. Managers cannot blame the adequate statutes under which the BLM operates for the condition of BLM lands. Lack of both commitment and direction from the top handicaps the small staff charged with management of riverine-riparian zones. Furthermore, BLM management areas, which often lie downstream from USFS lands, can receive degraded waters from upstream watersheds.

The BLM resolve often does not match rancher influence, historical habits, and politics (GAO 1988). The BLM has difficulty in decision-making that adversely affects the livestock industry. The GAO found the BLM endorsed a riparian policy and, at the same time, reduced the number of aquatic biologists necessary to put it into effect. The BLM proposes to implement riparian management, protection, and restoration so at least 75% of riparian areas reach "good or better" ecological condition by 1997. Performance in the last decade indicates that the agency will not attain this improvement.

In accord with the Endangered Species Act, the protection, enhancement, and recovery of threatened and endangered species should receive priority consideration in all BLM and Forest Service activities. With the Federal Land Policy and Management Act (FLPMA), the BLM received, for the first time, permanent authority to retain and manage fisheries and wildlife in multiple-use management. The FLPMA places fish on an equal footing with all other uses and authorizes designation of "Critical Areas of Environmental Concern." Resource Management Plans (RMPs) and Habitat Management Plans (HMPs) prescribe management to protect fish habitat. The NEPA requires the BLM to prepare an Environmental Impact Statement (EIS) on major BLM actions that could affect the environment. The FLPMA, now 15 years old, has but little improved riverine-riparian habitat. The GAO (1988) notes that restoration of riparian habitats has begun on only a small fraction of the thousands of degraded stream miles.

The BLM analogs of USFS AMPS do not incorporate fish resources with weight equal to livestock management objectives. Almost all BLM plans are outdated and lack direction that would benefit aquatic resources.

5.3 PRIVATELANDOWNERS

Most habitat of wild spring/summer and sockeye salmon lies on public lands in the Salmon River Basin. In Oregon and Washington, more habitat used by the former species lies on private land, thus, good grazing strategies are important on private land. Grazing strategies on private lands take on somewhat less importance for ESA-listed salmon in the Salmon River watershed. Continuance of livestock grazing in much of the Snake River drainage used by ESA-listed salmon relies on how effectively the landowner satisfies the BLM or USFS administrator and agency AMPs.

6. IRRIGATION WITHDRAWALS

6.1 UPPER SALMON RIVER

In the headwaters of the Salmon River, and in the Grande Ronde, Imnaha, and Tucannon rivers, irrigators divert summer flows to irrigated pastures. Irrigated valley bottom lands in the upper Salmon River contain coarse, porous glacial outwash and other fluvial materials that require large amounts of applied water to produce an AUM of forage. In some areas the base flow of the Salmon River has been fully appropriated, making difficult the future allocation of water for spawning and rearing flows. Some diversions in the drainage take the entire flow of the affected stream in summer (e.g., Fourth of July Creek and Champion Creek). Andrews et al. (1987) estimated that improved instream flows in the Sawtooth NRA could yield 884,000 more smolts annually [4].

Munther (1974) found that salmon used the lower three miles of Champion Creek when flows permitted passage, spawning, and rearing. Seven diversions completely de-water this stream annually to irrigate 435 acres of private land. In 1972, Munther (1974) measured 38 to 18 cfs upstream from the diversions and only 4 to 9 cfs downstream. In 1973, summer flows upstream from diversions ranged from 16 to 11 cfs. Downstream, the stream contained no water after June 15, 1973. It was dry in 1992 by June 1.

Fourth of July Creek, like Champion Creek, once supported spawning runs of large bull trout (Salvelinus confluentus) (personal communication, W. Platts) and rearing by juvenile chinook. Three diversions now divert the entire summer flow. In most summers the lower reaches of Fourth of July Creek contain no water. In 1972, Munther (1974) measured over 30 cfs in August above diversions and no flow below them. The lower end of this stream contained no flow by mid-June 1992. The diverted flow of this and other streams may reach the Salmon River at some downstream point as groundwater, reduced of course by evapotranspiration. The diversion reduces flow in the tributary and Salmon River downstream.

Spring/summer chinook once heavily used Valley Creek (Personal communication, W. Platts). Munther (1974) reported that irrigation diversions left portions of Valley Creek and its tributaries partially or wholly de-watered, and sent many salmon juveniles to the fields in unscreened diversions.

Many irrigation return flows bring polluted waters into the Lemhi River. These waters silt spawning gravels and raise water temperatures during summer. Gebhards (1958) reported that diversion berms had altered 21% of the channel. Gebhards (1959) estimated the loss of downstream migrant chinook salmon fingerlings to canals off the Lemhi River as 421,000 in 1958. Irrigation diversions dewater Lemhi River channels that chinook salmon use for spawning, rearing, and migration during crop-growing periods. Lemhi River Basin water rights leave little unappropriated water that BPA or other entities might obtain to benefit salmon and steelhead. Irrigation systems also

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[4]. This estimate assumes adequate adult seeding.

reduce instream flows in the Pahsimeroi River, and return silt-laden water.

Lease or purchase of water rights in the upper Salmon River can substantially improve instream flows. Forest Service acquisition of the Enright property in 1992 allowed the Breckenridge diversion to revert to non-use and permitted anadromous fish passage to the headwaters. The Forest Service plans to leave all water in the river for fish passage. Where current state water law does not recognize fish as a beneficial use, the water right may be at some risk after the allowed five-year period of non-use. Action by BPA to provide Alturas Lake Creek instream flows for migration, spawning, and rearing re-accessed many miles of habitat. The actions by the USFS and BPA to increase instream flows were the most important habitat measures implemented in the Salmon River Basin to date.

Purchase or lease of water rights upstream from lower Stanley, and return of this water to the streams, will improve instream flows and water quality, and decrease summer water temperatures. It would also reduce need for irrigation diversion screens and maintenance. It would help maximize egg-to-smolt survival for the limited escapements that currently reach the area. It would also enhance resident salmonid populations and recreational opportunities.

6.2 OREGON RIVERS

Approximately 98,350 acres are irrigated in the Grande Ronde and Wallowa valleys (Bureau of Reclamation 1981). Agriculture, irrigation diversions, dams and channelization have negatively affected anadromous runs to the Grande Ronde and Snake River (PNPPC 1986, 1989). In the Imnaha River, a diversion removes up to 162 cfs from the basin to irrigate the Wallowa Basin in summer. The subbasin plan for the Imnaha River indicates that neither depleted instream flows nor high summer temperatures negatively affect salmon populations of the river (NWPPC 1989). However, the plan notes that use of the diversion for instream flows in the Imnaha would help reduce ambient summer water temperatures.

6.3 SNAKE RIVER UPSTREAM FROM HELLS CANYON

Irrigation had severely reduced salmon and steelhead populations and availability of habitat of the Snake River Basin by the 1940s (Chapman et al. 1991, Kaczynski and Palmisano 1992). Irrigation and agricultural development reduced fish runs in the Chvyhee, Malheur, Burnt, Powder, Boise, Weiser, Payette, and Bnmeau rivers before the Hells Canyon Dam complex blocked access up the Snake River (NPPC 1986).

The annual flow of the Snake River upstream from Hells Canyon Dam contributes 12 million acre-feet (MAF) of water; unregulated tributaries downstream from Hells Canyon deliver 24 MAF (Hydrosphere Resource Consultants (HRC) 1990). The discharge from the area upstream from Hells Canyon would equal about 18 MAF without agricultural water management. Agriculture with irrigation concentrates in three areas: (1) Lower Boise, Payette, and Malheur rivers, (2) central Snake River mainstem betwen Lake Walcott and Ring Hill, and (3) upper Snake River and tributaries from Henry’s Fork downstream to American Falls Dam. Evapotranspiration associated with irrigated agriculture consumes about 6 MAF of water annually. Although some dams in the central and upper Snake have multiple purposes, including flood control, irrigation, recreation, and hydropower, there is no doubt that irrigation drives the hydrograph of the Snake River upstream from Hells Canyon Dam.

Water consumption for irrigation accelerated rapidly until the 197Os, prompting projections of development that would consume an additional 8 to 10% of the annual discharge to the lower Snake River by 2020 (USACE 1976). The projections have proved too expansive. About 3.4 million acres lay under irrigation in the Snake River Basin upstream from Hells Canyon in 1980; in 1987 the area had declined to 3.1 million acres as a result of urbanization, economics, and various conservation programs (HRC 1990).

Water management upstream from Hells Canyon has reduced total water available in the migration corridor downstream, and has altered timing of water movement, reducing spring flows to deliver water to irrigators later in the year. Flow reductions in spring equal about 19%) 3296, and 32% in April, May, and June, respectively (Chapman et al. 1991).

HRC (1990) estimated that hydropower storage, limited to Dworshak and Hells Canyon dams, could provide an additional 0.36 to 0.60 MAF of water for flows in the migration corridor without jeopardizing refill. HRC (1990) found a substantial potential for further increasing spring flows by systematic review and modification of current flood control operating criteria, and by moving all lower Columbia dry-year flood storage to Columbia River projects. Estimates of flow increases are as high as 0.7 MAF.

Natural flow rights, unused and uncontracted storage, and unsold Water Bank consignments were examined by HRC (1990). Although purchase of natural flow rights appears attractive at first glance, inasmuch as those rights are generally senior, serious institutional and legal problems obstruct their transfer to the downstream migration corridor. Purchase of contracted storage may jeopardize carryover storage and encounter considerable political resistance. Water Banks give priority to agriculture, penalize water users who lease their storage supplies for non-consumptive uses downstream from Milner, and discourage use of Water Bank water for instream flows. Instream flows for fish remain a non-beneficial use under Idaho law.

Uncontracted storage without encumbrance amounts to less than 0.05 MAF in the Snake River Basin upstream from Hells Canyon. As an example of such encumbrances, the Bureau of Reclamation has committed 0.3 MAF of uncontracted storage in Cascade Reservoir to maintenance of a minimum pool. Substantial water quality, resident fishery, and recreational values attend that minimum pool.

Conservation has limited potential for enhancing flows in the migration corridor. Many diverters rely on existing return flow patterns, most conservation does not significantly reduce consumptive use, and conservation has little economic attraction for users. HRC (1990) noted that if conserved water could be sold readily and transferred, or if a good market for stored water developed, then irrigators who conserve might find it advantageous to leave conserved water in streams or in Water Banks. A possible 0.075 to 0.275 MAF might then become available.

HRC (1990) pointed out that purchase of water rights, conservation, altered flood control rule curves, and use of hydro storage theoretically could yield about 2.0 **MAF.** However, HRC further noted that institutional constraints conspire to reduce the water available from each of the sources. The HRC report estimated that water managers might find somewhat over 1 .0 MAF for the water budget in the migration corridor without major adverse effects on supplies available to existing water users. If managers distributed all of it throughout the April, May, and June migration period for wild fish in the same proportions as current flows for the three months, or 27%, 38%, and 35 % respectively, this amount of water would produce, in the average year, discharge increases of 4,538 cfs, 6,386 cfs, and 5,882 cfs for the respective months.

The indicated increases would not approach the CBFWA demands for 140,000 cfs in the Snake River, given that average flows now equal about 77,470 cfs, 109,320 cfs, and 101,860 cfs in April, May, and June, respectively, at Clarkston, Washington (Chapman et al. 1991). A. Giorgi, in another appendix review, provides some perspective on the benefits that such flow increases might produce. If managers used the incremental 1.0 MAF in part for augmented flows in July and August (e.g., to lower water temperatures or increase river water velocities in summer) the flow increment in April, May, and June would decline.

The effects of additional spring-season flows on juvenile fall chinook salmon are unclear. One should remember that the increases would amount to 14.8%, 23.7%, and 26.4% over the respective April, May, and June flows at Hells Canyon Dam of 30,600 cfs, 27,000 cfs, and 22,300 cfs (1925-1989 mean flows). Thus, from Hells Canyon Dam to the mouth of the Salmon River, especially, effects of incremental flows on listed fall chinook emergence and early rearing require consideration by resource managers. Ecological investigations may reveal whether the increments would have negative or positive effects.

7. AGRICULTURE

7.1 CULTIVATION, CHANNELIZATION, AND FEEDLOTS

Field cultivation, stream channelization, and cattle feedlot operations all affect spring/summer chinook salmon. In the Grande Ronde and Imnaha Basins, streams have been relocated and channeled to facilitate farming and irrigation. Channelization reduces available stream miles by reducing sinuosity. It increases water velocity, reduces pool area, and destabilizes channels. "Wallowa" in Nez Perce language is said to mean "winding." The Wallowa River once did, but does no more. In a conversation with Dale Johnson, Wallowa, Oregon, he described why the Wallowa River between Bear Creek and Rock Creek was moved to high ground to accommodate irrigation. During high water, the Wallowa River often flows into the lower channel. Channelization is required to "put the river into its proper channel."

The Grande Ronde River meanders through the Grande Ronde Valley. In 1870, the State of Oregon constructed a ditch that eliminated approximately 33 miles of the original Grande Ronde River channel (D. West, ODFW, personal communication). The importance of the meandering channel to chinook is unknown but this habitat type could be important to wintering fish. ODFW is requesting a chinook salmon life history study for the Grande Ronde River to determine, in part, the importance of the river section through the Grande Ronde Valley to potential production of chinook.

The above descriptions of channelization projects are examples of channel modifications in the Grande Ronde and Imnaha basins since settlers arrived. Hundreds of channel modifications require repair and reestablishment after high water periods to protect fields, buildings, and bridges.

In recent years, cattle feedlot construction and operation has increased during winter months. Prior to the 1970s most cattle ranches in the Grande Ronde and Imnaha basins produced calves to be sold in the fall to “outside” buyers. Stockgrowers have constructed feedlots, usually on or very near year-around flowing streams, and feed the confined cattle during winter months.

Cattle feedlots are unsavory installations that pollute salmon habitat. In terms of wastes measured by biochemical oxygen demand, one cow in a feedlot is equivalent to six people in town. A cattle feedlot of 1,000 head equals a town of 6,000 population in certain wastes produced (EPA 1972). The impact of cattle feedlots on salmon production is unknown, but in some stream areas in the Grande Ronde Basin state water quality criteria are not met. Water quality is reduced in some areas in the Imnaha Basin.

Field cultivation increases soil erosion, causing sedimentation in salmon producing streams. Everest (1969) determined that interstices in the substrate are important to fish as hibernating areas in winter. Chapman (1966) speculated that the actual density regulator of salmonids changes seasonally from a space-food convention in spring, summer, and fall, to space alone in winter (see section on overwinter survival of spring/summer chinook).

7.2 OREGON RIVERS

Gary Findley, ODFW, provided a list of gravity diversions that are equipped with rotary fish Screens (Tables 5 and 6). There are large unscreened diversions from Wallowa Lake, the Wallowa River and Hurricane Creek as well as a few small unscreened canals throughout the Grande Ronde and Imnaha basins that are not included in the Tables (ODFW memo Findley to Schumacher, August 92). Also there are many pump stations diverting water that are not included in Tables. Few diversions have monitoring stations. Actual water diverted is unknown. The impact of water diversions on salmon production is unknown, but there is no question that the regulation of water use will be controversial for water users.

Table 5. Location of screened diversions in the Grande Ronde Basin in 1993.

Tributary	Diversions	Flow (cfs)
Grande Ronde River	4	150.74
Wallowa River	32	317.17
Hurricane Creek	1	2.12
Lostine River	14	213.65

Table 5, continued.

Tributary	Diversions	Flow (cfs)
Bear Creek	6	44.34
Catherine Creek	13	172.84
Spring Creek	1	0.80

Table 6. Location of screened diversions in the Imnaha Basin in 1993.

Tributary	Diversions	Flow (cfs)
Imnaha River	3	1.25
Big Sheep Creek	9	0.62
Miscellaneous streams	11	12.18

7.3 UPPER SALMON RIVER DRAINAGE

Like the Oregon streams, the upper Salmon River has suffered channelization and other agriculturally-caused damage (see Platts and Chapman 1992, and Chapman et al. 1991).

Construction of fish protection screens on irrigation diversions in the Salmon River Basin began in 1958. From 1958 to 1966, agencies installed over 200 fish screens. In the late 1970s another 25 diversions were screened in the Stanley Basin. Virtually all water diversions operate by mid-May and continue to mid- to late October. Some diversions operate all year for livestock watering. By 1965, the IDFG had screened 185 diversions, ranging from 2 to 90 cfs, on the main stem of the Lemhi River.

Fish screens presently operate on about 200 of the 220 irrigation diversions on the Salmon River and tributaries above the North Fork Salmon River (Table 7). Of these, only one on the Lemhi River meets the modem screen design criteria of the National Marine Fisheries Service as recommended in August 1989.

Andrews, et al. (1987) estimated that chinook salmon smolt production potential would be increased by 342,000 annually and sockeye salmon smolt production potential by 542,000 per year with proper diversion screening. Project cost to date for the BPA to assist in buffering the diversion problem are already substantial.

Schill (1984) estimated the economic value of screening juvenile salmon and steelhead from diversions in the Salmon River system. He estimated benefits from

Table 7. Location of screened diversions in the Salmon River Basin in 1983. Average flow in cfs and based on water permits (from Schill 1984).

Tributary	Diversions	Flow (cfs)
Lemhi River	88	16.9
East Fork Salmon River	25	10.9
North Fork Salmon River	15	7.8
Pahsimeroi River	22	20.0
Main Salmon River	35	29.7
Miscellaneous streams	13	10.8
Total	198	96.1

screening fry at $0.33 per chinook salmon and $0.14 for steelhead trout. He lacked information to apply these values to adult benefits. Returning adults, either harvested, observed, or spawning, constitute the real benefit of screening. A fry or smolt that dies within the system has no identifiable economic value.

Since 1990, the IDFG has released over six million salmon and steelhead smolts annually in the upper Salmon River Basin. Releases of anadromous smolts only amounted to 2 million fish in 1983. Schill (1984) believes these larger releases of smolts may make screening even more valuable. However, his analysis did not consider that adding more smolts to the system may not yield additional benefits. Large releases of hatchery smolts may already decrease survivals over those attainable with reduced releases (see Beamish et al. 1992). Large releases may already reduce overall survival of wild smolts in the migration corridor, estuary, and possibly in the marine environment, compared with survival possible with reduced releases (see Beamish et al. 1992).

The USFS estimated that complete screening will permit an additional 100,000 to 200,000 young salmon to migrate annually from spawning areas on the Salmon River within the SNRA. They estimate that for every 100,000 young salmon saved, 1,000 adults will return. This estimate implies a survival rate of 1%. No researchers have taggd diverted fish to evaluate survival to adulthood. Cost and benefit analysis of screening should also evaluate loss of fish habitat in irrigation canals downstream from screens. Some fish intercepted at screens would likely rear in the canals downstream from screens, then later move upstream to reenter the river. No ecological studies have evaluated loss of rearing in irrigation channels downstream from diversion screens. That rearing potential should be examined in relation to "saved" fish that would die in fields, but that must use reduced mainstem habitats of quality lower than that in irrigation canals. The millions of dollars spent on screening in the past 30 years may or may not have returned positive net benefits.

8. TIMBER HARVEST

Until the 1960s, timber harvest in central Idaho remained relatively low. Harvest increased in Idaho from only one million board feet in 1932 to 30 million board feet in 1959 (NWPPC 1986). By 1983, sawmills processed 600 to 700 million board feet. In 1987, harvesters cut 1.7 billion board feet of timber (Bauer 1989). Harvesters recently have taken about 388 million board feet of timber in the average year from salmon-steelhead drainages of the Snake River Basin. In the last three years, appeals and various restrictions have sharply reduced annual harvests.

Road construction, maintenance, and use add large volumes of sediment to streams. The USFS calculates, while modeling for impacts of timber sales, that new road construction produces 67,500 tons of sediment per square mile per year and that roads older than two years continually produce 5,000 tons of sediment per square mile per year (B. Stack, USFS, personal communication). The Wallowa-Whitman National Forest has approximately 9,485 miles of road with road densities exceeding 10 miles per section in some areas. Some 2,500 miles of roads have been closed and another 1,900 miles are planned to be closed. Excluding wilderness areas, there are presently 2.6 miles of open road per square mile on the Wallowa-Whitman National Forest (Bruce Kaufman, USFS, personal communication). Efforts to close roads have met with public opposition for those people who use the roads for gathering wood, mushrooms, and berries. Road closures to improve hunting opportunities, reduce wildlife harassment, and to decrease soil erosion, have met with less opposition.

Aquatic habitats recover slowly after timber harvests. Megahan et al. (1980) showed that habitat may not recover to previously undisturbed condition even within one to two decades after extensive reclamation programs. Negative effects of logging can last more than a half-century (Sedell and Everest 1990). The South Fork Salmon River exemplifies a stream that will remain degraded for many years because of past logging activities.

As with mining and irrigation, no studies quantitatively determine overall logging effects on salmon and steelhead populations in the Snake River Basin. Despite considerable evidence of profound changes in light, temperature, channel morphology, and stream flow regimes, much uncertainty remains about response of salmonids to timber harvest (Hicks et al. 1989). Hicks stated that certain logging-used increases in fine sediment in the channel, for example, appear less detrimental and more transient than originally perceived. Other changes, such as reductions in large woody debris and drastic changes in channel morphology, not foreseen as problems earlier, now appear much more significant over the long term.

Despite the high commercial value of salmon and steelhead, no study has determined the effects of timber sale and road construction on a salmon population in the Snake River Basin. Much federal and state money has been spent studying logging effects, largely soil-hydrologic influences. Yet we lack a true picture of the effects that logging and road construction have had on salmon and steelhead. The only way to visualize logging effects on salmon and steelhead populations in a basin perspective is to evaluate case histories, then attempt to extrapolate these findings to various areas of the Basin.

Best Management Practices (BMPs) available today can prevent recruitment of fines to spawning and rearing areas used by spring/summer chinook salmon and steelhead. Some resistant areas on gentler slopes can support logging without stream damage. Some steeper areas already roaded can support zero-impact logging. Some unroaded areas will require helicopter yarding. Managers should not allow roading or logging in some sensitive soils, gradients, and aspects. The Clean Water Act (PL 92-500) and Forest Service BMPs provide useful tools for preventing logging-caused damage to salmon habitat.

Idaho State Best Management Practices remain inferior to those of the U.S. Forest Service. The state standards are less restrictive, e.g., with respect to merchantable timber in the riparian zone. The Forest Service removes riparian areas from the harvest base, while the State permits removal of merchantable trees from the riparian zone.

Oregon Forest Practice Rules require that harvesters leave large woody debris in Class I streams and riparian zones (Class I indicates those streams that anadromous salmonids use). The rules also establish a formal riparian management area on each side of the stream, three times the stream width but not less than 25 nor more than 100 feet wide. The regulations specify a 75% shade rule and a 50% overstory canopy rule for the riparian zone. Harvesters may take trees from the riparian zone if the zone continues to meet the shade and overstory rules. Conifers are left in half of the riparian management zone closest to the stream. The Oregon Rules also provide protection for "significant streams not used by anadromous fish" (Kaczynski and Palmisano 1992).

The Oregon Forest Practice Rules are presently being reviewed as required by Senate Bill 1125. Bhagwati Poddar wrote in the February 9, 1993 edition of the Oregonian *'To have the Forestry Department draft rules protecting the waters of the state is like asking Jack the Ripper to protect the prostitutes of the streets of London. The department is not the guardian angel of streams, but rather of the timber industry.* " He also *states "Buffers that can be logged are no buffers at all. There is conclusive evidence that logging activities that remove riparian and adjacent vegetation ham water quality for both fish and humans by increases in sedimentation. For smaller streams the impact can be severe.* " Fish biologists generally agree with Mr. Poddar's assessment and field fish biologists often argue that small Class IV and III streams should receive the greatest protection because water quality in these streams determines water quality in the Class II and I streams.

State of Washington regulations for eastern Washington (WFPB 1992) require that harvesters leave 50% or more of the trees in the riparian zone. The trees left standing shall be randomly distributed where feasible. A riparian management zone width is specified to vary with timber harvest type. The regulations specify that certain sixes of trees and certain numbers of conifers must remain after harvest for wildlife. The rules specify leave-tree minima tied to stream substrate type. On streams with a boulder/bedrock bed, the minimum leave tree requirement is 75 trees per acre 4 inches or larger at breast height. On streams with a gravel or cobble bed, the minimum rises to 135 trees left per acre at 4 inches diameter. The rules also limit the size of cut areas when 10% of the harvest unit lies within any combination of a riparian management zone or wetland management zone in certain types of stream areas. Again, federal practices in riparian zones in a few forests are more restrictive, in that they remove riparian areas from the timber-producing land base. Unfortunately, some national forests continue to harvest trees from riparian zones.

9. MINING

Dredging and hard-rock mining damaged many miles of Idaho salmon and steelhead streams long before dams appeared in the Columbia or lower Snake rivers. Parkhurst (1950) reported that in the late 1940s gold dredges silted the stream bed of the Salmon River for the 161 miles from Shoup to Stanley. Sunbeam Dam, constructed to provide power for a mine, completely blocked anadromous fish from the Salmon River Basin upstream from the mouth of Yankee Fork (IDFG 1920).

Mining has damaged the Florence Basin, streams in the Warren-Burgdorf area, Yankee Fork, Main Salmon, North Fork Salmon, East Fork Salmon, East Fork South Fork Salmon, South Fork Salmon, the Little Salmon River, and Bear Valley, Loon, and Camas Creeks. The Blackbird Mine completely eliminated a salmon run of over 2,000 returning adults in Panther Creek (Martin and Platts 1981). In the 1950s, hard-rock mining polluted areas downstream from Stibnite, Camas Creek, Panther Creek, East Fork Salmon River, Kinnikinic Creek, Slate Creek, Yankee Fork, and others (FST-CBIC 1957).

Mining damage extends to the Oregon portion of the Snake River Basin as well. Dredges severely altered portions of the upper Grande Ronde River (Thomas et al. 1987). Sediment bedload many miles downstream from the sediment source receives little study or attention from researchers. However, those increases over the past 125 years may have profoundly damaged winter habitat for pre-smolts.

No study of the Snake River Basin has quantified mining impacts on salmon and steelhead populations. Therefore, one can only evaluate localized case histories and extrapolate them to the basin, a process made difficult by poor documentation.

Chinook salmon and steelhead trout were numerous in Panther Creek before large-scale mining began in 1945 (Corley 1967). The Blackbird Mine eliminated the large chinook salmon runs by continuously bleeding toxic materials from the mine area (Martin and Platts 1981; Platts 1972a; Platts, et al. 1979). Panther Creek historically supported spawning runs of over 2,000 adult salmon (Reiser et al. 1982; Reiser 1986; Platts 1972b). Runs declined in the 1940s, and no salmon remained by 1962. Reduction in salmon runs closely correlates with the amount of mining in the drainage.

The IDFG recorded a large salmon kill from mining in Panther Creek in 1954.

Observers counted over 200 killed adult chinook salmon, steelhead trout, resident trout, and whitefish. Salmon placed 135 redds in Panther Creek in 1957, but none in 1961. Observers counted 13 near the mouth of Porphyry Creek in 1963. Acid mine pollution does not affect Porphyry Creek.

Adits and waste dumps of the closed Blackbird Mine bleed toxic cobalt, copper, iron, manganese, lead, and zinc into tributaries of Panther Creek. High flows cause sediments (mainly toxic) from tailing dumps and soil waste piles to enter Blackbird, Bucktail, Meadow, Big Deer, and Panther creeks. The sediments redeposit in the channel and flood plains. Twenty years after mine closure, mine waste dumps remain severely acidic (pH 3.0 to 4.0), toxic, and infertile. Deadly pollution from the mine, still in the drainage after 40 years, will continue unless society rehabilitates mining areas.

The Thunder Mountain mining area covers parts of the Marble and Monumental Creek drainages in the Middle Fork Salmon River Basin. Mining has deposited effluent into Mule Creek, then to Monumental Creek. Bums (1987) compared Monumental Creek upstream and downstream from the confluence of Mule Creek. He found that mine effluent severely degraded fish habitat. This degradation began with the first effluents and continued through 1985. In 1986, large storm events flushed the mine-produced effluent downstream.

In the East Fork of the South Fork of the Salmon River, Bums (1987) found high levels of channel fine sediments downstream from Stibnite mining operations in 1983 through 1985. Fine sediments were flushed from the channels in 1986 because of improved mining practices. Bums (1984) reported significantly more channel fine sediments downstream from an open-pit mine in the Stibnite area than in control locations upstream or in adjacent drainages. The highest level of mean embeddedness was 50% in Sugar Creek, immediately downstream from open-pit mine effluent coming out of West End Creek. Affected channels below the open-pit mine were more embedded than channels without mine influence.

In the 1930s the East Fork South Fork Salmon River ran clear. During much of the 1940s and 195Os, turbidity from mining sharply increased. Effluent from the maintailings pond alone deposited 160,000 cubic yards of sediment in the tributary Meadow Creek between 1952 and 1964 (Montgomery Engineers 1980). When humans drowned, mines shut down so the river could clear enough for victim searches.

In the South Fork of the Salmon River, a ridge that formed the Oxbow was cut through to allow a mine exploration road of less gradient to reach the river area above the Oxbow. High water subsequently cut a deep channel through the road cut. Now all water except some at flood stage passes through the breach. The USFS has considered plugging this breach to route the SFSR back into its original channel. The breach eliminated 2,900 feet of flowing river channel. The breach resulted in erosion of the river channel upstream from the breach (includes a major salmon spawning area) anderosion of stream banks downstream. A consulting firm (CH2M Hill), contracted by the USFS, estimated repair cost. The four repair alternatives ranged from $213,700 to $441,600. Although mining caused the problem, rehabilitation cost will be borne by tax- and rate-payers.

The foregoing certainly do not exhaust examples. Mining damage will continue.

Sudden failures of existing tailings ponds will release large volumes of toxic waste into salmon-steelhead waters. Many tailings ponds, like the Blackbird, will fail with the right flood or other natural event.

Several small mines in Jordan Creek so badly polluted the Yankee Fork in the 1930s that no fish or aquatic insects could be found (Rodeheffer 1935). Fishery improvements in Yankee Fork downstream from the town of Custer were not recommended because of the present and expected future impacts of mining (Rodeheffer 1935). Dredge mining for gold in the late 1800s severely altered several miles of lower Yankee Fork and Jordan Creek stream channels. Much of the natural meander pattern of the river and associated instream habitat has been lost. The Shoshone-Bannock tribe, with BPA funding, has attempted to rehabilitate parts of the Yankee Fork drainage.

10. WATER RIGHTS

Even close analysis of the highly complex issue of water rights can result in different opinions among users and administrators. The basic rule of prior appropriation prevails; that is, "first in time, first in right." Priority date is extremely important, especially in drought years. Technically, the water right with the earliest priority can take all of its allocation without regard to any water users with junior rights. In fact, many irrigators act cooperatively, voluntarily sharing water.

In the drainages affected by the endangered species listings, many diversions have priority dates from the late 1800s and early 1900s, which implies that they have been continually diverted and put to beneficial use for over 90 to 100 years. Applicants have filed for more rights since 1960 than in previous years, but these are very junior rights. In dry years, insufficient water may exist to meet such junior claims.

In Oregon many streams are over-appropriated. As in Idaho, irrigators cooperatively volunteer to share water but the result to stream flow is the same: a dry channel. Very few water diversions are measured and few records of actual water used are available. The Oregon Water Resources Commission (WRC) has placed a moratorium on new water rights in the Snake River Basin. However, the Oregon Department of Agriculture (ODA) conducted a water availability study and submitted a reservation request to meet future agricultural water needs. A reservation gives the applicants 20 years to develop the water source and apply water to the approved users. Water rights issued under the reservation "have priority over all other water rights, including instream water rights, from the same source that are filed subsequent to the date the request for reservation is filed with the Department" (OAR 690-79-030). ODA filed for 580,800 acre feet direct flow from the Snake River and 40,000 acre feet of storage from the Grande Ronde Basin (memo from ODA to WRC November 18, 1992).

We discussed purchase or lease of irrigation water rights in the section on "Irrigation Withdrawals."

11. QUALITY OF HABITATIN THE MIGRATION CORRIDOR

For fall chinook and spring-migrating sockeye and spring/summer chinook salmon, the migration corridor includes tributary and mainstem waters between the natal area and the sea. We include overwintering areas in the natal and mainstem migration corridor, and the estuary and nearshore marine waters in my characterization of the migration corridor.

11.1 OVERWINTERING HABITAT

Sockeye must incubate and hatch in gravels of the natal lake or inlet stream. They spend their first winter and last pre-smolt winter in the natal lake (Bjomn et al. 1968). Habitat quality in winter for these fish should not cause concern. We know of no deterioration that would affect overwintering survival. Presence of holdover catchable rainbow trout has unknown effects on overwinter survival of sockeye.

Fall chinook juveniles emerge in spring and depart the natal area before the succeeding winter, hence overwinter habitat requires no discussion. D. Park (personal communication) reported that a few subyearling chinook that he marked at Priest Rapids Dam in summer passed The Dalles Dam the following spring. This suggests some variability in the emigration of subyearling chinook. The subyearling movement at Priest Rapids Dam includes some summer chinook from the mid-Columbia River. Isozymes of upriver bright fall chinook and summer chinook from the mid-Columbia area do not recognizably differ. The two groups may form part of a continuum. Hence, summer chinook from that system may tend to behave slightly more like spring chinook than do fall chinook. Water temperatures in the Snake River watershed preclude a continuum between subyearling and yearling migrant chinook, so one can infer that Snake River fall chinook may more likely have obligate summer migration. In any event, over-winter habitat for Snake River fall chinook as pre-smolts will not further enter discussion here.

Fall chinook may have increased their use of the lower Clearwater River recently (Amsberg et al. 1992) in response to temperature moderation caused by Dworshak Dam or because of increased straying of non-native fall chinook into the area upstream from Lower Granite Dam.

Pre-smolt spring and summer chinook over-winter in natal tributaries where they reared in the first summer of life, or move downstream into larger waters for the winter, as evidenced by the timing of movements of young spring chinook from the Lemhi River (Bjomn 1978). Other works (Fast et al. 1991, Lindsay et al. 1989, Kiefer and Forster 1990) document both fall and spring downstream movements of juvenile stream-annulus chinook. No research establishes relative survival of fall and spring emigrants from, for example, September-October and April. Kiefer and Forster (1991) PIT-tagged fall emigrants at a Salmon River irrigation diversion, and provided evidence that chinook that could not pass the diversion because of low fall flows had higher mortality than juveniles that did pass.

Juvenile chinook move into interstices in the substrate or to undercut banks for over-winter cover (Chapman and Bjomn 1969, Hillman et al. 1988) when water temperatures drop. They may become active again during the day in fall and early spring if temperatures rise, but reenter winter cover in the late afternoon when temperatures drop.

PIT tagging has begun to provide information on survival of pre-smolts over the winter. For 1988-1989, arguably a drought winter, Kiefer and Forster (1990) provide data useful in estimating survival of PIT-tagged juvenile chinook and steelhead in the migration corridor. The mean survival from fall to arrival at the scoop traps just upstream from Lower Granite Dam equaled about 5.2 %. No means exist to separate mortality during overwintering from mortality that occurred in the migration corridor after juveniles left winter cover.

Recovery rates at Lower Granite Dam for wild chinook PIT-tagged by NMFS in natal streams in the late summer have been lower than we would expect. About 10% or less of PIT-tagged pre-smolts have reached collector dams. The available tagging data apply only to years of drought, since NMFS tributary tagging programs did not begin until 1988.

The apparent low survival could conceivably derive from tag or tagging effects, for little information exists on tag effects on survival of PIT-tagged fish in natural environments. If, as seems probable, tags and tagging prove benign in consequence, the apparent very low survival should raise concern about the quality of overwintering habitat in the Snake River Basin. Over 100 years of accelerated sediment movement caused by mining, logging, grazing, and agriculture (Sedell and Everest 1990, Platts et al. 1989) may have reduced quality of stream substrata used by juvenile salmon and steelhead in many natal areas. Many pre-smolts use the main Salmon, the main Grande Ronde, the lower Imnaha, and the Snake River, for overwintering. Thus, substrate deterioration there should also concern us. The embeddedness that results from accelerated sedimentation, and degraded stream morphology in smaller streams, reduces availability of winter cover.

We have seen intensive use by presmolts of riprap areas in spring/summer chinook streams. Chapman and Bjomn (1969) demonstrated that addition of interstices in rock piles would hold presmolts into the winter. Presmolts use riprap in the middle Snake River and likely in the main Salmon River. Sedimentation can reduce spaces within such material.

Parr to smolt survival in the Snake River appears lower than that in other streams of the Columbia River system (Table 8). We find that unsurprising for at least two reasons. First, the data for Snake River stocks derived from drought years. Second, many natal areas for Snake River spring/summer chinook lie 5,000 to 6,500 feet above sea level. It is possible that size selectivity might explain some of the apparent low survivals estimated from SNT recoveries of PIT tagged fish. However, that argument weakens in light of the low interrogation rates at LGR. It is possible that FGE at LGR is much lower than the 55% that we used from Ledger-wood et al. (1987) and Swan et al. (1990). If that is true, more smolts would reach the dam than we think. For example, if FGE were really 45% instead of 55%, the parr to smolt survivals (at LGR) for the upper Salmon River would increase to about 20%-24%. On the other hand, FGEs higher than 55% would reduce survivals below those calculated for Snake River fish in Table 6.

Table 8. Parr-to-smolt overwinter survivals of juvenile stream-annulus chinook salmon in the Columbia and Snake River Basins.

Location	Period	Survival	Source of data
John Day River	Early fall to spring	25%-35%	Knox et al. 1984
Deschutes River			
Beaver Cr.	Summer to spring	20%	Lindsay et al. 1989
Warm Springs R.	" "	20%	" "
Deschutes R.	Fall to spring	52%’	
Yakima River			
Wapatox-Chandler	Oct-Nov to late Feb-end June	16% [6]	Fast et al. 1991
Clear-water River			
Crooked R. [7]	Early fall-spring	5%-14%	Kiefer and Forster 1991
Crooked R. [8]	" "	31%	Kiefer and Forster 1990, Petrosky 1990
Salmon River			
Upper Salmon [9]	Summer-spring	26%	Kiefer and Forster

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[5]. True value could have been lower, according to authors.

[6]. Three additional years of data were included in Table 37 of Fast et al. (1991), but not used here, largely because the marking period overlapped with the recovery period.

[7]. To head of Lower Granite Pool.

[8]. To Crooked River weir only. Adjustment to Lower Granite pool would reduce survival by over 50%.

[9]. To Sawtooth scoop trap only. If converted to head of Lower Granite pool, these survivals would decrease by over half.

Table 6, continued

Location	Period	Survival	source of data
			1990, Petrosky 1990
Various tribs.[10] to LGR Dam	Late summer-spring	10%-12%	Chapman et al. 1991
Upper Salmon[11]	Summer-spring	10%-12%	Kiefer and Forster 1990[12]

Another possible explanation for relatively low recovery rates for PIT tagged fish from various tributaries upstream from LGR is tag-caused mortality. McCann et al. (1993) found that subyearling fall chinook held for only 0.5 h after tagging did not survive predation as well as control or sham-tagged subyearlings. Fish held for 96 h survived predation challenge as well as control fish. The degree to which this tag-caused differential mortality applies to juvenile spring/summer chinook tagged in summer is unknown. The wild spring/summer chinook tagged in tributaries are generally somewhat larger than the subyearling fall chinook (59 mm mean fork length) tagged by McCann et al. (1993), which may reduce tag effects.

11.2 NATALAREATO LOWERGRANITEDAM

Habitat conditions for spring migrants in the free-flowing portions of the migration corridor have received little research attention. Although Raymond (1979) reported estimates of smolt migration rates, we found no investigations of diel habitat use, feeding, or intra- and inter-specific interactions during the spring migration. This void should particularly trouble managers in light of (1) the potential competition and predation interaction between and among various groups of wild and hatchery salmonids in the corridor between natal areas and Lower Granite Dam, and (2) the apparently low survival from pre-smolt to smolt.

Survival of wild chinook salmon from the Salmon River traps near Riggins and Whitebird to Ice Harbor Dam before construction of LMO, LGO, and LGR averaged 89% (85 96-95 % for 1966-1968). After completion of LMO and LGO, survival in the early 1970s averaged but 33 % (Raymond 1979), or less than 69% per project. Survivals

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[10]. Based on interrogations of PIT tags and fish guidance efficiency of 50% for turbine deflection screens.

[11]. To head of LGR Pool.

[12]. Included as Part II in Kiefer and Forster (1991) but dated 1990.

in the first few years after project construction likely do not reflect current project survivals (A. Giorgi, D. Park, personal communications).

Numbers of migrant smolts have increased sharply in recent years. For the early 196Os, Raymond (1979) estimated that less than 6,000,000 salmon and steelhead, in total, migrated down the Snake River. Recently, managers have liberated 18 to 25 million hatchery chinook and steelhead to the corridor (Figure 25). Agencies released about 10.4 million spring/summer chinook and 8.4 million steelhead in 1992; 8.2 million chinook and 10.2 million steelhead in 1991; and 11.6 million chinook and 12.1 million steelhead in 1990 (summed from weekly reports of the Fish Passage Center). Fifty to sixty percent of the liberated "smolts" did not reach Lower Granite Dam.

High total recovery rates at collector dams for smolts PIT-tagged at traps upstream from Lower Granite pool indicate that the pool does not account for the high death rate. Recovery of smolts tagged at the Snake River trap (thus more likely to include wild spring/summer chinook) have averaged 64% (39.3% at Lower Granite, 17.4% at Little Goose, and 6.7% at McNary) (Buettner 1991) before correction for FGE. Recoveries of chinook from the Clearwater trap have averaged 8 % to 13 % lower than recoveries of fish tagged at the Snake River trap. The time required for fish from the Clearwater trap to reach Lower Granite Dam has been two to three days longer than for fish from the Snake River trap. Data on recovery and migration rates from the two sites may indicate that the catches in the Clearwater trap contain more recently-released hatchery fish not ready to migrate promptly, and more fish that will soon die. Dworshak hatchery lies closer to the Clearwater trap than any Snake River hatchery to the Snake River trap. In any event, the high recoveries of chinook tagged at the Snake River trap translate to higher survival per project than agencies and the Council have assumed to date (see A. Giorgi appendix report).

Since many millions of hatchery smolts never reach Lower Granite pool, the possibility exists that before they die, they interact negatively with wild listed sockeye and chinook. Subtle social mechanisms may operate to cause stress and higher mortality in wild fish. Large numbers of non-viable hatchery smolts may affect relative food availability. They may attract predators in a density-related phenomenon such as that reported by Beamish et al. (1992). They may communicate diseases or increase severity of infections. They may interfere with prompt seaward movement of wild smolts. Steelhead may prey upon smaller wild chinook and sockeye. Several mechanisms may operate simultaneously. Once hatchery and wild smolts reach bypasses and collection facilities, high fish densities may increase stress in wild fish. Predation may occur in gatewells and containers in the system.

Work by Bennett et al. (1988, 1990, and 1991) provides the most extensive information on the quality of the migration corridor that lies within Snake River reservoirs. The pools upstream from each Snake River dam contain channel catfish (Ictalurus punctatus), smallmouth bass (**Micropterus salmoides**) and northern squawfish (Ptychocheilus oregonensis), all known to prey upon salmon smolts. They also contain a host of exotic and indigenous fishes that may interact with juvenile salmon for food or in other ways.

Unlike many of the upstream free-flowing rivers and tributaries, which we can consider in dynamic equilibrium in the morphologic sense, Lower Granite pool changes each year. About 611,680 m^3 of sediments collect each year in the upper end of the pool, altering the bottom configuration and depth, and likely the short-term availability of macroinvertebrates, in spring and early summer. The Corps of Engineers periodically must modify the configuration of the upper pool to prevent flooding and levee damage near Lewiston and Clarkston. One option involves transfer of dredged sediments to deeper portions of the pool 19 miles downstream from Lewiston. Bennett et al. (1991) studied effects of such transfers. In a long-term sense, Lower Granite pool will fill with sediments, reducing volume of the pool, and bedload will then begin to fill Little Goose pool.

Bennett et al. (1991) reported the results of experimental in-water disposal of dredged materials. Such disposal may offer a way to provide shallow water habitats for juvenile anadromous salmonids. The main difference between disposal test areas and undisturbed reference areas was that the former held few fish in the 100-200 mm and >3OOmm size classes. Bennett et al. (1991) suggested that the disposal sites may not provide suitable spawning and rearing habitat for some species. The disposal material consisted mostly of fine sand, a substrate not favored by many macroinvertebrate and fish species for reproduction and rearing. Oligochaetes and chironomids made up most of the macroinvertebrate fauna at all stations sampled in the reservoir.

Bennett et al. (1990 and 1991) found highest salmonid abundance (juveniles) in the spring, with lower abundances progressing through summer, fall, and winter. The modal length of chinook salmon in limnetic waters exceeded that at shallow stations by about 50 mm. In spring 1988, rainbow/steelhead were the most abundant species in the reservoir, suckers were next, then chinook. In spring 1989, chinook made up the greatest numerical fraction, then largescale suckers and rainbow/steelhead. In summer in both years, non-salmonids predominated in samples. Summer sampling took chinook salmon rarely. Spring samples took 15 and 1 sockeye in the respective years. Rainbow trout remained relatively abundant through the summer in the Bennett et al. (1990 and 1991) samples, suggesting considerable residualism. Fall samples contained few rainbow/steelhead.

Bennett et al. (1991) believed that they may have produced high abundances of young squawfish in sample sites by removing larger squawfish for food sampling. They suggested that increased compensatory survival of young fish had pertinence for managers currently attempting to crop large squawfish in the BPA-sponsored predator control program.

The excellent research of Bennett et al. (1990, 1991) does not assist managers greatly in the search for information on the migratory behavior of juvenile chinook and sockeye during the spring migration. It was not designed to do so. Neither was the work oriented toward interactions between hatchery and wild smolts.

We discuss predation in reservoirs in the next report section. **A.** Giorgi, in another appendix to this BPA report, discusses effects of discharge on smolt travel time and survival. He also treats feasibility of reservoir drawdown. Thus we do not discuss these topics.

12. HYDRO PROJECT MIGRATION CORRIDOR

Transportation, bypass habitats, discharge and drawdown effects on survival, and reservoir habitat are treated in other reports (see materials by A. Giorgi and D. Park) or elsewhere in our report. However, it seems appropriate here to summarize certain information on smolt survival per project. Snake River salmon smolts that remain in the migration corridor must pass 8 hydroelectric project pools and dams before they reach Bonneville tailrace and unobstructed routes to the sea.

Sims et al. (1983) estimated survival rates per project for 1973-1982. Survivals ranged from 55% to 85% per project in that period. Various workers have attempted to relate these survival estimates to river discharge (e.g., Sims and Ossiander 1981, COFO 1982, Sims et al. 1983, and Berggren and Filardo 1991). Giorgi (1991), Kindley (1991) and Chapman et al. (1991) expressed concern over the quality of the survival estimates of 1973- 1982. No measures of precision or assessments of accuracy of the data were reported by Sims et al. (1983, 1984). No data exist on project mortality for subyearling chinook or sockeye of the Snake River. Most workers have simply assumed that mortality for yearling chinook offers a surrogate estimate applicable to other salmon species or races.

Giorgi (1991) noted that many factors that affected early survival estimates have changed. Working groups of the NWPPC are now attempting to estimate project-related mortality for the several data years. Survival per project in the present hydro system very likely differs from survivals in the 1970s, if only because of various bypass measures, lower debris abundance, and management of gas supersaturation. Predator populations probably differ. Many more hatchery salmon and steelhead now use the corridor than in the 1970s.

Current survivals for various segments of the Snake River hydro system can best be estimated with interrogations and re-releases of PIT-tagged smolts at the beginning and end of each reach of interest (Skalski and Giorgi 1992, NMFS/UW 1993). Until reach-specific survival data become available, managers will flounder as they attempt to deal with the important water management regime of the Snake and Columbia River. Travel time has been used as a surrogate for survival, with many attendant confounding variables (see Giorgi 1991). There is no substitute for reach-specific tagging studies.

In the absence of other data, PIT-tag interrogations of smolts released at the Snake River trap (SNT) offer a temporary substitute for reach survival studies. Four years of interrogations are available. The rate of interrogation at LGR in the most recent four years (1988-1991), in which no spill occurred in late April, May, or early June, equaled about 39%. Ledgerwood et al. (1987) and Swan et al. (1990) report fish guidance efficiencies (FGE) of about 55% at LGR in the most recent tests. We can use these two statistics to estimate a survival through LGR pool of about 71%. We cannot regard this pool survival as appropriate for all hydro reservoirs on the Snake River. For example, the median arrival of PIT-tagged smolts at LGR occurred after about 16 days for groups early in the migration season and in as little as 2.4 days in mid-May. The overall median arrival took about 8 days. FPC (1988) reports indicate that smolts often take but 3 or 4 days to pass through a project (FPC 1988).

Another way to examine LGR project survival is to use a minimalist approach. That is, one can estimate survival to LGR from the Snake River trap on the basis of actual interrogations only (Buettner 1991) at all three collector dams in total. Average interrogations for 1988-1991 at LGR, Little Goose Dam (LGO) and McNary Dam (MCN) equaled 64%. Thus, at least 64% of the fish released at the Snake River trap reached Lower Granite Dam. This sets an extreme outside estimate of pool mortality in the LGR project. It cannot provide an estimate of project loss because the fish interrogated at LGR did not pass through the turbines at LGR.

Another approach would examine interrogation data for 1988 and 1989, years of no spill at Snake River projects and of zero or negligible spill at McNary Dam. One can use an estimated fish guidance efficiency, together with interrogation rates, to estimate reach survival. Of 9,989 PIT-tagged chinook smolts released at the Snake River trap for the two combined years, interrogators at LGR detected 3,621 in 1988 and 1989 combined. An additional 2,962 passed turbines, if we assume 55% FGE. We deduct 1,910 fish interrogated at LGO from the fish that entered LGR turbines. This leaves 1,053 PIT tagged fish "in the river." At MCN, 781 PIT tagged fish were interrogated. Using a 75% FGE for McNary (Swan et al. 1982), we estimate that 781/1,053/0.75 represents survival through LGO, Lower Monumental Dam (LMO), Ice Harbor Dam (IHR), and MCN (excludes turbine mortality on the group not diverted to the bypass at MCN but includes turbine loss at LGR). Reach survival (four projects) thus equals about 74%. Survival per project would thus equal about 92.8%.

A project survival of about 93% in the low-flow years of 1988 and 1989 would lead us to suggest that Council and BPA modelers now may use survival estimates per project that are too low. Modelers usually assume about 15% loss in turbine passage alone. The foregoing exercise leads us to suggest that project survivals may be higher in recent years than was the case in the 1970s. At minimum, the estimate of 7.2% loss per project in drought years with passage through turbines should encourage us to get on with directed studies of reach survival. The estimates that we offer indicate per-project survivals in the absence of bypass systems in 1988-1989[13] except at McNary Dam, for all fish passed through turbines (a few may have passed through navigation locks).

We cannot estimate project loss from MCN to Bonneville Dam (BDA). No PIT tag data exist to permit the calculation.

13. BYPASS-RELATEDHABITATS

The U.S. Army Corps of Engineers (USACE), over the past 20 years, installed bypass systems that divert salmon and steelhead smolts from and around turbines at six hydroelectric darns in the Snake and Columbia rivers. In the 199Os, the USACE plans to

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[13]. PIT tagged fish that arrived at MCN passed through turbines at LGR, LGO, LMO, and IHD. Had they passed into the LGO bypass system they would have been interrogated and/or transported to BDA.

retrofit two more dams with bypasses.

The design of contemporary bypass systems includes submersible traveling screens that project into turbine intakes and divert a fraction of migrating smolts upward into gatewells (Figure 30). Flow upward into the gatewell usually totals 10 to 15 m^3/s. Vertical barrier screens prevent smolts from exiting the gatewells with the flow that reenters the turbine intake. From the gatewell, fish may pass through an orifice that delivers them to a bypass conduit. The conduit carries them across the dam, then to some point in the tailrace downstream from the dam or to raceways that hold them for delivery to barges or trucks for transport to the lower Columbia River. Since first installation of deflection screens in the 1970s, screen types, operations, and bypass configurations have evolved. Early systems lacked the sophistication of current models, and damaged smolts more.

13.1 DESCALING

In 1973, the mean descaling rate for smolts [14] at Little Goose Dam (LGO) equaled about 14 % (Ebel et al. 1973). For Lower Granite Dam (LGR), the most upstream project that smolts pass, Park et al. (1976) observed a descaling rate in the fish sampling facility of 13% in 1975. By 1976, screen modifications had somewhat reduced descaling, and the mean rate of descaling equaled only 7% at LGR and 11.5% at LGO (Park et al. 1977). In 1977, descaling at LGR again increased to 26% for chinook salmon and 17% for steelhead . Scully and Buettner (1986) found low rates of descaling at release from hatcheries and at traps upstream from LGR.

Researchers documented severe descaling at several dams in the 1980s. From 1982 to 1989, the mean descaling rate at LGO averaged 7.1 to 26.0% for chinook salmon and 3.2 to 25 % for hatchery steelhead (Koski et al. 1990), with a maximum of 49 % descaling during peak passage of smolts on 11 May, 1983 (DeLarm et al. 1984). Descaling rates at John Day Dam averaged 12% for yearling chinook, nearly 10% for steelhead, and almost 13 % for sockeye for 1989 through 1991 (Hawkes et al. 1992). Descaling for subyearling chinook averaged under 6% in the same period, probably a result of the less-smolted condition of most subyearlings. For 1989-1991, descaling in the Bonneville Dam migrant sampler averaged under 7% for yearling chinook, 10% for steelhead, and about 27% for sockeye. At both John Day and Bonneville dams, descaling tended to be highest in 1991 (Hawkes et al. 1992). Hence, in spite of improvements in various bypass components, fish descale appreciably in the systems.

Many descaled fish die. Johnsen et al. (1990) and Hawkes et al. (1991) reported that 27 and 30%, respectively, of descaled fish collected for observation at Bonneville Dam (BDA) died within 48 hours when held in benign conditions. Virtually no nondescaled control fish died. In delayed mortality tests after handling, Hawkes et al. (1992) found that descaled fish made up about 60% of the fish that died, but only 8.4% of the sample

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[14]. A descaled fish is defined as one with loss of 40% of the scales in two or more of ten body sectors (Koski et al. 1990).

tested.

Park et al. (1984) marked nondescaled yearling chinook smolts at McNary Dam (MCN), and released groups in the gatewells and at various points downstream in the bypass system. They found that descaling increased by 4 % between the gatewell and the lower end of the bypass conduit. This evaluation only assessed descaling associated with a portion of the bypass system because it did not include abrasion caused by encounters with submerged traveling screens. The bypass system at BDA increased descaling in 1991 between the upper end of the bypass conduit and the bypass outfall at the tailrace (L. Gilbreath, NMFS, unpublished). River-run smolts appeared particularly vulnerable to descaling. In 1991, for example, passage through the conduit increased descaling of river-run migrants (as opposed to hatchery test fish) from 1.2 to 8.5%,0.3 to 11.696, and 1.4 to 28.696, respectively, for yearling coho (0. kisutch) and yearling chinook in early May, and for subyearling chinook in mid-July.

Although bypasses cause descaling, fish may lose some scales as they pass through debris-laden trash racks just upstream from turbine intakes, even though USACE operators regularly rake debris from racks. Also, spill and turbine passage may descale fish. Fish bypassed repeatedly during their downstream migration through several, or potentially up to eight dams, may have a high probability of incurring repeated descaling associated with bypass facilities, and perhaps with other routes of passage.

Descaling particularly affects sockeye salmon. Sockeye descale more easily than any other Columbia River salmonid, and more die after losing scales. Johnsen et al. (1990) reported descaling rates for sockeye at BDA that ranged from 13.8 to 23.5% in 1988 and 1989, rates three to five times greater than those observed for any other salmon species sampled at the same time in the same facility. Correspondingly, death rates in sampling facilities were three to five times greater for sockeye (Johnsen et al. 1990) than for other spring-migrating salmon. Hawkes et al. (1992) reported higher descaling rates in sockeye than in other species sampled at John Day and Bonneville dams.

13.2 INJURIES AND DEATHS

Descaling offers but one manifestation or symptom of bypass effects. At MCN in 1988 and 1989, head and body injuries for all species combined equaled 4.1 and 4.3%, respectively (Koski et al. 1990). Technicians classed nearly 14% of the collected yearling chinook salmon as either descaled or injured. Koski et al. (1990) also reported over 20% descaling or injury in steelhead and sockeye. One cannot directly assess the degree to which bypass facilities contributed to the injuries.

High rates of descaling and injury in facilities designed to protect smolts indicate that substantial bypass-associated mortality may occur at some facilities. The annual reports of the Fish Transportation Oversight Team (e.g.,Koski et al. 1990) record part of this mortality. The reported loss, which typically ranges from one to three percent (DeHart 1987) at collector dams (LGR, LGO, and MCN), seems relatively minor. However, the loss rate derives only from counts of smolt carcasses in raceways. Such raceways hold smolts for 24 to 48 hours before release or transport. Thus, the carcass counts, themselves sometimes incomplete, represent only a part of total bypass-related mortality.

Valid estimates of bypass-associated mortality at a given dam ideally should incorporate all losses that occur from the point at which smolts first encounter deflection screens to a point well downstream from influence of the outfall discharge downstream from the dam. One should define that downstream point as the location at which the bypassed smolts become entirely free of the effects of bypass passage. This definition should hold for transported fish, for which the point at which bypass effects disappear may lie well downstream from the transport release location.

Matthews et al. (1987) confirmed that deleterious effects of bypass can continue to express themselves long after fish have left the bypass system. Their investigation assessed yearling chinook survival associated with bypass through LGR in 1984 to 1986. They collected groups of fish from the gatewell and from a point near the lower end of the bypass, the pre-separator, and held them in a salt-water environment for at least 43 days. The 43-d test revealed surprisingly high mortality associated with the gatewell-to separator component of the bypass system. Matthews et al. (1987) observed the following mortality rates:

	Year		
Source of fish	1984	1985	1986
Gatewell	1.0%	7.9%	3.1%
Pre-separator	8.6	12.3	8.2

Clearly, smolts that passed through the bypass system to the pre-separator incurred higher mortality in each year than those that had not traversed the system. The difference in mortality between the two sampling sites equaled 7.6,4.4, and 5.1% in 1984-86, respectively. The incremental loss may have been associated with unwillingness of smolts to enter the downwell.

L. Gilbreath (NMFS unpublished data, 1991) found at Bonneville Dam that delayed mortality (48 h holding) in fish that transited from the upper end of the gallery to the outfall equaled an incremental 1.0 and about 4.5%) respectively, for spring and summer migrant chinook.

Matthews et al. (1987) reported their results 12 years after the USACE installed the first traveling screens at LGR. They thought that stress caused by extended swimming at a point just upstream from the downwell in the bypass conduit might have caused the delayed losses. Had observers relied on counts of carcasses in the collection system raceways to estimate mortality in the LGR bypass system, they would have concluded that bypass-related losses were about 0.5,0.3,and 0.3% in the years 1984 to 1986 (Koski et al. 1985, 1986, 1987). Matthews et al. (1987) demonstrated a mean loss of 5.8% in the same period. Thus, the identification of delayed effects permits managers to search for, and rectify, problem areas within the bypass system. Neither the short-term delayed losses in 1991 at BDA nor the 43 d delayed losses reported by Matthews et al. (1987) include losses of concentrated bypassed fish to predators downstream from bypasses.

13.3 PREDATION

Mortality downstream from the bypass outfall can be substantial, particularly for fall chinook, which move toward the sea as subyearlings during summer. Elevated water temperatures then increase predator activity and consumption rates. Sims and Johnsen (1977) first suggested the potential for high losses in the bypass-concentrated stream of fall chinook subyearlings. They reported that in the summer of 1976, branded subyearling chinook released at night at the MCN northshore outfall survived at half the rate of any group of fish released at any other site or time within the tailrace zone of that dam. They attributed the mortality to predation in the vicinity of the outfall.

Recent research at BDA second powerhouse identified high subyearling chinook mortality associated with the bypass (Ledgerwood et al. 1990). Although the work presented no absolute estimates of bypass mortality, it showed that fish released in the bypass conduit had significantly lower survival than other treatment groups. For four successive years, Ledgerwood et al. (1990) released test groups into the upper end of the bypass conduit, in the turbine entrance just downstream from traveling screens, and at a point 2.4 km downstream. Subsequently, freeze-branded fish were recovered in the Columbia River estuary. The recovery points downstream about 150 km allowed time for much delayed mortality to express itself. Combined data for four years of tests indicated that fish that passed through the turbines survived at a rate significantly higher than fish released in the bypass[15]. In the period 1988 to 1990, comparisons of bypass and frontroll releases 30 m downstream from the dam showed that about 8% more fish survived in the frontroll releases, which suggests that bypass-related losses, including predation on bypassed fish, equaled about 8%. Significantly higher survival for fish released 2.4 km downstream from BDA leads one to believe that predation was intense downstream from the dam. Furthermore, survival for fish released at the downstream site near mid-river exceeded that in shoreline releases (Ledgerwood et al. 1990). D. Park, in another appendix to the present BPA report, discusses point of release of transported fish.

Test fish released in the upper section of the bypass conduit at BDA second powerhouse may conceivably suffer stress from swimming for extended periods in the conduit. The water velocity of 0.79 m/s at the release point in the conduit may have permitted such holding. Park et al. (1984) showed that fish released in the upper end of the MCN bypass conduit did not, on average, move readily through the conduit. Over the length of the bypass conduit, or gallery, a velocity gradient exists. Lower velocities occur in bypass conduits at the upstream end. Velocities increase downstream in the conduits as more gatewell orifices feed water into the conduit, a pattern common to most bypass systems. Delay that increases stress would likely increase loss to predators downstream.

Delay occurs elsewhere in bypass systems as well. Fishery agencies evaluate delay in gatewells as orifice passage efficiency (OPE), defined as the percentage of fish in gatewells that exit them **via** gatewell orifices in 24 hours. Seventy percent is considered

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[15]. According to a research update reported in the Quarterly Report of the Northwest and Alaska Fisheries Center, July-September 1991.

an acceptable OPE. The complement of 30% should concern river managers. Park et al. (1984) found that 25% of marked spring chinook placed in gatewells did not exit the bypass system in 32 to 56 hours. Ten percent never appeared downstream in 68 hours, when the experiment ended. The OPE indicator has varied rather widely in tests at various dams and times. Residence in gatewells for extended periods is unlikely to benefit smolts. Cumulative delay in migration is often stated as deleterious to smolts, compromising the naturally-programmed timing of ocean entry (CBPWA 1991). It can lead to increased opportunity for descaling and stress to occur. Large predators, such as the larger steelhead smolts, may consume smaller smolts of other species, such as sockeye and wild yearling chinook salmon. In any event, prompt movement of smolts downstream and into the sea has been thought by agencies to be important for migrating smolts (Raymond 1979, 1988).

Subyearling chinook salmon that emigrate during the summer months are not the only race or species to suffer from concentrations of predators that stage downstream from bypass outfalls. Predators also consume spring-migrating smolts near bypass outfalls, although probably at lower rates than documented for summer-migrating subyearling chinook salmon. Predator activity and consumption rate increases with warmer temperatures, placing summer migrants at greater risk.

Traveling screen deflectors guide smolt population fractions that vary from dam to dam and species to species. The fish guidance efficiency (FGE) for yearling chinook, for example, ranges from near 50% (LGR) to perhaps 70%. Screens guide smolts distributed across the entire Snake or Columbia rivers at some prevailing efficiency and then concentrate them in bypass conduits. If bypassed, rather than transported, the fish enter the dam tailrace, concentrated in a stream of perhaps 15 m^3/s, or about 0.2% to 0.3 % of the Columbia River flow in the case of JDD. Even if the outfall delivers smolts to water that flows too fast for predatory fish to occupy, the latter can stage further downstream in less-swift water and target the concentrated stream of prey.

Concentrated streams of prey attract opportunistic predators (Krebs 1978, Glasser 1979, Vigg 1988). Thompson (1959) noted that squawfish abundance increased at points of prey concentration, such as at release locations for hatchery fish. Squawfish, the dominant fish predator in the Columbia River (Rieman et al. 1991), may have increased in abundance and become more widespread since the 1950s. Bennett et al. (1983) found that young-of-the-year squawfish were the numerically most abundant fish species in LGO pool. They also noted that larger northern squawfish in April and May, 1980, ate more salmonid smolts than other prey.

Predators such as squawfish can temporarily occupy water of higher velocity than they may prefer, if food intake justifies the greater energy expenditure (Puckett 1983, Glasser 1979, Krebs 1978, Vigg et al. 1988, Vigg 1988), although very high velocities will exclude them (Paler et al. 1988). Studies in JDD pool indicate that about three-fourths of predation on salmonid smolts takes place away from JDD and MCN, throughout the main body of the large pool (21,000 ha) (Rieman et al. 1991). However, predation rates per km in JDD pool are 50-fold greater immediately downstream from MCN than rates in the rest of the reservoir. The zone in MCN tailrace that makes up only 0.3 % of the JDD pool area hosts about 21% of total reservoir predation (Rieman et al. 1991, Beamesderfer et al. 1991). Thus, predation concentrates near MCN. Petersen et al. (1991) noted that the highest consumption indices were observed during summer in the tailraces of MCN, JDD and BDA. Squawfish concentrate in tailraces in spring as well, but have lower consumption indices.

Poe et al. (1991) and Vigg et al. (1991) indict squawfish as the principal predator on migrating smolts. Rieman et al. (1991) and Beamesderfer et al. (1991) show the most intense predation in areas of smolt concentration. These observations support the hypothesis that bypass outfalls increase predation downstream. Enhanced predation probably causes much of the high bypass-related mortality at BDA second powerhouse (Ledgerwood et al. 1990). The effects elsewhere of prey concentration by bypass systems have not been evaluated. Even the two bypass facilities considered by fishery agencies as "state of the art" at JDD and LGO have never received holistic evaluations.

Points at which the USACE releases transported smolts downstream from BDA may also attract predators. Solazzi et al. (1991) demonstrated that releases of coho salmon, transported from the hatchery, at Tongue Point, about 224 km downstream from BDA, had 1.56 times the survival of groups released near BDA tailrace. D. Park (1993) discusses this point further in another appendix report.

Even a few hours in a raceway can reduce stress in bypassed fish (Monk and Williams 1990, L. Gilbreath, unpublished). Other research (Schreck et al. 1985) shows that physiological indicators of stress decline in smolts held 24 to 36 h. This suggests that bypassed fish that are not transported may benefit from being held in acclimation ponds downstream from bypasses. With volitional egress and predator protection, smolts could exit the acclimation ponds voluntarily. Alternatively, egress could be provided only at night, or with a system that varies the actual outfall delivery point across some segment of the river to confound predators. Predator control programs may reduce predator concentrations in and near dam tailraces.

The alternative to repeated exposure to dam and bypass passage involves collection of smolts at dams with bypasses, and transportation to a point downstream from the last dam (Bonneville Dam (BDA)). Three dams currently have facilities for collection: LGR, LGO, and MCN dams. D. Park (1993) discusses the transportation option at length in another appendix.

14. LOWER COLUMBIA RIVER HABITATS

As we noted in the foregoing discussion, predators concentrate near high prey densities. Ledgerwood et al. (1990) estimated that predators took 7% of subyearling chinook released as part of the tests of survival at Bonneville Second Powerhouse, in the 2.5 km between Bonneville Dam and Hamilton Island.

Solazzi et al. (1991) reported over 50% better survival for hatchery coho transported to mid-river at Tongue Point than for similar groups released near Bonneville Dam tailrace. This finding, if it applies to other species and times of migration, may indicate the most important single tool for improving survival of Snake River listed salmon. On the basis of information available today, we believe no other single mitigative technique yet proposed would provide a similar gain in survival. Continued use of the Tongue Point area for a release point may attract predators, negating part or all of the apparent survival gain. Some species may spend longer in the estuary than the coho used by Solazzi et al. (1991); others may need the 128-mile passage from Bonneville to Tongue Point for physiological development. Intensive research should proceed on these critical points.

Sherwood et al. (1990) estimated that the estuary of the Columbia River lost, from 1870 to 1970, 20,000 acres of tidal swamps, 10,000 acres of tidal marshes, and 3,000 acres of tidal flats. These losses amount to a respective 78%, 62%, and 7.1% of the original 26,OOOacres of swamps, 16,OOO acres of marsh, and 42,OOOacres of tidal flats. Sherwood et al. (1990) further estimated an 80% reduction in emergent vegetation production, and 15% decline in benthic algal production.

Levy and Northcote (1982) and Reimers (1973) documented extensive use of estuaries by juvenile chinook. Levy and Northcote (1982) found only a few sockeye in the Fraser River estuarine marshes in spring. Rich (1920) found that subyearling chinook used the Columbia River estuary in all months of the year. Fish-of-the-year were still abundant until November, and some used the estuary over the winter. One would expect upriver bright fall chinook from the Snake River to use the estuary for some period that probably depends upon their size when they arrive. Snake River fall chinook juveniles normally would rear during the downstream migration in the free-flowing Snake and Columbia rivers. If transported, they may depend upon the estuary for growth to a size appropriate for ocean entry.

The degree to which LGR and LGO pools serve as substitute nurseries for subyearlings remains uncertain, as does the survival of chinook juveniles in those substitutes in comparison to that in the lower migration corridor and estuary. We question the desirability of delivering subyearlings of maladaptive size to a lower Columbia River and estuary that has dense predator populations. Those predators live in a clearer environment and lower summer discharges than occurred before upstream reservoir storage. They have access to large releases of hatchery fish and shad. They likely have keyed upon tailrace concentrations of prey, and upon limited areas of release of barged smolts. Rich (1920) found subyearling chinook rearing in the estuary through late fall. Subyearlings leave the free-flowing Hanford Reach at about 70 mm, but rear in McNary pool for some weeks before they depart, many at lengths over 100 mm. We believe upriver bright subyearlings, in predevelopment conditions, likely entered the sea at 100-130 mm.

Chapman et al. (1991) discussed the potential for negative interactions of the exotic American shad (Alosa sapidissima) and juvenile salmonids in the migration corridor and estuary. Numbers of shad in the Columbia River have increased sharply in recent decades (Figure 31). In the period 1967-1976, adult shad counts at Bonneville Dam averaged about 250,000. For the next decade they averaged under 1,000,000. Counts for 1989-1992 have averaged near 2,500,000, far higher than the counts of all salmonids combined.

Young-of-the-year shad pass through the estuary from September through December, and yearling shad use the estuary all year. Dawley et al. (1984) found yearlings at Jones Beach (RKm 75) from April through September, the period of their sampling. Juvenile shad prey on the most abundant foods (Walburg 1956, and Levesque and Reed 1972). Shad in the Columbia River estuary consume amphipods, calanoid copepods, cladocerans, and insects (Durkin et al. 1979). Hammann (1981) stated that shad in the Columbia River estuary consumed calanoid copepods, Neomvsis mercedis, Daphnia sp., and insects. Juvenile salmonids eat the same foods (McCabe et al. 1983). Sockeye appear to move rapidly through the estuary, hence interactions with juvenile shad may not affect them. The comparatively high abundance of Columbia River sockeye indicates broadly that shad have not had major effects on sockeye.

Simenstad and Wissmar (1983) cautioned that the estuary may limit potential summer rearing production for chinook subyearlings. For example, Reimers (1973) noted that growth rates of juvenile chinook in the Sixes River estuary declined at chinook populations that exceeded about 100,000 juveniles. Natural mortality should increase in chinook populations as individuals remain small longer (Parker 1971). However, Pearcy (1992) notes that some evidence contradicts this hypothesis (Mathews and Ishida 1989, and Holtby and Healey 1986). Pearcy suggests that when ocean conditions are favorable, large smolt size may confer little survival advantage. The converse would be that when ocean conditions are unfavorable (or perhaps even average), large smolt size and rapid growth aids survival.

15. NEARSHORE MARINE HABITATS

Healey and Groot (1987) state that ocean-annulus chinook enter the sea (Georgia Strait) at 70-80 mm fork length, usually in June or July, and rear close to shore and in sheltered waters for several months. Chinook subyearlings from the Nanaimo River used the estuary until late July (Healey 1980a). Purse-seine catches offshore in the Strait of Georgia included mainly yearling ocean-type chinook before May. In late May and June, subyearlings increased in catches, as did yearling stream-annulus chinook. By mid-August, yearlings disappeared from catches. The catch of sub-yearlings in marine areas coincided with movement out of the Nanaimo River estuary. Some subyearlings remained in the near-shore areas until November. Healey (1980a) notes that the sequence in which yearling ocean-type chinook give way to yearling stream-type juveniles, which in turn decline as subyearling ocean fish build up, is typical for the Gulf Islands region of British Columbia.

Miller et al. (1983) set purse seines offshore from Oregon and Washington from Tillamook Bay (ca. 45 degrees N. latitude) northward to Copalis Head (ca. 47 degrees 30 minutes N. latitude) in spring (27 May to 7 June, 1980), summer (4-15 July 1980), and early fall (28 August to 8 September, 1980). They found young spring (and/or Snake River summer) chinook mostly in the Columbia River plume and northward, and only during the early cruises. They caught fall chinook more uniformly throughout the sampling area and over all cruises. Fork lengths averaged 166 mm on cruise 1,190 mm on cruise 2, and 273 mm on cruise 3. Most fish were taken no more than 30 km offshore. Miller et al. (1983) thought their first cruise was somewhat late to capture many Columbia River yearling chinook. They noted that median passage of yearlings at Rkm 75 (Jones Peach) was 11 May, and average speed of movement to rkm 16 was only two days.

Miller et al. (1983) stated that they caught marked fish of Columbia River origin only on southward-facing net sets, almost entirely to the north of the plume, and only on cruise 1. These findings indicate a northerly movement of stream-annulus chinook from the Columbia River. Cruise 1 captured 44 sockeye, while later cruises took but 1 and 2 (Miller et al. 1983). These fish very likely originated in the Columbia River. Their disappearance indicates prompt movement, most likely northward.

Hartt (1980) summarized tag recoveries for juvenile sockeye tagged in the Fraser River. Those data indicated a rapid movement from the home estuary to the Gulf of Alaska soon after the juveniles entered the sea. Columbia River sockeye likely behave similarly. Hartt's analysis showed that juvenile sockeye during their first summer in the sea migrated along the coast to the northern, western, and southwestern parts of the Gulf. One Fraser River fish had travelled 1,500 nautical miles to southwest of Kodiak Island by the end of August of the first summer of ocean life. Another had migrated 1,100 nautical miles to near Prince William Sound by 9 August.

Fisher et al. (1983) captured one Dworshak, and three McCall hatchery yearling chinook in purse-seine sets in 1982. The Dworshak chinook was captured south of Cape Lookout (south of the plume). Two McCall chinook were taken north of the Columbia River plume, both near Willapa Bay, and one just south of the Columbia River mouth, at Seaside. Sets north of the plume took eighteen sockeye June 7-10, and a very few scattered individuals at other times. In 1983, Fisher et al. (1984) captured one McCall fish just south of the Columbia River, and one Rapid River fish off Willapa Bay in early May. Sets in May 1983 just north of the plume took 54 sockeye on May 21. Fisher and Pearcy (1985) caught two Lookingglass Creek chinook on 29 May, 1985, at Cape Disappointment, just north of the Columbia River, and five McCall Hatchery fish on the same date and at the same location. They took several sockeye north of the Columbia River in June.

Hartt (1980) noted that three juvenile chinook released in August in the northeastern Gulf of Alaska, near the coast at N. 58 degrees latitude, were recovered in the Columbia. They had migrated 1,000 nautical miles as juveniles in the first summer of ocean life. All three adult returns were probably spring chinook, as they were captured in the Columbia River between 17 March and 25 May. The one fish taken on May 25 could also have been a summer chinook. One juvenile chinook tagged in the northern part of Hecate Strait on 20 July 1969 was recovered in the Columbia River on 26 April 1970 as a spring chinook. Hartt (1980) stated that the four recoveries demonstrated more northerly movement of spring run fish than of fall chinook. Hartt and Dell (1985) found that sockeye and chinook, after the first summer in the Gulf of Alaska, moved out in the Gulf for the first fall and winter. One sockeye, tagged about 500 nautical miles south of Kodiak Island and about 1,500 miles northwest from Astoria, returned to the Columbia River. Thus, at least some Columbia River sockeye use the offshore North Pacific.

Healey (1991), examining the information on ocean recoveries of marked salmon, suggested that most ocean-type chinook salmon do not disperse more than about 1,000 km from their natal river, and do not often move far from shore. However, stream-type chinook disperse much more widely, and more often appear in research fisheries well offshore. Healey speculated that chinook from Washington and Oregon probably used areas mainly in the eastern North Pacific, with greatest concentrations over the continental shelf waters along the North American coast.

Miller et al. (1983) calculated a growth rate of 1.9 mm per day for a 271 mm marked fall chinook from a group released at the hatchery at 90-100 mm. This rate exceeds the 1.32 mm per day calculated by Healey (1980a) for fall chinook in the Nanaimo River estuary. Hartt (1980) estimated that sockeye from the Fraser River grew at l.l-1.6 mm per day in the first summer while moving at 7.6-14.4 nautical miles per day. Loeffel and Wendler (1969) showed extremely rapid growth in length for both ocean- and stream-type chinook in the first marine summer, although they calculated that ocean-type fish grew more rapidly.

Pearcy (1992) states that the early ocean life of juvenile salmonids "appears to be a dangerous period in their life history." Hartt (1980) summarized some principles pertinent for the ecology of juvenile sockeye and chinook salmon in the critical first summer of ocean life:

1. The high concentration of juvenile salmon in a limited area would seem to make them more vulnerable to predation and disease than if they dispersed widely. The main predator scars noted in sampling were from lampreys, seals, sea lions, sharks, and other predaceous pelagic fishes.

2. The nearshore distribution in the first summer in the Gulf of Alaska minimizes overlap with salmon that have spent the first winter or more at sea. This may minimize competition and cannibalism. It also minimizes exposure to large offshore predators like albacore (Thunnus alalunga), pomfret (Brama japonica), and jack mackerel (Trachurus svmmetricus).

3. Although juveniles use the pathways that adult salmon use to return to natal streams, predation by adults on juveniles was rare.

4. Large masses of juvenile salmon migrate continuously through a relatively restricted coastal belt. The band of fish extends over 1,000 nautical miles for at least three months. This raises interesting questions about stock and species interactions and effects on the food supply.

5. Little information exists on the extent to which juvenile salmon use inside passages during coastal migration. Movement in inside areas would place them in position to compete with smaller salmon from local production areas.

Mathews (1984) considered the causes of mortality in the first few months of ocean salmon life as elusive, variable from year to year, and dependent on complex ecological interactions. Pearcy (1992) emphasized a need for formulating testable hypotheses and focusing research on specific processes that affect marine survival.

16. DENSITY INTERACTIONS AT SEA

Several researchers have reported work that indicates that oceanic carrying capacity can be taxed, with feedback density effects in salmon populations. Adult size tends to decline in large populations of Fraser River pink salmon (Peter-man 1987). WDF (1992) notes that pink salmon average weight has decreased since the 1970s during a trend toward larger hatchery populations. Pink salmon weight should increase with temperature increases that have occurred in the Gulf of Alaska. Decreased mean size when increases are expected indicate operation of density-dependent factors. WDF (1992) also reports that the Japanese chum salmon culture program has increased enough so that density-dependent factors influence the population.

Marine survival of sockeye, once thought to vary little, has been estimated in Lake Washington sockeye to vary from 4% to 20% (Thorne and Ames 1987). Rogers (1980) reported declines in mean weight of sockeye in various age groupings as escapements of the brood year increased, suggesting density-dependent growth effects at sea. Eggers et al. (1983) found that mean length of returning sockeye in Bristol Bay related inversely to magnitude of the return. They noted that the effect of density dependent growth was reduced in years of higher ocean temperatures, suggesting that temperature effects moderated depression of growth in years of high fish density. Peterman (1984) showed significant decreases in adult body size and marine growth rate in sockeye when large numbers of sockeye reared in the Gulf of Alaska. Peterman (1987) reported that density-dependent processes, associated with available food during early ocean rearing, can reduce fish size. In his view, the density-dependent effects arise mainly during early ocean life, probably from food competition. Peterman suggested that sockeye management should take a broad, rather than a stock-specific, perspective that treats the ocean rearing area holistically.

Interactions may involve non-salmonids as well. Walters et al. (1986) report an inverse relationship between cod (Gadus macrocephalus) and herring (Clupea hareneus pallasi) in the Hecate Strait, British Columbia. Walters et al. (1986) recommend coordinated management of cod and herring to prevent the two fisheries from destabilizing each other's fishing opportunities. Salmon, particularly chinook, use herring as a key food supply. The possible cod-herring-salmon interaction represents but one of many possible interspecific interactions that man can affect by management policies.

Mass enhancement with fish culture should particularly concern us as a potential depressant of wild stocks. Prince William Sound pink salmon (WDF 1992), and Japanese chum salmon (Kaeriyama 1989) have declined in mean size as mass enhancement proceeded. Kaeriyama expressed concern that the enhancement program may have exceeded the ocean carrying capacity and may pose a risk to other salmon species. In 1990, total annual hatchery smolt production (202.5 million) plus estimated wild production (about 145.2 million) equaled 347.7 million smolts in the Columbia River, while historic wild smolt abundance equaled about 264.5 million (Kaczynski and Palmisano 1992). The hatchery plus wild output of fall chinook in 1990 totaled about 219.4 million, while historic natural production equaled about 89.2 million (Kaczynski and Palmisano 1992). This should alarm managers concerned with the status of threatened Snake River fall chinook. The subyearlings from the Snake must now compete with more summer-migrating fish than ever before in a reduced estuary and Columbia River plume much altered by storage in the upper Columbia. Kaczynski and Palmisano (1992) suggest that limited food supply in the lower Columbia River and estuary leads to brief residence time, which leads to reduced size at ocean entrance. Reduced size makes juveniles more subject to predation (Parker 1971).

17. TRENDS IN WATERDISCHARGE

17.1 EFFECTS OF FLOW ON STREAM REARING PHASE

The long-term trend in unregulated water discharge from the Snake River Basin, as indicated by discharge of the Salmon River at Whitebird, indicates a cycle over the past 80 years (Figure 32), with a possible 60-year periodicity. A cosine function seems to fit the data best ($F = 19.9, p = 0.001, R^2 = 0.20$). The least-squares linear trend does not differ from a zero slope ($t = 0.67$, $p = 0.51$, $R^2 = 0.01$).

The recent drought, of course, falls in the lower portion of the cycle in Figure 33. Egg to smolt survival in wild stocks will depend in part on the annual hydrograph. During higher flows, temperatures for pre-spawning maturation and overwintering will remain more favorable than during drought. As Chapman et al. (1991) speculated, the worst of all possible habitat worlds for overwintering spring/summer chinook occurs after several years of drought. Winter base flows do not wet as much suitable overwintering cover, and fish must move greater distances to reach cover. Low flows thus make juveniles more accessible to fish, avian, and mammalian predators. Juveniles may tend to move into larger streams where more, larger predators live. Seelbach (1987) found that steelhead overwinter survivals varied from a low of 13% to a high of 90% over three years, correlated with the severity of the winter as indexed by air temperature and precipitation. He could not, therefore, find a correlation between escapement and smolt production.

In low winter base flows and periods of low snowfall, reduced stream areas become open to the atmosphere, facilitating anchor ice. Streams that normally bridge over with snow cover do not. Thus, incubating embryos and overwintering pre-smolts become more vulnerable to freezing. The migration corridor in the following spring contains less water, concentrating predators, wild chinook, and millions of hatchery smolts in a reduced cross section.

While some of the foregoing only amounts to speculation, it should alert us to sediment-caused habitat degradation and loss of instream and riparian cover. We see fine sediments that fill substrate interstices as likely to exacerbate pre-smolt mortality in drought, forcing fish to move greater distances to find suitable winter habitat. Areas that lack full riparian cover cannot bridge with snow as readily, exposing the stream to temperature extremes.

The low cycle of discharge for the past six years will inevitably depress wild spring/summer chinook populations even without hydropower-related problems. Drought conditions may explain why survival rates from summer parr to smolt have averaged only about 10% (Giorgi 1991). The double jeopardy of drought and hydropower-related mortalities places even more pressure on populations. Triple jeopardy may stem from excessive numbers of hatchery fish in the system.

17.2 PRESSURE ON MIGRATORYPHASE

Storage projects in the main Snake River and tributaries upstream from Hells Canyon, and in the North Fork Clearwater, have sharply altered the natural hydrograph of the Snake River (Chapman et al. 1991). We discussed the effects of water manipulation upstream from Hells Canyon earlier in my report. Storage in the upper Columbia River altered the hydrograph of the main Columbia River.

Sherwood et al. (1990) analyzed monthly mean flows of the Columbia River, and found that large-scale regulation of the flow cycle began around 1969. Since the latter date, monthly mean flow has varied less. Average sediment supply to the estuary has decreased with flow damping. Without major floods, residence time of water in the estuary has increased, with a concomitant decrease in salinity. Detritus and nutrient residence has increased, vertical mixing has decreased. Sherwood et al. (1990) note that although hydrodynamic changes have probably enhanced the pelagic primary productivity within the estuary, the costs have yet to be evaluated. Change has enhanced estuarine conditions for detritivorous epibenthic and pelagic copepods, but converted to a less-energetic microdetritus-based ecosystem with higher sedimentation rates. Sherwood et al. (1990) conclude by stating:

> *"However, it is apparent that these changes, and other changes in the fluvial pan of the system, have contributed to the dramatic decline in salmon populations. The implications of major modifications such as have taken place in the Columbia River estuary and watershed need to be incorporated into contemporary estuarine and shorelands management strategies. In particular, proposals for comprehensive hydroelectric and water withdrawal developments, shoreline modifications, and navigation projects should all be evaluated in terms of potential consequences to the estuarine ecosystem and resulting effects on other resources, including fisheries, which depend on a highly coevolved and biologically diverse estuarine environment."*

A. Giorgi discusses effects of discharge on travel time and survival, hence we will not.

18. CRITICAL HABITAT DESIGNATION

18.1 DEFINITION

The Endangered Species Act of 1973 defines critical habitat as:

1. The specific areas within the geographic area occupied by the species, at the time it is listed in accordance with the provisions of Article 1553 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and

2. specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of Article 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species.

The ESA notes that critical habitat may be established for those species now listed as threatened or endangered species for which no critical habitat has heretofore been established as set forth in #l and #2 above. It also notes that except in those circumstances determined by the Secretary of Commerce or Interior, critical habitat shall not include the entire geographical area that the threatened or endangered species can occupy.

18.2 HABITATUSE

Spring/summer chinook listed as threatened in the Snake River Basin occupy, at various times (but always at some times during the life cycle), high mountain-valley tributaries used for maturation, spawning, incubation, rearing, and overwintering. They use the larger tributaries for rearing, overwintering and migration of adults and juveniles; still larger streams for rearing and migration; and the main Snake and Columbia rivers as migration corridors. They migrate through, and rear briefly in, the Columbia River estuary. Finally, they require various locations in the marine environment for rearing and migration. Sockeye use an equally extensive variety of habitats, but in the Snake River Basin require a lake environment for adult maturation, spawning, incubation, and juvenile rearing. They may use lake tributaries for spawning and incubation in some instances. Fall chinook use the main Snake River upstream from Lower Granite Dam for maturation, spawning, and incubation. They may use the Snake River throughout its length for juvenile rearing, then use the Snake and Columbia rivers as a migration and rearing corridor. As with the other listed species, fall chinook require the estuary and marine environments as well.

The panoply of environments of listed Snake River species contains "those physical or biological features essential to the conservation of the species." Thus all habitat used by the listed species seem to meet the first portion of the test (I) of item #l above. Less clear is the degree to which the second test (II) in #l is met. For example, may the marine environment of the listed species "require special management considerations or protection?" One of the authors (DC) has argued that NMFS should designate the marine environment as critical habitat, not only because of harvest threats but also because ocean systems important to listed species may have limited capacity to support enhanced populations of salmon from the Pacific Coast of North America. Many organizations pump billions of young pink, chum, sockeye, coho, and chinook salmon into the marine environment (releases to the North Pacific Ocean now total about 5 billion, according to Pearcy (1992)). They also fertilize sockeye lakes to enhance smolt output to the sea. Such actio ns could reduce the growth and survival of listed Snake River salmon species. However, we lack probative evidence for these species. Even in the case of coho salmon, for which the most data exist, we can only state that density effects may appear in years of poor upwelling (Peterson et al. 1982). Adult recruitment and survival rates of coho nonlinearly relate to smolt abundance during years of low upwelling, not during years of high upwelling, but the probability level for the former equals only 0.16. However, survival rates at high smolt densities are roughly one-fourth of those at low smolt abundance, and mean adult coho weight appears negatively related to ocean stock density (Nicholas et al. 1984). Brodeur (1992) concluded that juvenile coho and chinook do not consume near-maximum rations in all years, months, and areas for which information exists. Thus, localized depletion of resources, or times and areas of reduced production, can occur.

In the absence of probative information that indicts ocean density dependence or interspecific interactions pertinent for Snake River listed salmon, NMFS could avoid critical habitat designation for the marine environment of Snake River stocks on grounds that it could identify no required special management considerations or protection. Economic considerations would make designation of the open sea as critical habitat even less likely. However, NMFS should consider the migrations of chinook and sockeye, their occupancy of nearshore waters for the first summer of ocean life, and the many potential interactions with other species and stocks. These factors seem to meet criterion 1.11. Again, this criterion identifies physical or biological features essential to species conservation that **may** require special management or protection.

One can easily justify designation of the Columbia River estuary as critical habitat. The estuary has lost about a third of its original volume to dredging, filling, and various developments. Upriver storage has reduced flood flows and sediment bedloads that would help maintain estuarine habitats (Sherwood et al. 1990). Hatchery output tends to place huge numbers of juvenile salmonids in the estuary, very probably in a narrower time window than that of the predevelopment era. Many millions of exotic shad juveniles now use the estuary. Few studies address the effects of these ecological changes on upriver salmon, let alone listed Snake River species. The estuary certainly meets test I (essential to species conservation) in #l above.

Few would dispute that the migration corridor used by listed Snake River stocks meets both tests in #l . Many would argue that the cri tical habitat designation should extend from the head of Lower Granite pool to the estuary; the area most altered by hydropower development. Special management consideration or protection would apply to downstream and upstream passage of Snake River species. Those most likely include flow management, smolt bypass and transportation, predator control, and fishway improvements, among others.

Many members of the biological community argue strongly that the migration corridor between the head of Lower Granite pool and the headwater spawning and rearing habitats of the Snake River should also receive critical habitat designation. They argue that pre-spawning mortality for spring chinook lies close to 50% (Bjomn 1990, Chapman et al. 1991). They also point out that very high mortality apparently may occur in juvenile wild fish between upriver points and the head of Lower Granite pool, based on PIT tag recoveries (Giorgi 1991). Overwinter loss, some or much of which may occur in the migration corridor, appears high, at least in recent drought years. About half or more of hatchery smolts disappear between release point in the watershed and Lower Granite Dam. Recent hatchery releases of 18 to 25 million steelhead and yearling chinook may exceed by a large margin the total output of the remaining habitat areas upstream from Lower Granite pool before hydro development occurred (Raymond 1979). The large numbers of hatchery smolts may affect survival and spring growth of wild fish through predation or other interactions. The free-flowing portions of the migration corridor will likely require special management considerations or protection.

The spawning and rearing areas used by wild fall chinook between Hells Canyon Dam and Corps of Engineers dams on the Snake River likely meet the tests of #l above. This “species” may require flow management to assure maximum survival from egg to smolt. Conceivably, measures designed to improve survival of spring migrants could conflict with measures needed by fall chinook.

Spawning and rearing areas used recently and historically by sockeye salmon in the Stanley Basin appear to meet the tests not only of #l but likely of #2. Redfish Lake spawning and rearing areas may require special management considerations or protection; e.g. ,elimination of stocking of potential predators and competitors, removal of influence of recreationists on spawning beaches, riparian protection in the migration corridor, and possibly other measures. Alturas, Yellowbelly, Pettit, and Stanley Lakes, historically used by sockeye, may be needed in a sockeye recovery effort, depending on NMFS planning.

Spawning and rearing areas of wild spring/summer chinook probably meet the tests of #l. Clearly, this “species” requires the physical and biological features of the spawning and rearing habitat within its range in the Snake River Basin. Those features include a productive riverine/riparian habitat and water of suitable quantity and quality. That special management considerations or protection are required is demonstrated in another section of our report. Portions of tributaries of the Snake River Basin now not seeded by wild fish because of low escapements would meet the test of #2.

18.3 DESIGNATIONS NEEDED

In Table 7, we offer a simple matrix that reflects our judgement as to the need for critical habitat designation for various habitat components for each species. If one totals the “+“indications for criteria #l-I (essential to species conservation) and #l-II (requires special management), a measure of the importance that one places on critical habitat designation may be derived. For example, our judgement tells me that the highest priority for designation includes the spawning/rearing and migration corridors. The priority of the estuary would fall next, followed by marine environments. For sockeye, criterion #2 falls out as a high priority.

How might NMFS designate critical habitats in spawning and rearing areas? One option might omit from designation any spawning/rearing stream that lies wholly within a wilderness area. Thus, for example, Chamberlain Creek, the Wenaha River, and the Minam River would not require critical habitat designation under this option. Loon, Camas, Big, Sulphur, which lie partly within and partly without a wilderness, would require designation. Where the wilderness component lies upstream from a multiple-use component, NMFS would not designate it as critical habitat in this option.

How might NMFS designate the area included in the watershed of a stream declared critical habitat? Three options come to mind: ridge-to-ridge (entire watershed), partial watershed, and live stream length. The first could apply where soil and vegetation classifications do not permit land managers to designate only part of the watershed. The partial watershed designation could apply only where managers can, with ecological classification, determine that spawning and rearing habitat is insensitive to land management in excluded watershed portions. Such partial exclusion could occur where the geologic district, landtype association, landtype, and valley bottom type indicate stability. Partial exclusion would not serve where the excluded areas include existing mine claims or are open under mining laws. The final alternative, of designation of entire stream lengths, would offer a relatively simple option, as would subbasin designation.

How would NMFS designate critical habitat in the migration corridor? One option would simply designate all instream habitat from the estuary to the upper end of named rivers. That designation would extend upstream, e.g., to the junction of Bear Valley and Marsh Creeks, where the Middle Fork Salmon River begins. It would include the South Fork Salmon River, East Fork of the South Fork, main Salmon River, Imnaha River, and Grande Ronde River. It would include the Snake River and Columbia River from the mouth of the Snake River to the estuary. This designation would seamlessly connect with designated critical spawning and rearing habitat.

As noted elsewhere in our report, the area upstream from Hells Canyon Dam is a candidate for designation as critical habitat. It can produce approximately 1 .0 MAF of water to supplement flows at Clarkson in April-June by about 8% in the average year. It would fall under criterion #2. In the matrix, we have not shown a benefit for summer flow augmentation for fall chinook, for the available data do not document survival gains from summer flow.

The Clearwater River does not include production areas for wild fish. However, the North Fork Clearwater to the head of Dworshak pool seems to fit criterion 1.11, because flows from Dworshak Dam figure so prominently in schemes to mitigate hydropower effects or temperatures in the migration corridor. Thus, it qualifies as critical habitat.

Table 7. Matrix of degree to which habitats used by listed Snake River "species" appear to meet the criteria for critical habitat under the Endangered Species Act[16]. Degree is expressed by judgement-based number of " + "designations.

	Sockeye	Fall chinook	Spring/summ. chinook
Criterion #l-I			
Spawning/rearing[17]	+ + +	+ + +	+ + +
Migration corridor juvenile	+ + +	+ + +	+ + +
Estuary	++	+ + +	++
Ocean nearshore	+	+	+
Ocean offshore	+	+	+
Migration corridor, ad.	++	++	++
Criterion #l-II			
Spawning/rearing[18]	+ + +	+ + +	+ + +
Migration corridor, juvenile	+ + +	+ + +	+ + +
Estuary	+	+	+
Ocean nearshore			
Ocean offshore			
Migration corridor, adult	++	++	++
Criterion #2			
Spawning/rearing[19]	+ + +	+	++
Migration corridor, juvenile			

[16]. 1. The specific areas within the geographic area occupied by the species, at the time it is listed in accordance with the provisions of Article 1553 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and

2. specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of Article 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species.

[17]. Spawning/rearing habitat for sockeye includes a lake.

[18]. Spawning/rearing habitat for sockeye includes a lake.

[19]. Spawning/rearing habitat for sockeye includes a lake.

Table 1, Continued.	Sockeye	Fall chinook	Spring/summer chinook
Upstream from Hells canyon	++	++[20]	++
No. Fork Clearwater	++	+	++
Columbia R. [21]	+	+	+
Estuary			
Ocean nearshore			
Ocean offshore			
Migration corridor, adult [22]	++		

The upper Columbia River qualifies as critical habitat under criterion #2. Clearly the storage capacity and management of Columbia River reservoirs in Canada and at Grand Coulee affect the migration corridor in the mainstem Columbia River downstream from the mouth of the Snake River. This effect would become more important if society were to abandon transportation in favor of reservoir drawdown and in-river migration.

18.4 NMFS DRAFT DESIGNATIONS

The critical habitat designation proposed by NMFS on December 2, 1992 (Proposed Rule in Federal Register, Volume 57, No. 232), would declare critical habitat from the mouth of the Columbia River upstream to the mouth of the Snake River, and from the mouth of the Snake River upstream to the mouth of the Salmon River for all species. For fall chinook, NMFS adds the Snake River upstream from the mouth of the Salmon River to Hells Canyon Dam, and lower reaches of the Grande Ronde, Imnaha, Salmon, and Tucannon rivers.

For spring and summer chinook, the agency adds the Snake River from the mouth of the Salmon River to Sheep Creek, which enters the Snake River several miles downstream from Hells Canyon Dam. It also adds the Grande Ronde, Imnaha, Salmon, and Tucannon subbasins, Asotin, Granite, and Sheep creeks.

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20. Spring flow management may negatively affect fall chinook. Hence the + + indicates effects that could be negative.

21. Columbia River reservoirs from Coulee upstream become more important relatively if society elects to eliminate transportation of smolts from the Snake River and McNary Dam.

22. From Salmon River to Stanley, Pettit, YellowBelly, and Alturas Lakes.

For sockeye, NMFS adds the Salmon River to the mouth of Alturas Lake Creek, Alturas, Pettit, Redfish, Stanley, and Yellow Belly Lakes, including inlet and outlet creeks, and Alturas Lake Creek and Valley Creek

The NMFS recommendation, taken literally, would incorporate *the entire subbasins of the Salmon, Grande Ronde, Imnaha, and Tucannon River systems. This* would mean ridge-to-ridge designation of critical habitat, for the subbasins include the entire watersheds of those stream systems (e.g., see p. 5-7 of the draft salmon and steelhead production plan for the Salmon River Subbasin). The NMFS announcement, shortly after mentioning inclusion of subbasins, states:

> *'Criticalhabitat includes the bottom and water of the waterways and adjacent riparian zone. The riparian zone includes those areas belonging or relating to the bank of the river, stream, lake, or pond and those areas of or on the bank, including the flood plain of the body of water."*

If the italicized explanation supersedes the subbasin inclusion in the NMFS announcement, it may de-emphasize consultation on watershed activities that lie out of the riparian zone and flood plain. This would create unfortunate problems, for upslope activities can easily have major effects on the riparian zone. Consultation under Section 7 already has the potential for weakness because NMFS personnel [23] who consult with federal land management agencies may lack sufficient experience with livestock effects and management to force needed change in grazing management on allotments.

The NMFS recommendation ignores critical habitat designation for the area upstream from Hells Canyon Dam. This oversight seems mistaken in light of the possible yield of 1 .0 million acre-feet of water for spring flow augmentation. NMFS also does not include the North Fork Clearwater (Dworshak Reservoir). It ignores Canadian and Grand Coulee storage. Yet these three areas seem to precisely fit Criterion #2.

Designation of the "lower reaches" of the Salmon, Tucannon, Grande Ronde, and Imnaha rivers for fall chinook seems too broad. We know of no evidence that wild fall chinook used or use the lower Salmon River. Sighting of an occasional redd or test digging does not justify designation. A few redds, some of which may consist of test digging rather than areas that contain egg pockets, have been sighted in some years in the lower Grande Ronde and Imnaha rivers. The lower Clearwater River has had some redds in it in recent years, perhaps a result of straying by fall chinook of non-Snake origin, or possibly because temperatures of the lower Clearwater have become more moderate since Dworshak completion. We would provisionally exclude the lower Clearwater and lower reaches of the Salmon River from critical habitat designation for fall chinook, and provisionally include the lower Imnaha and Grande Ronde rivers.

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[23]. Well-intentioned and dedicated NMFS personnel will find themselves overwhelmed by the sheer magnitude of the consultation task. They may well find themselves under pressure to make quick decisions without adequate information; a climate that will favor continued grazing damage in riparian zones.

Justification for the latter is not weak.

19. FEASIBLE HABITATRECOVERY MEASURES

Inasmuch as managers have reduced harvest rates for spring and summer chinook (WDF/ODFW 1992, Tables 24 and 29), the current status of wild populations reflects other mortality factors. Dam-related mortality, interactions of hatchery and wild fish, marine factors, and freshwater habitat problems seem likely candidates. The prevailing opinion of biologists familiar with the Columbia River system blames dam reservoirs and dam passage.

In considering effects of various mortality agents, one must remember that historical information indicates that runs of salmon failed in predevelopment years (Chance 1973). Thus, one cannot dismiss such factors as drought and decreased ocean survival as irrelevant, even as we focus on dam-related mortality agents. Abundance of naturally-produced chinook salmon has decreased in areas outside the Columbia River Basin and unaffected by dams while Snake River populations declined.

As noted earlier, Sedell and Everest (1990) demonstrated that the quality of freshwater habitats in the Snake River Basin declined over the past 50 years in streams exposed to multiple use. One can easily prepare graphs that would indicate a negative correlation between total releases of salmon and steelhead from hatcheries and abundance of wild spring and summer chinook.

The foregoing, rather than minimizing effects of dams on declines, cautions against single-factor responses to the reduced populations of listed species. Holistic management response would address all key decline factors, with most emphasis on mitigable ones. Other appendices treat flow, drawdown, transportation, and hatchery supplementation. We emphasize other habitat mitigation.

A common perception of biologists in the Columbia River Basin holds that *'We have plenty of habitat. All we need is improved dam passage so that we seed it. Habitat quality is not a priority concern until we get that seeding."* Rich et al. (1992) demonstrated that ungrazed control streams in the drainage of the Middle Fork Salmon River contained juvenile chinook densities about ten-fold greater than densities in Bear Valley and Elk creeks. The latter two streams receive heavy grazing pressure, and contained more than twice as much sand in the substrate as ungrazed streams. Chamberlain Creek, a Salmon River tributary that lies within a wilderness and suffers no grazing, mining, roading, or logging, has higher parr densities than streams exposed to multiple use (IDFG 1992). Chinook salmon produced in Chamberlain Creek and the streams of the Middle Fork Salmon all lie upstream from eight hydropower dams, and are managed by the IDFG as wild fish streams.

Degraded habitats do not produce wild salmon as well as undamaged habitats. Egg to smolt survival declines with habitat damage. We cannot realize the highest possible egg to smolt survival for the limited escapements that pass Lower Granite Dam until all habitats used by wild fish reach their best achievable state. This statement holds at low and high escapements. In the material that follows, we suggest measures that will improve habitat quality.

19.1 INSTREAM FLOW ENHANCEMENT

Accelerated BPA purchase of water rights, especially in the Salmon River and Grande Ronde River basins has great promise for fishery enhancement. Such purchase will open access to presently unused habitat for spawning and rearing, improve water quality and quantity in areas with depleted instream flows, and reduce need for diversion screening and screen maintenance. Lease or purchase of water upstream from Hells Canyon Dam should have high priority. Dependent upon results of reach survival studies in relation to flows, use of upper Columbia River, Dworshak, and Hells Canyon storage for flow enhancement in the migration corridor will be required to an unknown degree. The HRC (1990) study revealed important potential for augmenting spring flows with water from areas upstream from the Hells Canyon complex.

The proposed Prairie Creek pipeline from Wallowa Lake provides an opportunity to conserve irrigation water and supplement stream flows in the Wallowa River during periods critical to anadromous fish. The premise is to conserve enough water by replacing the existing open-ditch irrigation water conveyances with a pipeline system to make surplus flows available for fish habitat improvement. Water savings possible with a pipeline system are estimated at 36,OOO acre-feet (B.R. 1981). Flood irrigation could be converted to pressurized sprinkler systems, thus reducing sedimentation in Prairie Creek. Property owners oppose the pipeline, arguing that the open ditches enhance property values. This issue has resulted in a critical review of water resources in Wallowa County; a review long overdue.

Any water conservation measure, large or small, should be reviewed. We believe that an holistic Snake River water conservation review could reveal important sources of enhanced instream flows.

19.2 IRRIGATION SCREENING

Until evaluations demonstrate that spring/summer smolt production would improve if irrigation screens were removed, screens should be modernized and monitored closely for performance. Too many screens do not remain in best operating configuration between agency visits. This results in part because some irrigators think screens decrease flow down the ditch. Unscreened diversions should be screened (again, we assume the screens benefit fish, on balance, although we have no data from objective evaluations to support the assumption).

19.3 RIPARIAN SYSTEMS

The most important measure for riparian protection and enhancement is prioritization and early completion of allotment management plans to Forest Plan Standards and Guidelines on federally-owned drainages that surround anadromous fish habitat used for spawning and rearing by spring and summer chinook salmon.

Reduction of permitted animal use, until allotment management plans become available and implemented, is warranted on many allotments critical to listed spring/summer chinook. Such reduction would trigger prompt completion of AMPS and reduce ongoing damage to riparian systems. Habitat improvement will involve pasture management or corridor fencing to reduce or eliminate livestock damage.

The Nez Perce Tribe and interest groups in Wallowa County are developing a salmon recovery plan for Wallowa county streams. The plan mission is to "assure that watershed conditions in Wallowa County provide the spawning, rearing, and migration habitats required to assist in the recovery of Snake River salmonids by protecting and enhancing conditions as needed".

Furthermore, the NPPC selected the Grande Ronde Basin as the model watershed project for Oregon. The draft mission statement in part aims "to develop and oversee the implementation, maintenance and monitoring of coordinated resource management that will enhance the natural resources of the Grande Ronde River Basin". Certainly this draft statement reflects problems in restoring salmon runs. Each cooperator is most interested in protecting individual interests. The Grande Ronde model watershed cannot succeed unless the cooperators partially subordinate those interests for the broader public good.

19.4 INSTREAM HABITAT STRUCTURES AND MODIFICATION

The BPA has funded many habitat enhancement projects in the Snake River Basin. These projects have removed barriers, developed off-channel habitat, added structures to streams, and aimed at sediment reductions. Funds for monitoring to assess success of such efforts have not often been provided.

Scully and Petrosky (1991) reported that "barrier removals, followed by instream structures, have had the largest positive effect on anadromous fish production to date." The evaluations of Scully and Petrosky (1991) rely on a protocol reported in Petrosky and Holubetz (1986), and compare untreated sections to treated ones. Petrosky and Holubetz (1986) and Scully and Petrosky (1991) do not provide sufficient information in their progress reports to permit the reader to determine if "control" (untreated) sections meet the most critical assumption of statistical design and models; namely, independence of test and control sections. If treated sections can attract fish from untreated ones, the design violates independence. Even sections some distance apart may not meet the independence test. Many control sections apparently lay upstream from, but adjacent to, treated sections. The final report to BPA may clarify design protocol and eliminate the concern with independence. An additional problem may derive from "expectation bias." This bias [24] results where the snorkel observer who counts juveniles expects a result from the treatment, namely, that instream habitat improvement should provide more fish.

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[24]. No disrespect is indicated by the term. It is extremely difficult for investigators to remove this form of bias.

Petrosky and Holubetz (1986) caution that evaluation of total benefits of habitat modification require that adults fully seed the area. Partial evaluations reported in Scully and Petrosky (1991) include 16 pairings of treated v. "control" sections from 1984 through 1989 in Lo10 Creek, Crooked Fork, and Red River. The authors state that *"although the evidence is statistically weak (due to high variability in the &a and thus low power of the tests), it appears that modest density increases have occurred due to the three instream stmctureprojects. -* However, we ran a sign test of the pairings, and found no significant effect ($p = 0.05$) of treatment (Chi square value = 3.12). Using Rich et al. (1992), we added the 1990 chinook densities in test and "control" reaches in Lo10 Creek and Crooked Fork, thus gaining two more pairings. Again the sign test indicated no significant effect ($p = 0.05$) of instream structural modifications (Chi square value = *2.78).*

Rich et al. (1992) stated that *". . . it is important to note that it is extemely difficult to differentiate between an increase in actual densities (increased parrproduction) and mere attraction to instream stuctures (site specific increased parr concentration)."* The authors reported project benefits for chinook parr that were heavily influenced by fry stocking in barrier-removal sections.

W. Platts (personal communication), evaluated the Fish Creek (North Fork Clackamas River, Oregon) habitat modifications, which included 12 years of work and 55% of the Fish Creek channel modified with structures. He found that the structural changes did not significantly increase numbers of juvenile anadromous fish that reared in the stream or numbers of anadromous adults that returned to either Fish Creek or the Clackamas River. His findings differ from U.S. Forest Service reports that stated *"A step-wise (evaluation) procedure has been largely successful in identifying the most promising enhancement techniques'* and *"Based on several years of experience improvement projects selected for Fish Creek include those that provide the most immediate and long lasting benefit to fish production capability in a most cost-effective manner.. .* '(quotes from Forsgren et al. 1988).

The Fish Creek study lacked independent controls. It also suffered from confounding effects of logging, road building, blowdown, and artificial channel modifications.

Platts and Phillips (1990) found documentation inadequate to determine if fish responded to instream structures in the John Day River drainage. Platts and Beschta (1992), in a review of stream habitat improvement in Fifteen Mile Creek, Oregon, stressed the need to address land husbandry. Fencing to keep livestock out of the riparian area, and thus permit recovery of the riverine/riparian system, appeared to have promise. Agricultural BMPs were recommended. Beschta et al. (1991) criticized instream habitat improvements that attempted to address problems caused by poor land husbandry, saying:

> *"The addition of structures to a stream does not alleviate the overriding need of land managers to alter grazingpractices on those streams that have been severely degraded by grazing.. . . . . . artificaleans of habitat restoration (i.e. , hard structures) or other practices that altered natural biotic or fluvial processes*

were observed to have largelyfailed. These treatments ofien resulted in declines in habitat quality, ecosystem productivity, and biological diversity. "

The authors further stated:

> *"We often observed that the interactions of various wooden instream structures were dramatically different from natural wood inputs, Human-made structures may result in longterm decline in restoring the relationships or interactions between woody vegetation and streams. For example, we observed structures that often resulted in wider and shallower streams and decreased sinuosity....... The greatest barriers to reestablishment (of woody vegetation) are losses in natural channel dynamics due to the construction of hard structures and excessive levels of utilization by grazing animals. n*

Li et al. (1992) investigated the utility of log weir pools in Camp Creek, a tributary of the John Day River. They reported that addition of such weirs "was not efficacious. " Addition of 256 log weirs added but 4.1% to the pool volume of Camp Creek, at a mean cost of $750 per weir. The constructed pools held no more rainbow trout than did unmodified habitat. Log weirs in series were particularly counterproductive, trapping drift in the first pool. Failure to identify temperature as a limiting factor in Camp Creek caused part of the failure of the enhancements. That is, a microhabitat solution addressed a macrohabitat problem, dooming the enhancement to fail.

Beschta et al. (1991) stated that the recovery of streamside vegetation most efficiently improves fish habitat. They believed that addition of human-made structures was seldom justified. The National Research Council (1992) states that "Restoration means returning an ecosystem to a close approximation of its condition prior to disturbance. Accomplishing restoration means ensuring that ecosystem structure and function are recreated or repaired, and that natural dynamic ecosystem processes are operation effectively again. * The essence of a fluvial ecosystem is the dynamic equilibrium of the physical system, which in turn establishes a dynamic equilibrium in the biological components. Therefore, the goal of fluvial restoration should be to restore the river or stream to dynamic equilibrium, not to "stabilize" a channel or bank (National Research Council 1992). The Council offers objectives for the goal:

1. Restore the natural sediment and water regime.
2. Restore a natural channel geometry.
3. Restore the natural riparian plant community.
4. Restore native aquatic plants and animals.

Beyond the question of response of fish to instream habitat improvement lies that of the durability of man-made structures. Many structures have not yet faced high flow events.

WDF (1992) stated: *"The Bonneville Power Administration, U.S. Forest Service,* *Bureau of Land Management, and other agencies are planning to spend about $10 million a year during the next decade on salmonid habitat enhancement projects in the Pacific Northwest. This $100 million investment is projected to yield hundreds of thousands of "new"salmon each year. If this happens, a significant incremental contribution will be made to the goal of doubling Washington's catch. However, a U.S. Forest Service official (Meehan 1989) made the following comment in a November 1989 letter to WDF:*

> *'We agree that the track record of [our] past enhancement is dismal. Hopefully, our research will identify how, when, and where to utilize these funds in the most efficient manner. We also agree that this work should only be accomplished where spawning escapement is adequate. "*

The final statement, and perception of some biologists that habitat quality only becomes important at or near full seeding, seems to be based on the assumption that all unoccupied carrying capacity is created equal. This logically leads to the assumption that survival rates of lightly seeded cohorts cannot improve with improved habitat quality. We firmly reject this thesis, as noted at the beginning of the report section titled "Feasible habitat recovery measures. .

BPA has spent about $6,000,000 in the John Day basin to improve instream habitats. Unfortunately, no monitoring money accompanied the construction funds (Li et al. 1992). Thus, one cannot determine the degree of effectiveness of the restorations.

Improved habitat for spring and summer chinook salmon depends ultimately on land husbandry, not on instream structural modifications. Management entities, including BPA, BLM, the USFS, and state fish agencies, should aggressively pursue a land management policy that protects riverine/riparian habitat from livestock, roading, mining, logging, and recreationists. Instream habitat modification will not compensate for poor land husbandry, and may only delay recognition by managers and the public of the need for improved land management to protect riverine/riparian zones. Streams should operate dynamically in that protected ecosystem so that bank-building and vegetative communities develop good habitat without human intervention. Man-made structures can actually retard that development (Beschta et al. 1991).

19.5 MINE WASTEMITIGATION

We believe the region should place very high priority on assuring that future mining is done safely and effectively (see discussion of Clean Water Act that follows). The second priority would be to safeguard all existing tailing ponds, toxic waste dumps and sediment sources.

19.6 LOGGING MITIGATION

We suggest a need for timber harvest practices that exceed Idaho State Best Management Practices, which we consider as minimal. The BMPs used by the U.S. Forest Service should provide a guideline. The BMP feedback loops should be used for compliance and improvement.

20. CLEAN WATERACT

20.1 APPLICABLE SECTIONS OF THE CLEAN WATER ACT (PL 92-500)

Point and nonpoint sources of pollution reduce water quality for spawning, rearing, and migration of salmon. Implementation of Clean Water Act programs should be accelerated in the Columbia River Basin as a key component of salmon recovery. The Clean Water Act contains sufficient authorities for EPA and the states to restore degraded habitats and maintain high quality waters. Current state and federal programs are not adequately focused on salmon recovery and resources are limited for program implementation. If fully used, the Clean Water Act can play a significant role in restoring threatened and endangered salmon stocks.

20.1.1 Section 101(a)

This section provides the goal of the Clean Water Act:

> "The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." (PL 92-500).

The law requires biological integrity of our waters, but this was not the focus of regulatory agencies for the first 20 years of the act (Karr 1991). Historically, the application of the Clean Water Act focused on chemical and physical criteria. Today EPA requires states to adopt Biological Criteria (EPA 1990; Gibson 1991) in their water quality standards. Idaho, Oregon, and Washington have not adopted bio-criteria adequate to protect salmon stocks. Bio-criteria should address the habitat requirements for spawning and rearing, such as adequate streamflows, pool volume and quality, substrate quality, and cover. The U.S. Forest Service has developed similar criteria, called the Desired Future Condition. This would provide an excellent starting point for State bio-criteria.

The EPA and states should reemphasize the importance of adopting, as water quality standards, specific bio-criteria for spawning and rearing habitats. That emphasis should include investigation of impacts of toxins, temperature, and sediment within migration corridors and the estuary. Little is known about the potential effect that these pollutants have in the Columbia Basin on migration in the river and rearing in the estuary.

20.1.2 Section 303

Section 303 (a-c) provides authority to the states to adopt water quality standards under the direction and approval of EPA. The process for adopting state water quality standards requires approval by the state legislature and final approval by the EPA. *When states fail to adopt water quality standards or EPA disapproves state water quality standards, EPA must promulgate standards for the state.*

20.1.3 Section 303(a)

EPA promulgated an Antidegradation Policy (40 CFR 130.17) implementing Section 303(a), which requires protection of high quality waters. For waters that constitute an outstanding National Resource, such as Snake River sockeye and chinook habitat (ecologically significant), the policy requires that the water quality (including biological integrity) be maintained and protected. Antidegradation Policy **§131.12(3)** states:

> " *Where high quality waters constitute an outstanding National Resource, such as waters of National and State parks and wildlife fefuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.* "

As an example, The Idaho Legislature has failed to pass legislation designating the Middle Fork of the Salmon River as an outstanding resource water for the last two years. This failure demonstrates the State's ambivalence toward protection of high quality waters and EPA's lack of oversight of Clean Water Act authorities.

The states should designate salmon habitats that are in good to pristine condition as outstanding res ource waters. By definition, the quality of these waters must be maintained. Legal action against EPA and the States may be justified when these entities fail to designate high quality waters for protection under the Antidegradation Policy.

20.1.4 Section 303(d)

This section requires states to identify water quality-limited waters. These are water bodies that do not meet or are not expected to meet water quality standards with technology-based controls (NPDES permits for point sources and best management practices for non point sources). For these waters, states must develop a Total Maximum Daily Load (TMDL), which is used to set Waste Load Allocations for each point source and Load Allocations for nonpoint source activities (EPA 1991). This action may increase waste treatment for point sources and modification of best management practices to speed stream recovery.

In 1986, the Oregon Department of Environmental Quality (DEQ) designated the Grande Ronde River water quality-limited for fecal bacteria and pH. Due to its water quality-limited status, the Grande Ronde is a priority waterbody under the Department's critical basin program and is being evaluated for the adoption of total maximum daily loads (TMDL's). Violations of pH and bacteria standards and high temperatures have been recorded (DEQ 1993).

States need to examine current state listings under Section 303(d) for adequacy in protecting salmon habitat. Where warranted, the states should designate specific segments as Water Quality-Limited and increase the priority for development of TMDL's and associated waste load allocations.

20.1.5 Section 313

Section 313 addresses Federal Facility Compliance. Under this section, federal facilities must comply with all federal, state, local, and interstate laws and regulations concerning control and abatement of water pollution. Federal facilities include federal lands, structures, and operations. States have not used this section fully to protect salmon habitat on public lands. Section 3 13 provides states the authority to require federal land management compliance with state water quality standards (including TMDLs for water quality-limited segments and the Antidegradation Policy for high quality waters).

20.1.6 Section 319

Section 319 requires that states follow a two-step process; first, development of State Assessment Reports that inventory nonpoint source impacts and second, development of State Management Programs that identify programs to remedy these impacts. States in EPA Region 10 are currently in the implementation phase using Section 319 funds for program implementation and watershed improvement projects. Oregon and Idaho also have state programs for funding watershed projects. Federal programs are required to be consistent with these plans in implementing nonpoint source controls. Because of the predominance of nonpoint-, rather than point-, source impacts in the Columbia River Basin, this section of the Act has a high potential for contributing to recovery of fish habitat if the program were fully implemented.

State Assessments, which provide the basis for nonpoint source programs, are inconsistent and based on minimal data. The EPA and States need to improve state assessments for salmon habitats through reevaluation and monitoring. Watershed improvement projects are based on state priority lists. The NMFS should identify priority stream segments for salmon recovery and encourage EPA and the states to adopt these priority segments. Critical habitat designation may help focus attention on priority segments.

20.1.7 Section 401

Section 401 requires that applicants for federal licenses and permits obtain certification from the State water quality authority prior to construction or operation of the facility. The State bases certification on compliance with applicable sections of the Clean Water Act and State Water Quality Standards. Section 401 applies to NPDES permits, Federal Energy Regulatory Commission licenses, and Section 404 dredge and fill permits. State implementation of Section 401 certification could be improved to assure protection of Snake River salmon stocks. The EPA should review State certification procedures in the Snake River Basin with specific application to recovery of salmon stocks.

18.1.8 Section 402

Section 402 regulates discharge of pollutants from point sources. Each point source must have an NPDES permit to comply with the Act. The Clean Water Act established two types of regulatory requirements: technology-based effluent limitations and water quality-based effluent limitations. Water quality-based limits may require additional treatment to achieve the desired water quality for protection of the beneficial uses in that water body. Point source pollution is generally a minor source of pollution in drainages where Snake River salmon occur, but mining discharges may cause some significant localized effects. All NPDES permits for point sources should be reviewed to assure that permit limitations adequately address protection of salmon spawning and rearing.

20.2 POLLUTION CONTROL OPPORTUNITIES UNDER THE CLEAN WATERACT

20.2.1 Point Sources

Point source effects are minor in the basin in comparison to nonpoint source ones, but are important locally. For example, the State of Idaho lists only three major industrial discharges in the Salmon River Basin; these are discharges from mines in the Panther Creek drainage. Although mining has severely damaged water quality in this drainage, the remaining problems primarily involve unstabilized tailings, roads, and stockpiles that fall into the nonpoint source category.

Cattle feedlots violate water quality standards in the Grande Ronde Basin and adversely affect water quality in the Imnaha Basin. Complaints about feedlots are directed to ODA, which requests action by the local Soil and Water Conservation Districts (SWCD). Generally, the SWCD recognize the problem. New procedures are needed to control cattle feedlots so that they do not adversely affect salmon habitat. A field survey should determine feedlot locations, numbers of confined livestock and impact of the feedlot operations on salmon habitat.

Point sources are controlled through NPDES permits. The NPDES program includes discharge monitoring, regular inspections, and penalties for violations. These procedures should assure control of point source pollution.

20.2.2 Nonpoint Source Activities

Control of nonpoint source pollution depends on implementation of best management practices (BMPs). Under Section 319, states identify the extent of nonpoint source pollution and mechanisms to control these pollutants. Although the control programs vary by nonpoint source category, common elements include monitoring, application of BMPs, and information and education. The Clean Water Act does not contain enforceable requirements for nonpoint sources similar to the point source program, hence a mix has developed of mandatory BMPs and voluntary programs that depend on incentives. Since federal land managers must comply (Section 313) with water quality programs, there is an implied mandatory requirement on federal lands. This is an important concept because spring and summer chinook salmon spawn and rear primarily on federal lands.

Forest or agricultural practices cause most nonpoint pollution on private lands. The Conservation Reserve Program has greatly reduced soil erosion problems. As more farmers change from flood to sprinkler irrigation systems, sedimentation declines. Large volumes of commercial fertilizers are placed on land, an activity that may benefit or damage stream productivity, depending upon the volume of fertilizer to reach the stream. An agricultural practices act would provide a good start toward BMPs on private land.

20.2.3 Forest Practices

Chapman, et al. (1991) and Kaczynski and Palmisano (1992) discussed effects of timber harvest on stream habitats. Best management practices for forest practices are mandatory In the Pacific Northwest. State laws, such as the Idaho Forest Practices Act (Title 38, Chapter 13, Idaho Code), require use of certain minimum practices in timber harvest, road construction and maintenance, reforestation, and use of chemicals. State land departments administer the laws and regulations. These practices are approved as BMPs by reference in State Water Quality Standards. Historically, regulations have aimed at reducing sedimentation and controlling temperature. Recently, rules have been revised to include minimum leave-tree requirements to provide large organic debris for fish cover and stream stability. State requirements for stream protection are less restrictive than policies on Forest Service lands.

Watershed restoration in forested areas receives very little attention. Application of BMPs alone will not restore degraded watersheds. Existing roads are a primary source of sediments to watersheds. An aggressive program of road closure, relocation, or rehabilitation is needed on all ownerships.

Managers should evaluate BMPs for adequacy in the Snake River drainages. State rules and regulations provide a process for drainage- or region-specific BMPs. Site-specific BMPs that reduce the risk of impacts to spawning and rearing habitat used by salmon should be adopted into state law. The region needs a comprehensive and aggressive program to reduce existing sediment sources. Existing roads should be evaluated and treated through closure, relocation, or rehabilitation.

20.2.4 Livestock Grazing

Livestock grazing has received little attention by State water quality agencies to date, as illustrated by the program in Idaho. Idaho does not currently have a set of approved best management practices for grazing. Livestock grazing was given a low priority in the 1983 Agricultural Pollution Abatement Plan, which is a voluntary program based on education and cost-share incentives. The most recent plan developed in response to Section 319 now recognizes livestock grazing as a high priority. Idaho recently began to include watershed projects for grazing in the State Agricultural Water Quality Program and develop riparian monitoring programs for these projects.

Although little progress has been made to date in improving watersheds damaged by grazing, there is a high potential for change. Considerable knowledge has been developed in methods to improve riparian areas;these areas begin to improve relatively quickly once overgrazing ceases.

Livestock graze extensively in the basin of the Snake River on federal lands. Since federal agencies must comply with State water quality programs (Section 3 13 of the Clean Water Act), identification of a minimum set of BMPs would provide a legal framework for watershed improvement.

The EPA and the states should promptly develop minimum requirements or best management practices for grazing. Federal land management agencies should aggressively evaluate existing grazing allotment plans for protection of fisheries in critical basins and implement new plans where needed to restore these habitats. The EPA and state water quality agencies should exercise their authorities under Section 3 13 and Section 319 to require riparian restoration on federal lands.

20.2.5 Mining

A number of laws regulate mining to help provide water quality protection. In Idaho, this includes the Dredge and Placer Mining Act (Title 47, Chapter 13, Idaho Code), the Surface Mining Act (Title 47, Chapter 15, Idaho Code), Rules and Regulations for Ore Processing by Cyanidation (Title 1, Chapter 13, Idaho Code), the Stream Channel Protection Act (Title 42, Chapter 17, Idaho Code), and relevant sections of the Clean Water Act. On federal lands, mining projects are subject to environmental analysis under the National Environmental Policy Act (NEPA) and are required to complete a comprehensive mine operating plan.

Because of these interrelated laws, present mining is subject to greater regulation and oversight than many other pollution sources. However, mining often presents high risks for water quality degradation due to large-scale failures and blowouts. Nonpoint sources of pollution result from activities that disturb vegetative cover and soils.

The greatest threat to water quality comes from historic mining. Erosion of surface-mined areas from abandoned and orphaned mines continues since the soils do not support vegetative cover. Acid mine drainage has eliminated salmon from some drainages.

Although abandoned mined lands present difficult problems for rehabilitation, some successes have occurred. The region needs an evaluation of degraded drainages such as Blackbird Creek and restoration programs where warranted.

20.2.6 Hydrologic/Habitat Modification

Hydrologic/habitat modification includes those nonpoint source impacts resulting from changes to in-channel hydrologic functioning, channel and aquatic habitat condition, and adjacent riparian condition. Hydrologic modification occurs as a secondary impact in conjunction with other nonpoint source activities. In Idaho's Nonpoint Source Management Program (Bauer, 1989), livestock grazing was identified as the most significant pollutant category associated with hydrologic modification of streams.

Hydrologic/habitat modification has only recently been recognized as a category of nonpoint source pollution that should be regulated under the Clean Water Act. State management programs have not adequately addressed this issue as a nonpoint source activity. The importance of this recognition is that it provides another tool under the Clean Water Act for improving salmon habitats that have been modified by various activities.

20.3 HATCHERY REFORM

Hatchery reform appears to some to lie outside the province of a habitat report. However, as war is too important to leave to generals, hatchery policies should not be left to hatchery administrators. Hatchery output affects habitat quality. Numbers of hatchery juveniles released into the Snake River system rose from a few thousand fish in the early 1960s to 20-25 million by the late 1980s (Figure 33). Releases in the past two years have equaled about 19 million yearling chinook and steelhead combined. Possible negative interactions between hatchery fish, many of which never reach the first dam from the point of release, and wild fish should concern us. We know very little about such interactions. As noted earlier in our report, they may include competition for food, attraction of predators, density-related stress, disease transfer, and effects on migratory behavior.

Liberations of hatchery yearling chinook and steelhead in the mid-Columbia system have remained relatively low while releases in the Snake River climbed sharply. For example, in the period from 1982 through 1986, mid-Columbia releases of yearling chinook and steelhead averaged about 3.6 million. In the same period, average releases in the Snake River totaled about 15.5 million. Mean discharge in the spring months in the mid-Columbia river is greater, often by two-fold, than that in the Snake River, so that the density of hatchery fish per acre-foot of spring flow is less than the relative hatchery numbers would suggest. One cannot eliminate the possibility that hatchery fish interactions with listed salmon in the migration corridor caused part of the decline of Snake River chinook and sockeye.

Many steelhead residualize in the Snake River, remaining through the summer. At the same time, subyearling fall chinook must rear and move from natal areas through LGR and downstream pools, or enter bypass systems. Hatchery policies must reduce residualism, at the very least, reducing potential interactions between steelhead and fall chinook. At best, reduced residualism will improve production rates for adult steelhead. The role of excessive numbers of hatchery fish in increasing predator concentrations and rates of predation on wild fish requires prompt research attention.

Kaczynski and Palmisano (1992) calculated that total smolt production by hatcheries in 1990 was 202,493,200 fish. Together with an estimated wild output in 1990 of 145,176,200, their estimates suggest that the total of 347,669,400 smolts would exceed by 31% the wild historic smolt production. We must remember that societal decisions led to construction of dams and facilities that have concentrated deliveries of many hatchery (and wild) smolts at bypass and hatchery outfalls, and at transport barge release points. Those decisions, however uncoordinated in some policy areas, have reduced river cross-section, discharge, and turbidity, thus enhancing predator efficiency (Junge and

Oakley 1966). They have decreased estuary habitat and added shad and other exotic species as a bridging food base for predators. Kim et al. (1986) reported increased abundance of squawfish in the estuary.

21. MONITORING

In several report sections we mentioned needs for monitoring. Monitoring should include:

1. Annual assessments of condition of riverine/riparian habitats in areas subjected to grazing in each allotment used by listed salmon. To move those habitats toward their best achievable state, managers must know from year to year how they progress.

2. States and federal entities should monitor BMP compliance on all timber sales.

3. State monitoring under Section 3 19 of the Clean Water Act should become consistent.

4. State and federal monitoring and inspection should become more rigorous and frequent for point-source discharges.

5. Any instream habitat modification to enhance listed species should incorporate evaluation of untreated control areas independent from treated areas. Usually, this will demand controls outside the treated stream.

6. Redd index monitoring will continue to offer the best tool for evaluation of status of disaggregated populations of spring and summer chinook. Careful records of monitoring conditions should accompany annual reports on status of populations. Redd counting should be completed by experienced personnel, not summer aides. It should account for annual variations in temperature, so that in years of early or late spawning, special effort is expended to count redds after completion of all spawning.

7. A water use monitoring program should be implemented to assess all water use, both consumptive and nonconsumptive. Stream gauge networks should be expanded as part of this program.

8. Irrigation water withdrawals should bemonitored regularly to assure compliance with any required instream flows and with the existing water right.

22. RESEARCH NEEDS AND OPPORTUNITIES

We recommend cost:benefit analysis of the screening program in the Salmon River Basin. That analysis should help managers to evaluate whether biological benefits and economics support purchase of water rights in some instances, obviating the need for screening.

We strongly recommend comprehensive evaluations of bypass-related mortality be initiated at all dams equipped with bypass facilities. This would require evaluation of entire systems, from the point at which smolts first encounter deflection screens in turbine intakes to a point downstream from the bypass outfall or release point at which smolts become free of all effects of bypass, including bypass-induced concentration. The bypass segment upstream from the gatewell to the first encounter with deflection screen is very difficult to evaluate, and will require ingenuity. The effects of delayed loss and predation downstream from bypasses can be evaluated in a research mode similar to that used at BDA second powerhouse (Ledgerwood et al. 1991).

The most comprehensive evaluation of bypasses to date (Ledgerwood et al. 1990, 1991) indicates that bypass of fish to the tailrace at the dam of bypass is of doubtful or negative merit. Until bypass effects have been clearly demonstrated by comprehensive research at several dams, prudent application of bypass technology would collect fish for transportation. Thus, reliance on transportation trades off the mortality associated with bypasses against the savings in fish not taken by predators or turbine kill in downstream dams.

It may be even more effective, in terms of net smolt survival, to collect fish even at the most downstream dam (BDA) and transport them to a point near the ocean, close to Astoria, Oregon, rather than to subject them to the intense predation that apparently exists downstream from BDA (Ledgerwood et al. 1991).

Clearly, much critical research remains undone. Bypass systems with deflection screens exist in six powerhouses in the Snake and Columbia rivers. More are authorized at The Dalles and Ice Harbor. Other bypass facilities are proposed for installations at Priest Rapids, Wanapum, Rock Island, and Rocky Reach dams on the upper Columbia River. For the six existing systems, only at BDA second powerhouse has total bypass-related mortality been studied. Even in those tests (Ledgerwood et al. 1990), the test fish did not encounter deflection screens in turbine intakes, gatewells, vertical barrier screens in the gatewells, or orifices to the gallery. That is, test fish entered the bypass system in the upper end of the gallery. Thus, bypass-related mortality estimates at BDA do not include all bypass-caused losses.

Managers have evaluated bypasses principally on the basis of guidance efficiency and carcass counts in raceways and sampling facilities, not on the basis of overall bypass-related mortality. A momentum developed that gathered adherents and advocates. Critical thinking about bypasses was suspended. Thus, early researcher warnings lay unheeded. Collins et al. (1975) cautioned that if bypasses functioned poorly, "... losses to juveniles might be greater from screening and bypass than from turbines." It is time to heed that warning and to examine the appropriate hypotheses at all bypass-equipped dams.

Water and fish managers desperately need modem estimates of reach and project survivals. These can be obtained with the proposed research of Skalski and Giorgi (1992) and NMFS\UW (1993). We need baseline data for reach and project survival before major dam reconfigurations or bypass modifications.

The over-wintering life history phase for spring and summer chinook remains largely unstudied. We need better information on survival of pre-smolts that remain in rearing areas and those that move downstream into larger tributaries. We need to learn what agents of mortality cause high overwintering losses. We should determine survival rates in overwintering habitats of differing quality.

Research on survival of PIT tagged salmon juveniles is required to determine if they survive at rates lower than untagged fish. Effects of tagging and tags on the ecology and survival of wild fingerlings should be evaluated.

Intra- and inter-specific interactions in the migration corridor remain a "black box" to managers. We know almost nothing about competition, behavior, staging, and disease transfer in the migration corridor between natal areas and the sea. We know little about predator response to the extraordinary abundance of hatchery salmonids that enter the Snake and Columbia rivers and the estuary. Research has concentrated on moving fish across dams, and on predation. Research in the migration corridor might include such diverse treatments as sharply reduced hatchery output in a series of test years, or transport of hatchery fish from the hatchery directly to transport barges (with appropriate water exchange to assure homing). These measures would permit assessment of survival of trapped and tagged wild fish under conditions of high and low numbers of chinook and steelhead in the migration corridor. Scoop traps well up in the drainage, coupled with PIT tagging, would provide tools for measurement of survival of wild fish to traps just upstream from Lower Granite Dam, and to collector dams. Marking of all hatchery fish will, of course, facilitate collection of information on relative survival of wild and hatchery fish in various river reaches.

The BPA-funded project to study ecology of juvenile fall chinook should continue and include study of relative survival of various size groups of subyearlings that migrate naturally and that are transported. Survival in the estuary of subyearlings may depend upon fish size at arrival.

The degree to which fall chinook spawn and rear in the reservoirs downstream from LGR is important. We need to determine if spawners there derive from the same gene pool as fish produced upstream from LGR or in Lyons Ferry Hatchery.

An Estuaries and Inlets Working Group (in Pearcy 1983) offered useful suggestions for research on estuarine mortality in salmon. They offered several basic hypotheses requiring testing:

1. Mortality in estuaries is size and density dependent.
2. Within-estuarine mortality is habitat-specific.
3. Within-estuarine mortality is fitness-dependent.
4. Timing and duration of estuarine residence affect within-estuarine mortality.
5. Size, density, condition, and time of emigration from estuaries influence coastal and oceanic mortality rates.

The Group suggested ideas for approaching hypothesis testing. Considering the lack of published works on the hypotheses as they apply to the Columbia River estuary and, perhaps particularly, ocean-annulus chinook that spend extended periods in the estuary, an intensive research effort is warranted. The estuary and nearshore marine environment may also affect survival of stream-annulus chinook salmon and sockeye, as Simenstad and Wissmar (1983) suggest.

"Controls" for condition of Snake River listed stocks deserve some attention by researchers. An index of the status of salmon populations unaffected by dams might reveal effects of ocean conditions on a broad spectrum of populations. Condition of stocks that enter undammed streams of northern Oregon, Washington, and the western side of Vancouver Island might indicate marine conditions in areas used by listed Snake River fish. Quinault and Fraser, or Vancouver Island sockeye populations might serve as indicators for ocean conditions for sockeye.

REFERENCES CITED

Allendorf, F. W. 1991. Evaluation of genetic issues for Snake River spring and summer chinook salmon. Div. of Biol. Sci., Univ. of Montana, Report to BPA, Contr. No. DE-AP79-91BP21862. 4 p.

Andrews, J., J. Lloyd, and B. Webster. 1987. Alturas Lake flow augmentation. Final Report, Project Number 83-415, Bonneville Power Administration, Portland, OR.

Arnsberg, B. D., W. P. Connor, E. Connor, M. J. Pishl, and M. A. Whitman. 1992. Mainstem Clearwater River study: assessment for salmonid spawning, incubating, and rearing. Final Report to BPA, Proj. No. 88-15, Contr. No. DE-BI79-87BP37474.

Bauer, S. B. 1989. Idaho nonpoint source program. Idaho Department of Health and Welfare, Boise, ID. 195 p.

BCF (Bureau of Commercial Fisheries). 1960. Memo from R. T. Pressey to C. E. Atkinson, E. Mains, R. Larson, D. Marriage, W. Pitney, and F. Hauch, dated Sept. 13, 1960.

Beamish, R. J., B. L. Thomson, and G. A. McFarlane. 1992. Spiny dogfish predation on chinook and coho salmon and the potential effects on hatchery-produced salmon. Trans. Amer. Fish. Soc. 121:444-455.

Beamesderfer, R. C., B. E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:439-447.

Bennett, D., P. Bratovich, W. Knox, D. Palmer, and H. Hansel. 1983. Status of the warmwater fishery and the potential of improving warmwater fish habitat in the Lower Snake reservoirs. Final report to U.S. Army Corps of Engineers, Contract No. DACW 68-79-CO057. 451 p.

Bennett, D. H., J. A. Chandler, and L. K. Dunsmoor. 1990. Lower Granite Reservoir in-water disposal test: results of the fishery, benthic and habitat monitoring program - year 1 (1988). Department of Fish and Wildlife Resources, Univ. of Idaho, Completion Report to U.S. Army Corps of Engineers, Walla Walla District.

Bennett, D. H., J. A. Chandler, and G. Chandler. 1991. Lower Granite Reservoir in-water disposal test: results of the fishery, benthic and habitat monitoring program - year 2 (1989). Department of Fish and Wildlife Resources, Univ. of Idaho, Completion

Report to U.S. Army Corps of Engineers, Walla Walla District.

Berggren, T. J., and M. J. Filardo. 1991. An analysis of variables invluencing the migration of juvenile salmonids in the Snake and Lower Columbia Rivers. FPC Report for ESA Admin. Record. 38 p.

Beschta, R. L., W. S. Platts, and B. Kauffman. 1991. Field review of fish habitat improvement projects in the Grande Ronde and John Day River basins of Eastern Oregon. Report to BPA, Proj. No. 910069, Contr. No. DE-AP79-91BP21493.

Brodeur, R. D. 1992. Factors releated to variability in feeding intensity of juvenile coho salmon and chinook salmon. Trans. Amer. Fish. Soc. 121:104-114.

Bjomn, T. C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. Forest, Wildlife, and Range Experiment Station, University of Idaho, Bulletin 27, Moscow, ID.

Bjomn, T. C. 1990. An assessment of adult losses, production rates, and escapements for wild spring and summer chinook salmon in the Snake River. Pp. 29-38 IN: D. Park, Convenor, Status and Future of Spring Chinook Salmon in the Columbia River Basin -- Conservation and Enhancement. NOAA, NMFS Tech. Memo. NMFS F/NWC-187.

Bjomn, T., D. Corley, and J. Mallet. 1963. Survey of chinook salmon spawning grounds in the upper Salmon River drainage - 1962. Idaho Fish and Game Department. 41 p.

Bjomn, T. C., D. R. Craddock, and D. R. Corley. 1968. Migration and survival of Redfish, Lake, Idaho, sockeye salmon, Oncorhvnchus nerka. Trans. Amer. Fish. Soc. 97:360-373.

Brannon, E. L., A. L. Setter, T. L. Welsh, S. J. Rocklage, G. H. Thorgaard, and S. A. Cummings. 1992. Genetic analysis of Oncorhvnchus nerka . Ann. Prog. Rep. Proj. No. 90-093, BPA Contract No. DE. BI79-9OBP12885.

Buettner, E. W. 1991. Smolt monitoring at the head of Lower Granite Reservoir and Lower Granite Dam. Idaho Department of Fish and Game, Annual Report to BPA, Proj. No. 83-323B, Contr. No. DE-BI79-83BP11631.

Bugert, R., P. LaRiviere, D. Marbach, S. Martin, L. Ross, and D. Geist. 1990. Lower Snake River compensation plan salmon hatchery evaluation program 1989 annual report. Washington Department of Fisheries AFF l/LSR-90-08.

Bureau of Reclamation. 1981. Grande Ronde River Basin Appraisal Report.

Bums, D. 1984. An inventory of embeddedness of salmonid habitat in the South Fork Salmon River drainage, Idaho. USDA Forest Service Unpublished Report, Payette National Forest, McCall, ID.

Bums, D. 1987. Embeddedness of salmonid habitat of selected streams on the Payette National Forest. USDA Forest Service Unpublished Report. Payette National Forest, McCall, ID.

Carmichael, R. Redd counts for Oregon spring and summer chinook salmon, 1957-1990. Letter from ODFW dated 26 September 1990.

CBFWA (Columbia Basin Fish and Wildlife Authority). 1991. The biological and technical justification for the flow proposal of the Columbia Basin Fish and Wildlife Authority. 72 p.

Chance, D. H. 1973. Influences of the Hudson's Bay Company on the native cultures of the Colvile District. Northwest Anthroop. Res. Notes. Memoir No. 2.

Chapman, D. W. 1966. Food and space as regulators of salmonid populations in streams. Amer. Naturalist 100:345-357.

Chapman, D. W., and T. C. Bjomn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. IN: T. G. Northcote (Editor), Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Univ. Brit. Columbia, Vancouver, Canada.

Chapman, D. W., D. E. Weitkamp, T. L. Welsh, T. H. Schadt, and M. B. Dell. 1985. Effects of river flow on the distribution of fall chinook salmon redds, Trans. Amer. Fish. soc, 115:537-547.

Chapman, D. W., W. S. Platts, D. Park, and M. Hill. 1990. Status of Snake River sockeye salmon. Don Chapman Consultants, Inc., Final Report for Pacific Northwest Utilities Conference Committee, Portland.

Chapman, D., A. Giorgi, M. Hill, A. Maule, S. McCutcheon, D. Park, W. Platts, K. Pratt, J. Seeb, L. Seeb, and F. Utter. 1991. Status of snake river chinook salmon. Prepared for: Pacific Northwest Utilities Conference Committee. Don Chapman Consultants, Inc., Boise, ID. 251 p.

Claire, E. W., and R. L. Storch. 1977. Streamside management and livestock grazing in the Blue Mountains of Oregon: A case study. Pp. 111-128 IN: J. W. Menke, Editor. Proceedings of the Workshop on Livestock and Wildlife-Fisheries Relationships in the Great Basin, May 3-5, 1977, Sparks, Nevada, Univ. of California, Berkeley.

COFO (Committee on Fisher Operations). 1982. 1981 Annual Report of the Columbia River Water Management Group.

Collins, G. B., W. J. Ebel, G. E. Monan, H. L. Raymond, and G. K. Tanonaka. 1975. The Snake River salmon and steelhead trout crisis: Its relation to dams and the national energy crisis. processed Report, National Marine Fisheries Service, Montlake, WA. 30 P.

Confederated Tribes of the Umatilla Indian Reservation. 1984. Grande Ronde River Basin recommended salmon and steelhead habitat improvement measures. Gary James, Principal Investigator.

Confederated Tribes of the Umatilla Indian Reservation. 1984. Imnaha River Basin recommended salmon and steelhead habitat improvement measures. Gary James, Principal Investigator.

Connor, W. P., H. L. Burge, and W. H. Miller. 1992. Migratory behavior of subyearling fall chinook salmon from the free-flowing Snake River to Lower Granite Dam. Chapter Five IN: D. W. Rondorf and W. H. Miller, Eds., Identification of the Spawning, Rearing, and Migratory Requirements of Fall Chinook Salmon in the Columbia River Basin. U.S. Fish and Wildlife Service, Ann. Prog. Rep. Aug. 1991-July 1992 to BPA, Proj. No. 91-029, Contr. No. DE-AI79-91BP21708.

Connor, W. P., A. P. Garcia, and H. L. Burge. 1992. Fall chinook salmon spawning in free-flowing reaches of the Snake River. Chapter One IN: D. W. Rondorf and W. H. Miller, Eds., Identification of the Spawning, Rearing, and Migratory Requirements of Fall Chinook Salmon in the Columbia River Basin. U.S. Fish and Wildlife Service, Ann. Prog. Rep. Aug. 1991-July 1992 to BPA, Proj. No. 91-029, Contr. No. DE-AI79-91BP21708.

Corley , D. 1967. Biological sampling of Panther Creek above and below the introduction of mining wastes. Idaho Fish and Game Department Report, Boise, ID.

Cramer, S. P. 1990. The feasibility for re-introducing sockeye and coho salmon in the Grande Ronde River and coho and chum in the Walla Walla River. S. P. Cramer and Associates, Fisheries Consultants, Corvallis, Oregon.

Dawley, E. M., R. D. Ledgerwood, T. H. Blahm, R. A. Kim, A. E. Rankis, and F. J. Ossiander. 1984. Migration characteristics and survival of juvenile salmonids entering the Columbia River estuary during 1982. NOAA, National Marine Fisheries Service, Coastal Zone and Estuarine Studies, Montlake, WA.

DeHart, D. 1987. Downstream migrant juvenile protection systems for low to medium head hydroelectric dams. PhD. dissertation, Univ. Washington, Seattle. 222 p.

DeIarm, M., L. Basham, S. Pettit, J. Atheam, and J. Barker. 1984. Fish Transportation Oversight Team Annual Report - FY 1983 Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR-7. 88 p.
Department of Environmental Quality. 1993. Grande Ronde Critical Basin Project. January 21,1993 Progress Report.

Durkin, J. T., S. J. Lipovsky, and R. J. **McConnell.** 1979. Biological impact of a flowlane disposal project near Pillar Rock in the Columbia River estuary. NOAA, NMFS, CZES Final Report to U.S. Army Corps of Engineers, Portland District, Contr. No. DACW57-77-F-062 1.

D. W. Kelley and Associates. 1982. Ecological investigations on the Tucannon River, Washington. Report by D. W. Kelley and Associates for H. Esmaili and Associates, Inc, of Berkeley, California, as part of a project for the USDA Soil Conservation Service.

Ebel, W., R. Krcma, and H. Raymond. 1973. Evaluation of fish protective facilities at Little Goose and Lower Granite dams and review of other studies relating to protection of juvenile salmonids in the Columbia and Snake rivers, 1973. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. DACW 68-71-093. 52 p.

Eggers, D. M., C. P. Meacham, and D. C. Huttunen. 1983. Population dynamics of Bristol Bay sockeye salmon, 19561983. Pp. 200-225 IN: W. G. Pearcy, Ed., The influence of ocean conditions on the production of salmonids in the North Pacific. Workshop November 8-10, 1983, Newport, Oregon. Oregon State Univ. Sea Grant College Prog. ORESU-W-83-01.

Environmental Protection Agency. 1972. Cattle feedlots and the environment, control guidelines.

EPA (Environmental Protection Agency). 1990. Biological criteria: national program guidance for surface waters. EPA-440/5-90-004, Washington, D.C., 57 p.

EPA (Environmental Protection Agency). 1991. Guidance for water quality-based decisions: the TMDL process. EPA440/491001, Washington, D.C., 58 p.

Everest, Fred H. 1969. Habitat selection and spatial interaction of juvenile chinook salmon and steelhead trout in two Idaho streams. PhD. dissertation, University of Idaho.

Evermann, B. W., and S. E. Meek. 1896. A report upon salmon investigations in the Columbia River Basin and elsewhere on the Pacific Coast in 18%. Bull. U.S. Fish Comm. 17: 15-55.

Evermann, B. W. 1897. A report upon salmon investigations in the headwaters of the Columbia, in the State of Idaho, in 1895, together with notes upon the fishes observed in that state in 1894 and 1895. Bull. U.S. Fish Comm. 16:149-202.

Faler, M., L. Miller, and K. Welke. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. North American Journal of Fisheries Management 8:30-35.

Fast, D., J. Hubble, M. Kohn, and B. Watson. 1991. Yakima River spring chinook enhancement study. Yakima Indian Nation report to BPA, Proj. No. 82-16, Contr. No. DE-A179-83BP39461.

Fisher, J. P., W. G. Pearcy, and A. W. Chung. 1983. Studies of juvenile salmonids off the Oregon and Washington coast, 1982. Oregon State Univ. Sea Grant Coll. Prog. Ref. 83-2,ORESU-T-83-003.

Fisher, J. P., W. G. Pearcy, and A. W. Chung. 1984. Studies of juvenile salmonids off the Oregon and Washington coast, 1983. Oregon State Univ. Sea Grant Coll. Prog. Ref. 84-2,ORESU-T-84-001.

Fisher, J. P., and W. G. Pearcy. 1984. Studies of juvenile salmonids off the Oregon and Washington coast, 1985. Oregon State Univ. Sea Grant Coll. Prog. Ref. 85-14, ORESU-T-85-004.

Forsgren, H., D. Heller, D. Holer, K. MacDonald, and R. Medel. 1988. Clackamas\Hood River habitat enhancement project -- 1988-1992 implementation plan and statement of work. USDA Forest Service, Mt. Hood Nat. For., Estacada, OR.

FST-CIC (Fishery Steering Committee--Columbia Basin Interagency Committee). 1957. Columbia River Basin fishery program--Part 2, Inventory of streams and proposed improvements for development of the fishery resources. Portland, OR.

GAO (Government Accounting Office). 1989. All is not well on the range. U.S. Congress, Committee on Government Operations. Number 342. 99th Congress, 2nd Session. House Report 99-593. U.S. Government Printing Office, Washington, D.C.

Gebhards, S. 1958. Stage reduction and channel relocation on the Lemhi River and the effects on fish production. Unpublished Report. Idaho Department of Fish and Game, Boise, ID.

Gebhards, S. 1959. The effects of irrigation on the natural production of chinook salmon in the Lemhi River, ID. Masters Thesis, Utah State University, Logan, UT.

Gibson, G. R. 1991. Draft procedures for initiating narrative biological criteria. U.S. EPA, Washington, D.C., 10 p.

Gilbreath, L. 1991. Unpublished review of research for U.S. Army Corps of Engineers. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA.

Giorgi, A. 1991. Mortality of yearling chinook salmon prior to arrival at Lower Granite Dam, on the Snake River. Don Chapman Consultants, Inc., Progress Report to BPA, Proj . No. 9 l-05 1, Contr. DE-BI79-87BP35885.

Giorgi, A. 1991. Biological issues pertaining to smolt migration and reservoir draw-down in the Snake and Columbia Rivers, with special reference to salmon species petitioned for listing under the Endangered Species Act. Report by Don Chapman Consultants, Inc., for U.S. Army Corps of Engineers and BPA under the System Operation Review.

Glasser, J. W. 1979. The role of predation in shaping and maintaining the structure of communities. The American Naturalist 113:631-641.

Hammann, M. G. 1981. Utilization of the Columbia River estuary by American shad (Alosa sapidissima (Wilson)). M.S. thesis, Oregon State Univ., Corvallis.

Hartt, A. C. 1980. Juvenile salmonids in the oceanic ecosystem - the critical first summer. Pp. 25-57 IN: W. J. McNeil and D. C. Hinsworth (Editors), Salmonid Ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis.

Hartt, A. C., and M. B. Dell. 1985. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. Bull. No. 46, Intern. North Pac. Fish. Comm. 105 p.

Hassemer, P. 1992. Revised redd counts for spring and summer chinook salmon in Idaho. Letter from IDFG to D. Chapman, dated 14 December 1992.

Hauck, F. 1955. Return of the big redfish. Idaho Wildlife Rev. 7(6): 3-4.

Hawkes, L., W. Smith, R. Martinson, W. Hevlin, and R. Absolon. 1991. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities, 1990. Annual Report to Bonneville Power Administration, Contract No. DOE/BP-20733-5, Ms in preparation.

Hawkes, L. A., R. D. Martinson, and W. W. Smith. 1992. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities - 1991. NMFS Report to BPA, Proj. No. 84-14, Contr. No. DE-AI79-85BP20733.

Healey, M. C. 1980a. Utilization of the Nanaimo River estuary by juvenile chinook salmon, Oncorhvnchus tshawvtscha. Fish. Bull. 77:653-668.

Healey, M. C. 1980b. The ecology of juvenile salmon in Georgia Strait, British Columbia. Pp. 203-229 IN: W. J. McNeil and D. C. Hinsworth (Editors), Salmonid Ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis.

Healey, M. C., and C. Groot. 1987. Marine migration and orientation of ocean-type chinook and sockeye salmon. American Fisheries Society Symposium 1:298-312.

Healey, M. C. 1991. Life history of chinook salmon. Pp. 313-393 IN: C. Groot and L. Margolis, Editors, Pacific Salmon Life Histories. Univ. of British Columbia Press, Vancouver.

Hicks, B. J., J. D. Hall, P. A. Bisson, and J. R. Sedell. 1989. Response of salmonid populations to habitat changes caused by timber harvest. In Compendium, Influences of Forest and Range Management On Anadromous Fisheries. Amer. Fish. Soc. Special Publication, Bethesda, MD.

Hillman, T. W., D. W. Chapman, and J. S. Griffity. 1989. Seasonal habitat use and behavioral interaction of juvenile chinook salmon and steelhead. I. Daytime Habitat selection. P;. 43-92 IN: Summer and Winter Ecology of Juvenile Chinook Salmon and Steelhead Trout. Final Report by Don Chapman Consultants, Inc., to Chelan County Public Utility District, Washington.

Holtby, L. B., and M. C. Healey. 1986. Selection for adult size in female coho salmon (Oncorhynchus kisutch). Can. J. Fish. and Aquat. Sci. 43:1946-1959.

HRC (Hydrosphere Resource Consultants, Inc). 1990. Water supplies to promote juvenile anadromous fish migration in the Snake River Basin. Hydrosphere Resource Consultants, Inc., Report to the National Marine Fisheries Service.

IDFG (Idaho Department of Fish and Game). 1920. Eighth Biennial Report, 1919 through 1920. Boise, Idaho.

IDFG. 1924. Tenth Biennial Report, 1923-1924. Boise, Idaho.

IDFG. 1992. Anadromous fish plan 1992-1996. Idaho Department of Fish and Game, Boise, ID.

Johnsen, R., L. Hawkes, W. Smith, G. Fredricks, R. Martinson, and W. Hevlin. 1990. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities - 1989. NMFS Annual report to Bonneville Power Administration, Contract No. DOE/BP-20733-5. 18 p. + appendices.

Kaczynski, V. W., and J. F. Palmisano. 1992. A review of management and environmental factors responsible for the decline and lack of recovery of Oregon's wild anadromous salmonids. Tech. Report for Oregon Forest Industries Council, Salem, OR. 292 p.

Kaeriyama, M. 1989. Current situation and future prospects of salmon culture in Japan. Pp. 118-123 IN: P. A. Knudsen, Editor, 14th Northeast Pacific pink and chum workshop. Washington Department of Fisheries, Olympia.

Karr, J. R. 1991. Biological integrity: a long-neglected aspect of water resource management. Ecological Applications l(1): 6684.

Kauffman, J. B. 1988. The status of riparian habitats in Pacific Northwest forests. Pp. 45-55 IN: J. Raedeke, Editor. Streamside Management:riparian wildlife and forestry interactions. Univ. Wash. Inst. For. Res. Contr. No. 59.

Kauffman, J. B., and W. C. Drueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications.. .a review. J. Range Management 37:430-437.

Kiefer, R., and K. Forster. 1990. Intensive evaluation and monitoring of chinook salmon and steelhead trout production - Crooked River and Upper Salmon River sites. Part II, Idaho Department of Fish and Game, Ann. Prog. Report 1988, BPA Proj. No. 83-7, Contract No. DE-BI79-84BP13381.

Kiefer, R. B., and K. A. Forster. 1991. Intensive evaluation and monitoring of chinook salmon and steelhead trout production - Crooked River and Upper Salmon River sites. Part II, Idaho Department of Fish and Game, Ann. Prog. Report 1989, BPA Proj. No. 83-7, Contract No. DE-BI79-84BP13381.

Kindley, R. 1991. The flow/survival/travel time relationship: review and analysis of supporting information and rationale for flows for juvenile spring and summer chinook migrations. Report prepared by PNUCC for the ESA Admin. Record. 35 p.

Knox, W. J., M. W. Flesher, R. B. Lindsay, and L. S. Lutz. 1984. Spring chinook studies in the John Day River. John Day Salmon Studies, Oregon Department of Fish and Wildlife, Ann. Report FY 1984 to BPA, Proj. No. 79-4, Contr., No. DE-AC79-84BP39796.

Koski, C., S. Pettit, J. Atheam, and A. Heindl. 1985. Fish Transportation Oversight Team annual report - FY 1984 transport operations on the Snake And Columbia Rivers. NOAA, NMFS Tech. Memo. NMFS F/NWR-11. 80 p.

Koski, C., S. Pettit, J. Athearn, and A. Heindl. 1986. Fish Transportation Oversight Team annual report - FY 1985 transport operations on the Snake And Columbia Rivers. NOAA, NMFS Tech. Memo. NMFS F/NWR-14. 70 p.

Koski, C., S. Pettit, J. Atheam, and A. Heindl. 1987. Fish Transportation Oversight Team annual report - FY 1986 transport operations on the Snake And Columbia Rivers. NOAA, NMFS Tech. Memo. NMFS F/NWR-18. 70 p.

Koski, C., S. Pettit, and J. McKern. 1990. Fish Transport Oversight Team Annual Report - FY 1989: transport operations on the Snake and Columbia Rivers. NOAA Technical Memorandum F/NWR-27. 65 p.

Krebs, J. R. 1978. Optimal foraging: decision rules for predators. Pp. 23-63 IN: J. R. Krebs and N. B. Davies, Eds. Behavioral Ecology. Blackwell Scientific, Oxford.

Kaczynski, V., and J. Palmisano. 1992. A review of management and environmental factors responsible for the decline and lack of recovery of Oregon's wild salmonids. Tech. Report for Oregon Forest Industries Council, Salem.

Ledgerwood, R., G. Swan, and R. Krcma. 1987. Fish guiding efficiency of submersible traveling screens at Lower Granite Dam - 1986. Annual Report to U.S. Army Corps of Engineers, Portland. 19 p.

Ledgerwood, R., E. Dawley, L. Gilbreath, P. Bentley, B. Sandford, and M. Schiewe. 1990. Relative survival of subyearling chinook salmon which have passed Bonneville Dam via the spillway or the second powerhouse turbines or bypass system in 1989, with comparisons to 1987 and 1988. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. E85890024/E86890097. 64 p.

Ledgerwood, R., E. Dawley, L. Gilbreath, P. Bentley, B. Sandford, and M. Schiewe. 1991. Relative survival of subyearling chinook salmon that have passed through the turbines or bypass system of Bonneville Dam second powerhouse, 1990. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. E86900104. 90 p.

Levesque, R. C., and R. J. Reed. 1972. Food availability and consumption by young Connecticut River shad, Alosa sapidissima. J. Fish. Res. Bd. Can. 29:1495-1499.

Levy, D. A., and T. G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River estuary. Can. J. Fish. Aquat. Sci. 39:270-276.

Li, H. W., T. N. Pearsons, C. K. Tait, J. L. Li, and R. Gaither. 1992. Approaches to evaluate habitat improvement programs in streams of the John Day Basin. Completion Report, Oregon Coop. Fish. Res. Unit, Oregon State Univ.

Lindsay, R., B. Jonasson, R. Shroeder, and B. Gates. 1989. Spring chinook salmon in the Deschutes River, Oregon. ODFW Information Report 89-4.

Locke, S. B. 1929. Whitefish, grayling, trout, and salmon of the Intermountain Region.

Bur. Fish. Doc. 1062:173-190.

Loeffel, R. E., and H. 0. Wendler. 1969. Review of the Pacific Coast chinook and coho salmon resources with special emphasis on the troll fishery. IN: Report by the U.S. Section, Informal Committee on Chinook and Coho, Volume I. 107 p.

Mains, E., and J. Smith. 1964. The distribution, size, time and current preferences of seaward migrant chinook salmon in the Columbia and Snake Rivers. Wash. Dept. of Fisheries, Fish. Res. Papers Vol 2(3):543.

Mallet, J. 1974. Long range planning for salmon and steelhead in Idaho. Job 2. Inventory of salmon and steelhead resources, habitat, use and demands. Idaho Department of Fish and Game. 212 p.

Martin, S., and W. Platts. 1981. Effects of mining. in Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Mathews, S. B. 1984. Variability of marine survival of Pacific salmonids: A review. Pp. 161-182 IN: W. Pearcy, Ed., The Influence of Ocean Conditions on the Production of Salmonids in the North Pacific. Oregon State Univ., Sea Grant Program.

Mathews, S. B., and Y. Ishida. 1989. Survival, ocean growth, and ocean distribution of differentially timed release of hatchery coho salmon (Oncorhvnchus kisutch). Can. J. Fish. Aquat. Sci. 46: 12161226.

Matthews, G., D. Park, J. Harmon, C. McCutcheon, and A. Novotny. 1987. Evaluation of transportation of juvenile salmonids and related research on the Columbia and Snake Rivers - 1986. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. DACW68-84-H-0034. 34 p.

McCabe, G. T., Jr., W. D. **Muir,** R. L. Emmett, and J. T. Durkin. 1983. Interrelations between juvenile salmonids and nonsalmonid fish in the Columbia River estuary. Fish. Bull. 81.

McCann, J. A., H. L. Burge, and W. P. Connor. 1993. Chapter Four IN: D. W. Rondorf and W. H. Miller, Eds., Identification of the Spawning, Rearing, and Migratory Requirements of Fall Chinook Salmon in the Columbia River Basin. U.S. Fish and Wildlife Service, Ann. Prog. Rep. Aug. 1991-July 1992 to BPA, Proj. No. 91-029, Contr. No. DE-AI79-91BP21708.

Meehan, W. R. 1989. Letter to WDF regarding proposed anadromous fish habitat research in the Pacific Northwest and Alaska during the period 1990-1995. USDA Forest Service, Juneau, AK.

Megahan, W. F., W. S. Platts, and B. Kulesza. 1980. Riverbed improves over time: South Fork Salmon. Pp. 380-395 IN: Symposium on Watershed Management, Vol. I. Amer. Soc, Civ. Eng., New York.

Mendel, G., D. Milks, R. Bugert, and K. Petersen. 1992. Upstream passage and spawning of fall chinook salmon in the Snake River, 1991. Wash. Dept. Fisheries Completion Report to U.S. Fish and Wildlife Service, Coop. Agreement No. 14-16-0001-01502.

Messmer, R. 1992. Redd counts for chinook salmon in Oregon streams, 1990-1992. Letter from ODFW dated 30 November 1992.

Miller, D. R., J. G. Williams, and C. W. Sims. 1983. Distribution, abundance and growth of juvenile salmonids off the coast of Oregon and Washington, summer 1980. Fish. Res. 2:1-17.

Monk, B., and J. Williams. 1990. Evaluation of the juvenile collection, bypass, and sampling facility at Little Goose Dam 1990. Abstract, Annual Research Review to U.S. Army Corps of Engineers, October 1990.

Montgomery Engineers. 1980. Draft Environmental Impact Statement - Stibnite mining project. Rep. to USDA Forest Service, Payette National Forest, McCall, ID.

Montgomery Engineers. 1985. Bear Valley Creek, Idaho fish habitat enhancement project selected alternative report. Prepared for the Shoshone-Bannock Tribes, Boise, ID.

Munther, G. 1974. Fishery effects of irrigation diversion and related structures in the Sawtooth National Recreation Area - Progress Report 1, Sawtooth National Forest, Twin Falls, ID.

Mundy, P. 1992. Salmon recovery program Columbia River Inter-tribal Fish Commission. Discussion draft of the Tribal Salmon Production Report to Congress.

National Research Council. 1992. Restoration of aquatic ecosystems - science, technology, and public policy. National Academy Press, Washington, D.C.

Nicholas, J. W., T. W. Downey, D. Bottom, and A. McGie. 1984. Research and development of Oregon’s coastal chinook stocks. Oregon Department of Fish and Wildlife, Ann. Prog. Rep., Contr. No. 82-ABD-ORIE.

NMFS/UW (National Marine Fisheries Service and University of Washiington). 1993. Survival estimates for the passage of juvenile salmonids through dams and reservoirs. Project proposal to BPA by NMFS and Univ. of Washington.

NPPC (Northwest Power Planning Council). 1986. Compilation of salmon and steelhead losses in the Columbia River Basin. Appendix D. of the 1987 Columbia River Basin Fish and Wildlife Program. Portland, OR.

NPPC. 1989. Grande Ronde River subbasin salmon and steelhead draft plan. Columbia Basin System Planning.
OEA Research. 1986. Upper Salmon River aquatic and riparian area inventory, Appendices A through E. Helena, MT. Available Boise National Forest, Boise, ID.

Orsbom, J. F., K. Ameman, B. Clark, K. Coulton, B. Naik and J. Stypula. 1985. Crooked River habitat improvement project, Final Report, Planning for the restoration of meanders on a trial basis. Albrook Hydraulics Laboratory, Washington State University, Pullman, WA.

Ortmann, D., and M. Richards. 1965. The gathering and compilation of relevant data for Idaho salmon and steelhead runs. Idaho Department of Fish and Game. 53 p.

Park, D., E. Dawley, R. Krcma, C. Long, E. Slatick, J. Smith, and G. Swan. 1976. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams and review of other studies relating to protection of juvenile salmonids in the Columbia and Snake Rivers, 1975. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. DACW 68-75-C-01 11.50 p.

Park, D., J. Smith, E. Slatick, G. Swan, E. Dawley, and G. Matthews. 1977. Evaluation of fish protective facilities at Little Goose and Lower Granite Dams and review of nitrogen studies relating to protection of juvenile salmonids in the Columbia and Snake Rivers, 1976. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. DACW 68-75-C-001 1.47 p.

Park, D. L., G. M. Matthews, J. R. Smith, T. E. Ruehle, J. R. Harmon, and S. Achord. 1984. Evaluation of transportation of juvenile salmonids and related research on the Columbia and Snake Rivers, 1983. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. DACW 68-78-C-005. 58 p.

Parker, R. 1971. Size selective predation among juvenile salmonid fishes in a British Columbia inlet. J. Fish. Res. Bd. Can. 28:1503-1510.

Parkhurst, 2. 1950. Survey of the Columbia River and its tributaries, Parts l-6. U.S. Fish and Wildlife Service, Special Scientific Reports, Portland, OR.

Pearcy, W.G., Editor. 1983. The influence of ocean conditions on the production of salmonids in the North Pacific. A workshop November 8-10,1983, Newport, Oregon, Oregon State Univ. Sea Grant College Program ORESU-W-83-001.

Peek, J., and J. Gebhardt. 1981. Report on field trip to riparian zones in Sawtooth National Recreation Area and vicinity, Idaho. Rangelands 3(5): 192-193.

Peterman, R. M. 1984. Density-dependent growth in early ocean life of sockeye salmon (Oncorhynchus nerka). Can. J. Fish. Aquat. Sci. **41:1825-1829.**

Peterman, R. M. 1987. Review of the components of recruitment of Pacific salmon. Amer. Fish. Soc. Symposium 1:417-429.

Peterson, W. T., R. D. Brodeur, and W. G. Pearcy. 1982. Food habits of juvenile salmon in the Oregon coastal zone, June 1979. Fish. Bull. 80:841-851.

Peterson, C., D. Geppsen, R. Nelle, R. Shively, R. Tabor, and T. Poe. 1991. System-wide significance of predation on juvenile salmonids in Columbia and Snake River reservoirs. U.S. Fish and Wildlife Service, Annual Report to Bonneville Power Administration, Contract No. **DOE/BP-07096-1.** 53 p.

Petrosky, C. 1990. Estimating spring chinook parr and smolt abundance in wild and natural production areas. Pp. 57-61 IN: Status and future of spring chinook salmon in the Columbia River Basin --- conservation and enhancement. Abstracts of a Spring Chinook Salmon Workshop, 8-9 November, 1089, Pasco, WA; NOM technical Memorandum NMFS FNWC Memorandum NMFS F/NW/C-1187, Coastal Zone and Estuarine Studies Division, National **Marine** Fisheries Service, Montlake, WA.

Petrosky, C., and T. Holubetz. 1986. Idaho habitat evaluation for off-site mitigation record. Idaho Fish and Game Department Annual Report, Project 83-7, Contr. No. DE-AI7984BP 1338 1, Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR.

Platts, W. S. 1972a. The effects of heavy metals on anadromous runs of salmon and steelhead in the Panther Creek drainage, Idaho. Western Proceedings of the 52nd Annual Conference of the Western Association of State Game and Fish Commissioners. Boise, ID.

Platts, W. S. 1972b. Aquatic environment and fisheries study proposed Sawtooth National Recreation and Wilderness Areas. Sawtooth National Forest, Twin Falls, ID.

Platts, W. S. 1990. Fish, wildlife and livestock: Protection of riparian areas. Western Wildlands 16(2): 1619. University of Montana, School of Forestry, Missoula, MT.

Platts, W. S., S. B. Martin and E. J. Primbs. 1979. Water quality in an Idaho stream degraded by acid mine waters. USDA Forest Service, Intermountain Research Station, GTR-INT-67, Ogden, UT.

Platts, W. S., and R. Nelson. 1985a. Impacts of rest-rotation grazing on stream banks on forested watersheds in Idaho. North American Journal Fisheries Management 5:547-556.

Platts, W. S., and R. Nelson. 1985b. Streamside and upland vegetation use by cattle. Rangelands 7(1):5-7.

Platts, W. S., R. Torquemada, M. McHenry, and C. Grahm. 1989. Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. Transactions of the American Society 118:274-283.

Platts, W. S., and R. W. Phillips. 1990. A field review of Forest Service stream rehabilitation projects in John Day River tributaries. Don Chapman Consultants, Inc., Boise, ID.

Platts, W. S., and R. L. Beschta. 1992. A one day field review of stream habitat improvement projects in Fifteen Mile Creek, Oregon. Don Chapman Consultants, Inc.

Platts, W. S.,and D. W. Chapman. 1992. Salmon and steelhead habitat condition, improvement needs, and courses of action in the Salmon River drainage. Don Chapman Consultants, Inc., typed report.

PMFC (Pacific Marine Fisheries Commission). 1981. 33rd Annual Report of the Pacific Marine Fisheries Commission for the year 1980. PMFC, 528 S.W. Mill St., Portland.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Puckett, K. 1983. The energetics of feeding territoriality in juvenile coho salmon (Oncorhynchus kisutch). M.S. thesis, Simon Fraser University, New Westminster, B.C.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.

Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon in the Columbia River Basin. North American Journal of Fisheries Management 8: l-25.

Reimers, P. 1973. The length of residence of fall chinook salmon in Sixes River. Oregon Fish Comm. Research Report 4:2-43.

Reiser, D. W. 1986. Panther Creek, Idaho habitat rehabilitation. Final Report. Contract Number DE-AC79-84BP17449. U.S. Department of Energy, Bonneville Power

Administration, Portland, OR.

Reiser, D.W., M.W. Vitter and J. Todd. 1982. Reestablishment of fish and aquatic invertebrate populations in a stream severely impacted by acid mine drainage. Proceedings of the Annual Conference of Western Fish and Game Agencies 62:555-563.

Rich, W. 1920. Early history and seaward migration of chinook salmon in the Columbia and Sacramento Rivers. Bull. U.S. Bur. Fish. 37:1-74.

Rich, B. A., R. J. Scully, and C. E. Petrosky. 1992. Idaho habitat/natural production monitoring, Part I General Monitoring Subproject. Ann. Rep. 1990, Idaho Department of Fish and Game, BPA Contr. No. DE-A179-84BP13381, Proj. 83-7.

Richards, M., and S. Gebhards. 1959. Aerial survey of spring chinook salmon redds in the Salmon and Weiser River drainages, Idaho. 1958. Idaho Department of Fish and Game. 46 p.

Rieman, B. E., R. C. Beamesderfer, and S. Vigg. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.

Rodeheffer, I. A. 1935. A survey of the waters of the Challis National Forest, Idaho. Department of Commerce, Bureau of Fisheries, Washington, D.C.

Rogers, D. E. 1980. Density-dependent growth of Bristol Bay sockeye salmon. Pp. 267-283 IN: W. J. McNeil and D. C. Himsworth, Eds. Salmonid ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis.

Schiewe, M. H. 1993. Sockeye abundance. NMFS Memorandum to J. G. Smith from Coastal Zone and Estuarine Studies Division, Montlake.

Schill, D. 1984. Evaluating the anadromous fish screen program on the upper Salmon River. Idaho Fish and Game Department, Unpublished Report, Boise, ID.

Schoeneman, D. E., R. T. Pressey, and C. 0. Junge. 1961. Mortalities of downstream migrant salmon at McNary Dam. Trans. Amer. Fish. Soc. 90:58-72.

Schreck, C. B., H. W. Li, A. G. Maule, C. S. Bradford, B. A. Barton, L. Sigismondi, and P. J. Prete. 1985. Columbia River salmonid outmigration: McNary Dam passage and enhanced smolt quality. Completion Report to U.S. Army Corps of Engineers, Contract No. DACW68-84-C-0063.

Schreck, C., H. Li, R. Hjort, C. Sharpe, and S. Stone. 1986. Stock identification of Columbia River chinook salmon and steelhead trout. Oregon State Univ. Final Report to BPA, Proj. 83-451, Agreement No. DE-A179-83BP13499.

Scully, R. J., and E. Buettner. 1986. Smolt condition and timing of arrival at Lower Granite Reservoir. Idaho Department of Fish and Game, Annual Report to Bonneville Power Administration, Contr. No. DE-A179-83BP11631, Proj. No. 83-323B. 78 p.

Scully, R. J., and C. E. Petrosky. 1991. Idaho habitat/natural production monitoring, Part I, general monitoring subproject. AM. Rep. 1989, Idaho Department of Fish and Game, Project No. 83-7, Contr. No. **DE-A179-84BP13381.**

Sedell, J., and F. Everest. 1990. Historic changes in pool habitat for Columbia River Basin salmon under study for Threatened and Endangered Species listing. USDA Forest Service Briefing Paper by C. W. Philpot, Pacific Northwest Research Station, Corvallis, OR.

Seelbach, P. W. 1987. Effect of winter severity on steelhead smolt yield in Michigan: an example of the importance of environmental factors in determining smolt yield. Amer. Fish. Soc. Symposium 1:441450.

Sherwood, C. R., D. A. Jay, R. B. Harvey, P. Hamilton, and C. A. Simenstad. 1990. Historical changes in the Columbia River estuary. Prog. Oceanography 25:299-352.

Simenstad, C. A., and R. C. Wissmar. 1983. Variability of estuarine food webs and production may limit our ability to enhance Pacific salmon (Oncorhvnchus spp.). Pp. 273-286 IN: W. Pearcy, Editor, The Influence of Ocean Conditions on the Production of Salmonids in the North Pacific. A workshop November 8-10,1983, Newport, Oregon, Oregon State Univ. Sea Grant College Program ORESU-W-83-01.

Sims, C., and R. Johnsen. 1977. Evaluation of the fingerling bypass system at John Day Dam and the fingerling bypass outfall at McNary Dam. NMFS Annual Report to U.S. Army Corps of Engineers, Contract No. DACW 57-76-F-0630. 15 p.

Sims, C., and F. Ossiander. 1981. Migrations of juvenile chinook salmon and steelhead trout in the Snake River from 1973 to 1979. NMFS Report to U.S. Army Corps of Engineers. 31 p.

Sims, C., A. Giorgi, R. Johnsen, and D. Brege. 1983. Migrational characteristics of juvenile salmon and steelhead in the Columbia Basin - 1982. NMFS Final Report to U.S. Army corps of Engineers. 22 p.

Skalski, J. R., and A. Giorgi. 1992. Juvenile passage proposal: estimating smolt travel time and survival in the Snake and Columbia Rivers. Proposal by Center for Quantitative Scien, Univ. of Washington, and Don Chapman Consultants, Inc., Boise, Idaho.

Skovlin, J. M., W. R. Meehan, J. C. Buckhouse, and M. Vavra. 1977. Determining the influence of grazing on riparian and aquatic habitats in the Blue Mountains of northeastern Oregon. Pp. 164-173 IN: J. W. Menke, Editor. Proceedings of the Workshop on Livestock and Wildlife-Fisheries Relationships in the Great Basin, May 3-5, 1977, Sparks, Nevada, Univ. of California, Berkeley.

Solazzi, M. F., T. E. Nichelson, and S. L. Johnson. 1991. Survival, contribution, and return of hatchery coho salmon (Qncorhvnchus kisutch) smolts. Canadian J. Fisheries and Aquat. Sci. 37:765-769.

Swan, G. A., R. F. Krcma, and C. W. Long. 1982. Research to develop an improved fingerling-protection system for John Day Dam, 1981. NMFS Annual Report to U.S. Army Corps of Engineers, Contr. No. DACW57-81-F-0341. 22 p.

Swan, G. A., E. M. Dawley, R. D. Ledgerwood, W. T. Norman, W. F. Cobb, and D. T. Hartman. 1988. Distribution and relative abundance of deep-water redds for spawning fall chinook salmon at selected study sites in the Hanford Reach of the Columbia River. NOM, NMFS, Coastal Zone and Estuarine Studies, Final Report to U.S. Army Corps of Engineers, Contr. No. E86-87-3082, Montlake, WA.

Swan, G., B. Monk, J. Williams, and B. Sandford. 1990. Fish guidance efficiency of submersible traveling screens at Lower Granite Dam - 1989. Annual Report to U.S. Army Corps of Engineers, Walla Walla, Contract No. DACW68-84-H-0034.

Thomas, S.,M. Leonard, R. Miller, and R. Uberuaga. 1987. Grande Ronde River habitat enhancement on the Wallowa-Whitman National Forest. U.S. Forest Service, Annual Report to BPA. IN: Natural propagation and habitat improvement Vol. I - Oregon, Final and Annual Reports, 1986.

Thompson, R. B. 1959. Food of the squawfish Ptychocheilus oregonensis (Richardson) of the Lower Columbia River. U.S. Fish and Wildlife Service Bulletin 158, Vol. 60:43-58.

Thompson, R. N., and J. B. Haas. 1960. Environmental survey report pertaining to salmon and steelhead in certain rivers of Eastern Oregon and the Willamette River and its tributaries. Oregon Fish Commission, Clackamas, Oregon.

Thome, R. E., and J. J. Ames. 1987. A note on variability of marine survival of sockeye salmon (Oncorhvnchus nerka) and effects of flooding on spawning success. Can. J. Fish. Aquat. Sci. 44: 1791-1795.

U.S. Forest Service. 1981. Final environmental impact statement, Hells Canyon National Recreation Area Comprehensive Management Plan.

USACE (U.S. Army Corps of Engineers). 1976. Irrigation depletions/instream flow study. Report CRT-29, Walla Walla District, Walla Walla, WA.IDFG (Idaho Department of Fish and Game). 1920. Eighth Biennial Report, 1919-1920, Boise, Idaho.

USFS (U.S. Forest Service). 1990. Sawtooth National Recreation Area Stanley Basin C&H Allotment Management Plan - Draft Environmental Impact Statement. U.S. Forest Service, Sawtooth National Forest, Twin Falls, ID.

Utter, F. M. 1982. Population structures of fall chinook salmon, Oncorhynchus tshawytscha, of the mid-Columbia and Snake Rivers. NOAA, NMFS, Northwest and Alaska Fishery Center Proc. Report 82-10, Seattle, WA. 14 p.

Utter, F. M., G. B. Miller, G. Stahl, and D. J. Teel. 1989. Genetic population structure of chinook salmon in the Pacific Northwest. Fish. Bull 87:239-264.

Vigg, S. 1988. Functional response of northern squawfish predation to salmonid prey density in McNary tailrace, Columbia River Pp. 174-207 IN: T. P. Poe and B. E. Rieman, Eds. Predation by resident fish on juvenile salmonids in John Day Reservoir, 1983-1986. Final Report, Bonneville Power Administration, Portland, Oregon.

Vigg, S., T. P. Poe, L. A. Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Walburg, C. H. 1956. Observations on the food and growth of juvenile American shad, Alosa sapidissima. Trans. Amer. Fish. Soc. 86:302-306.

Walters, C., M. Stocker, A. V. Tyler, and S. J. Westrheim. 1986. Interactions between Pacific cod (Gadus macrocenhalus) and herring (Clupea harengus pallasi) in the Hecate Strait, British Columbia. Bull. No. 47, International North Pacific Fish. Comm.:87-100.

Waples, R., D. Teel, and P. Aebersold. 1991. A genetic monitoring and evaluation program for supplemented populations of salmon and steelhead in the Upper Columbia River Basin. Draft summary report to BPA, Proj. No. 89-096, Contract No. DE-a179-89BPOO911, CZES, NMFS, Montlake, WA.

WDF (Washington Department of Fisheries)/ODFW (Oregon Department of Fish and Wildlife). 1992. Columbia River fish runs and fisheries, 1938-91. Status Report of the Washington Department of Fisheries and Oregon Department of Fish and Wildlife. 224 p.

WDF (Washington Department of Fisheries). 1992. Salmon 2000 technical report. Phase 2: Puget Sound Washington Coast and Integrated Planning. Washington

Department of Fisheries, Olympia.

WFPB (Washington Forest Practice Board). 1992. Washington forest practice rules and regulations. Washington Forest Practice Board.

Welsh, T. 1962. The reintroduction of chinook salmon into the Clearwater River drainage, Idaho. Idaho Department of Fish and Game. 24 p.

Welsh, T. 1991. Stanley Basin sockeye salmon lakes, upper Salmon River drainage, Idaho. Fish stocking history, fish eradication projects. Present status of the kokanee salmon stocks. Univ. Idaho Aquaculture Institute. 21 p.

Welsh, T. L., S. V. Gebhards, H. E. Metsker, and R. V. Coming. 1965. Inventory of Idaho streams containing anadromous fish including recommendations for improving production of salmon and steelhead. Idaho Fish and Game Department, Report to U.S. Fish and Wildlife Service, Contr. No. 14-19-001-431.

Williams, S. H., A. L. Reece, W. T. Noll, and R. N. Reeve. 1987. Grande Ronde habitat improvement project: Joseph Creek and upper Grande Ronde River drainages. Oregon Department of Fisheries and Wildlife, BPA Contr. No. DE-AI79-84BP16114, Proj. No. 84-25.

Winans, G. A. 1989. Genetic variability in chinook salmon stocks from the Columbia River Basin. North Amer. J. Fishery Management 9:47-52.

Witty, K. L. 1964-1970. Annual fishery reports. Wallowa Fisheries District. Oregon Department of Fish and Wildlife. Enterprise, Oregon.

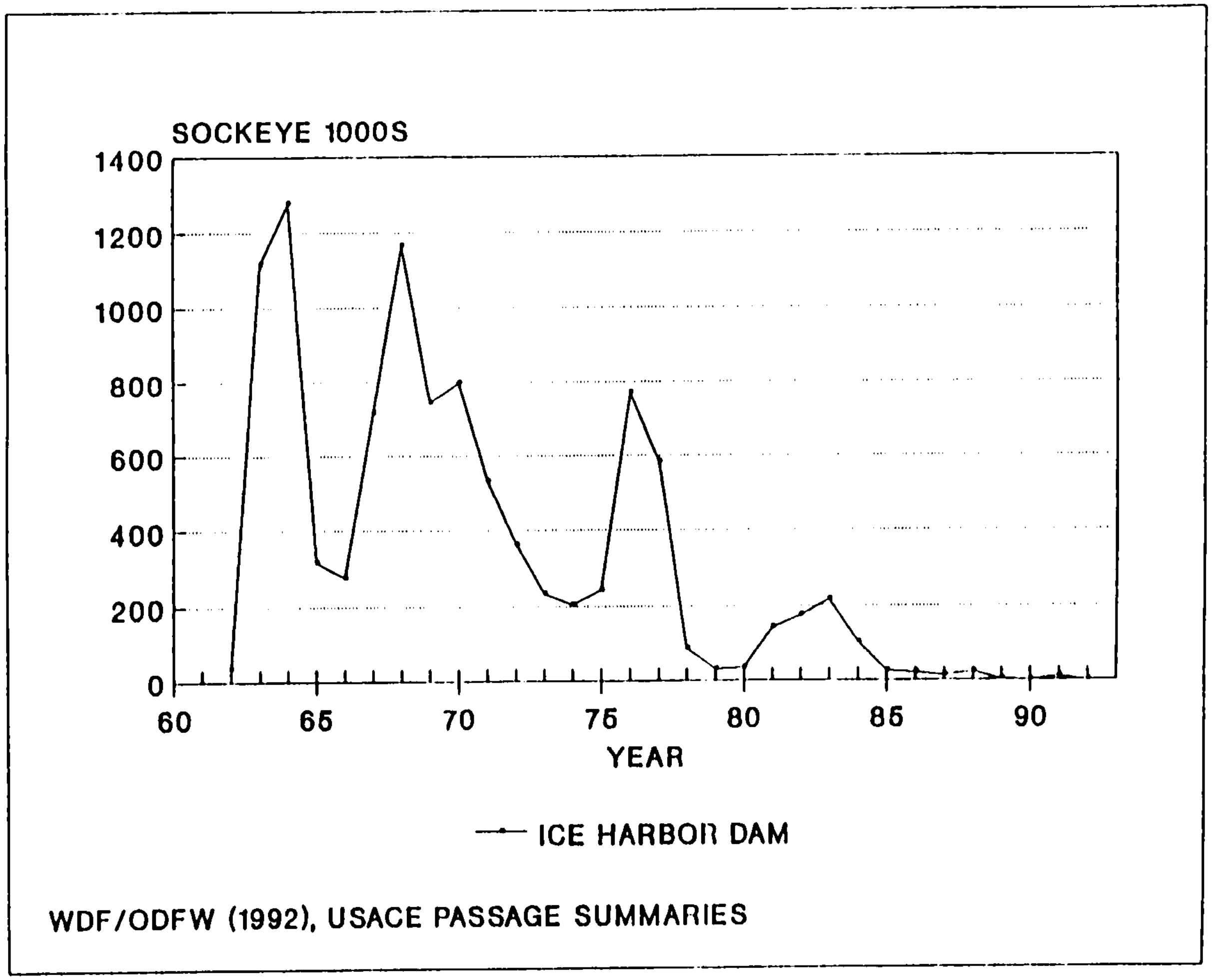


Figure 1. Fishway counts of sockeye salmon at Ice Harbor Dam.

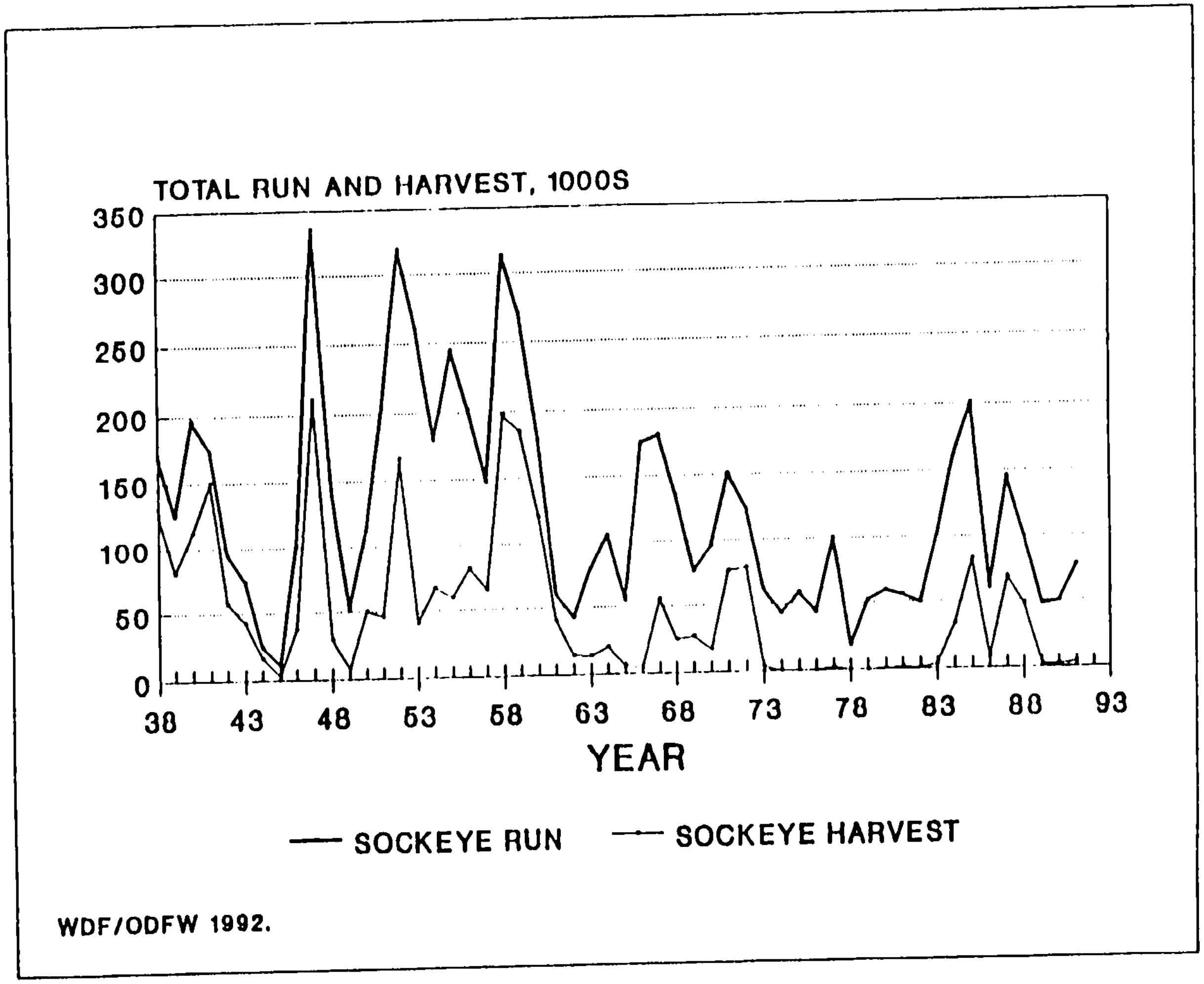
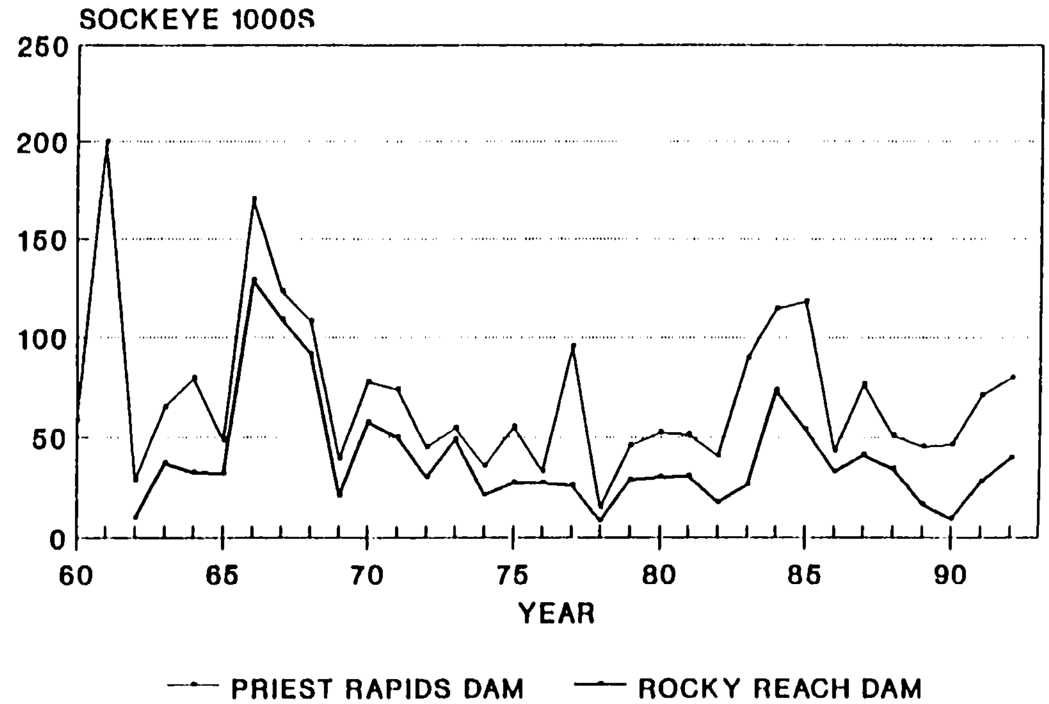


Figure 2. Sockeye run entering the Columbia River and sockeye harvest.



WDF/ODFW (1992), USACE PASSAGE NOTES,
NWPPC 1986, FISH PASSAGE CENTER.

Figure 3. Fishway counts of sockeye salmon at Priest Rapids and Rocky Reach Dams, mid-Columbia River.

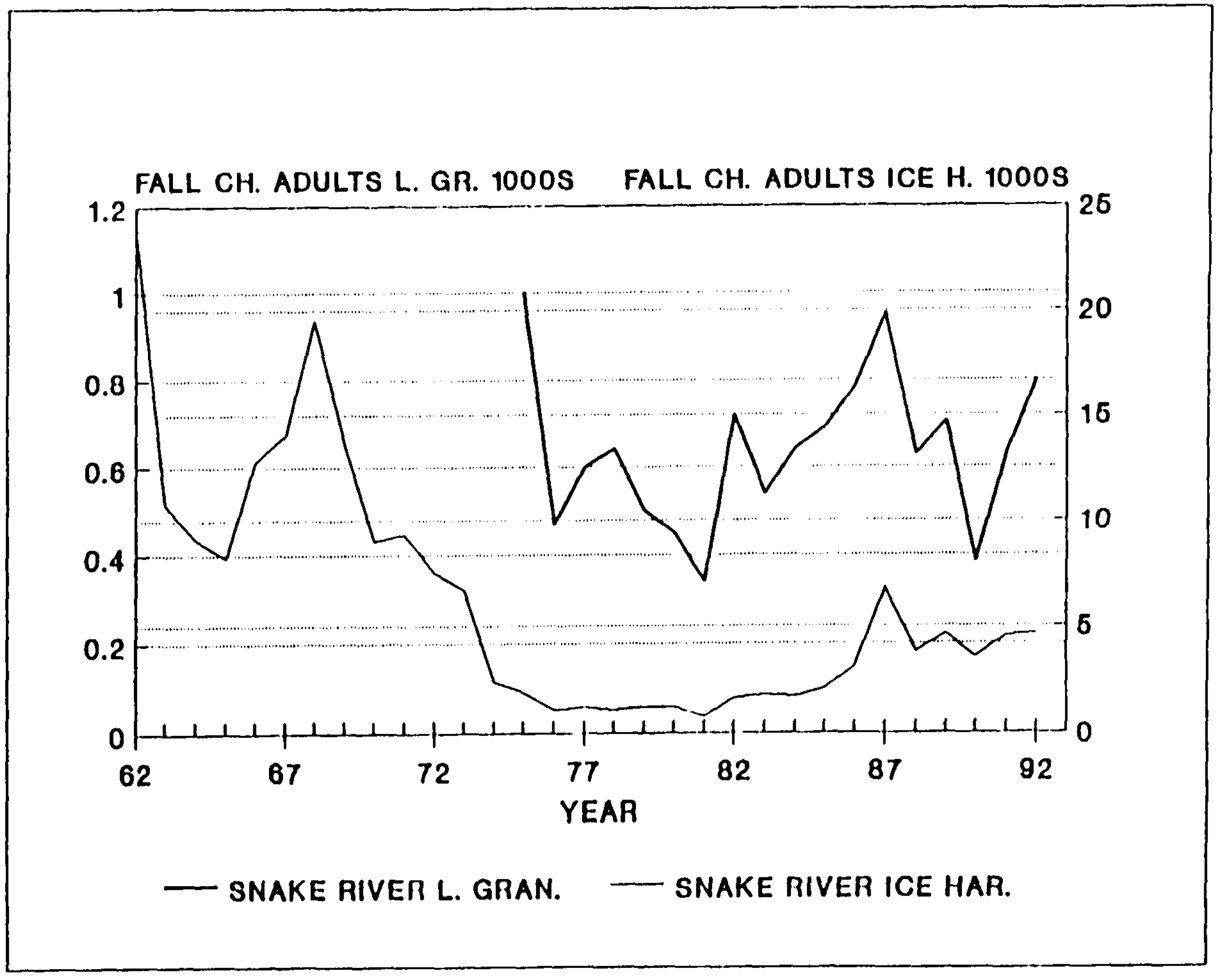
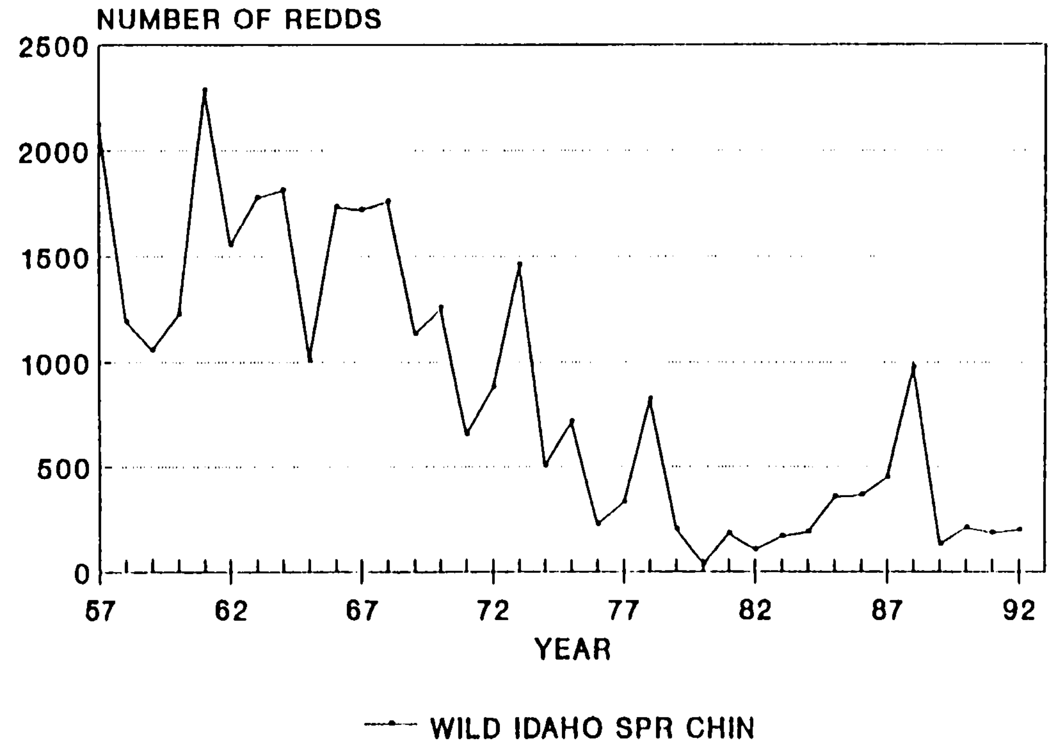


Figure 5. Fishway counts of fall chinook at Ice Harbor and Lower Granite Dams, Snake River.



Hassemer 1992.

Figure 6. Index area redd counts for wild spring chinook, Idaho.

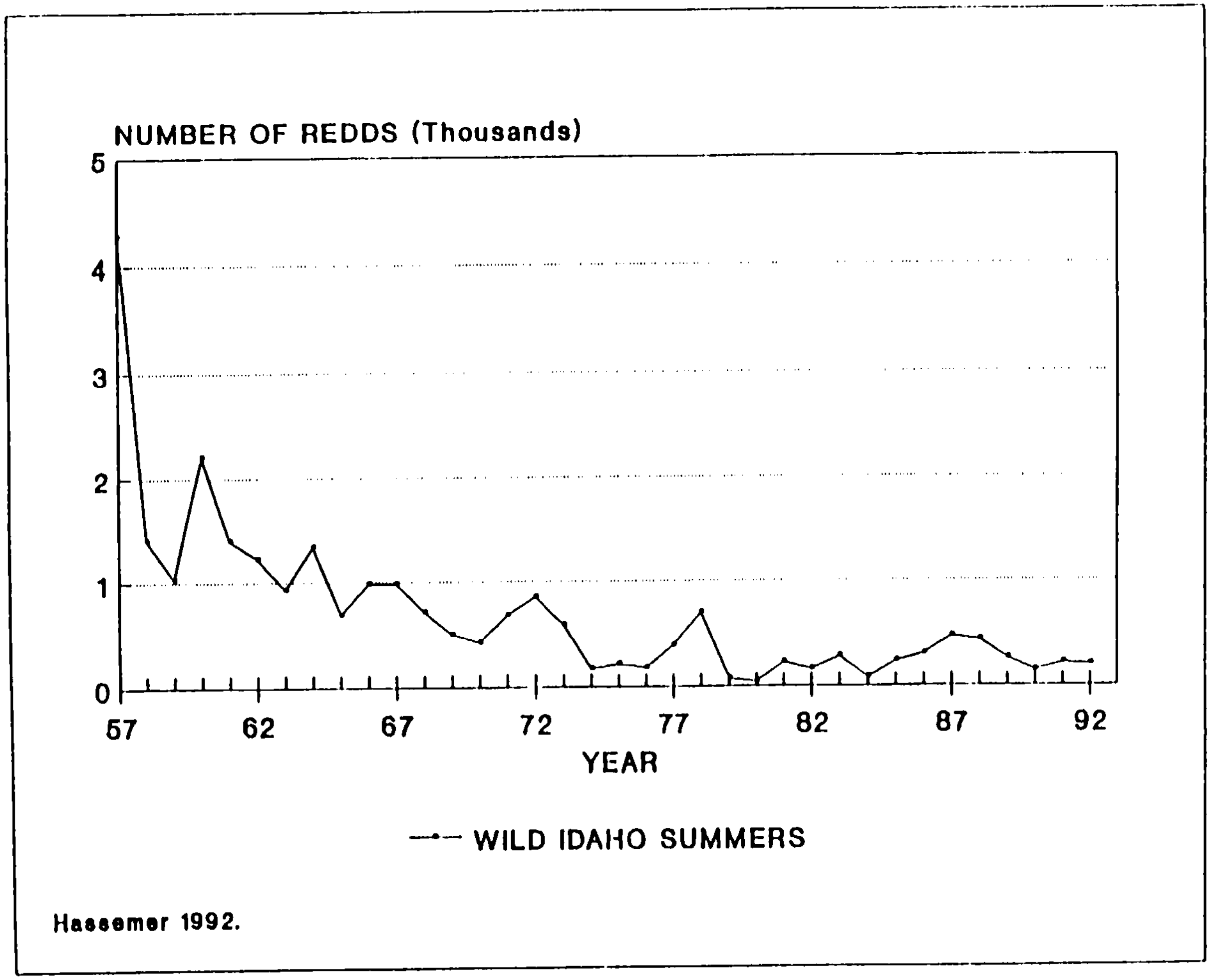
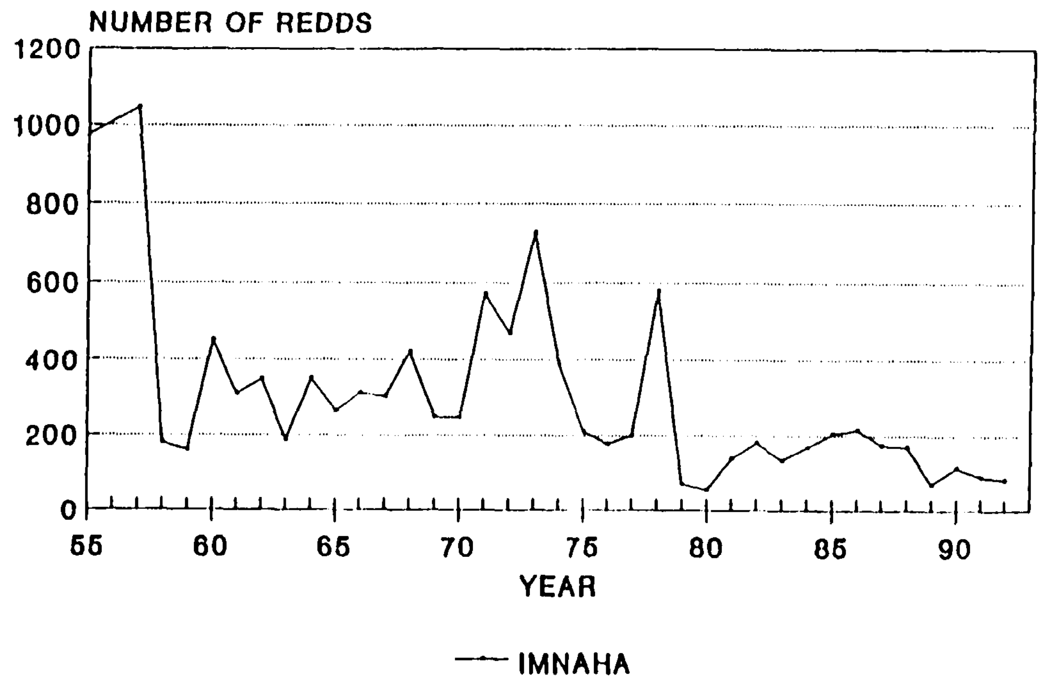
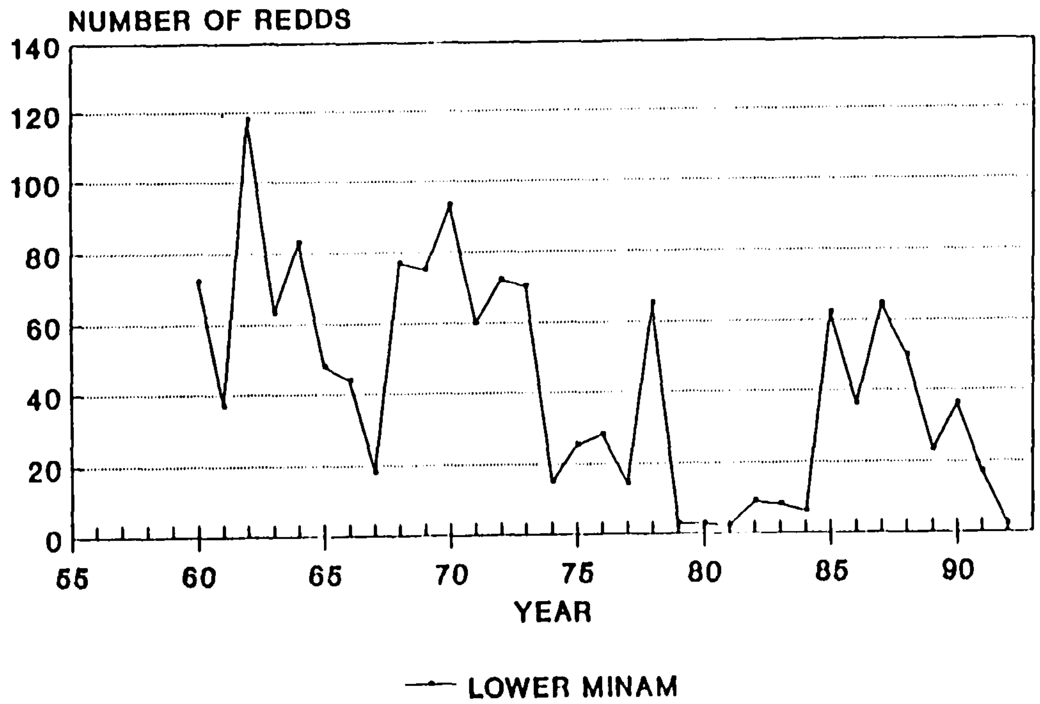


Figure 7. Index area redd counts for wild summer chinook, Idaho.



ODFW (1990, 1992). Expansion factor 1.4 except for 1986-1992, when year-specific expansion was used.

Figure 8. Chinook salmon redd counts, Imnaha River.



ODFW unpublished. Expansion factor 1.0.
Index area = 7.5 miles.

Figure 9. Chinook salmon redd counts, Lower Minam River (tributary to Wallowa River).

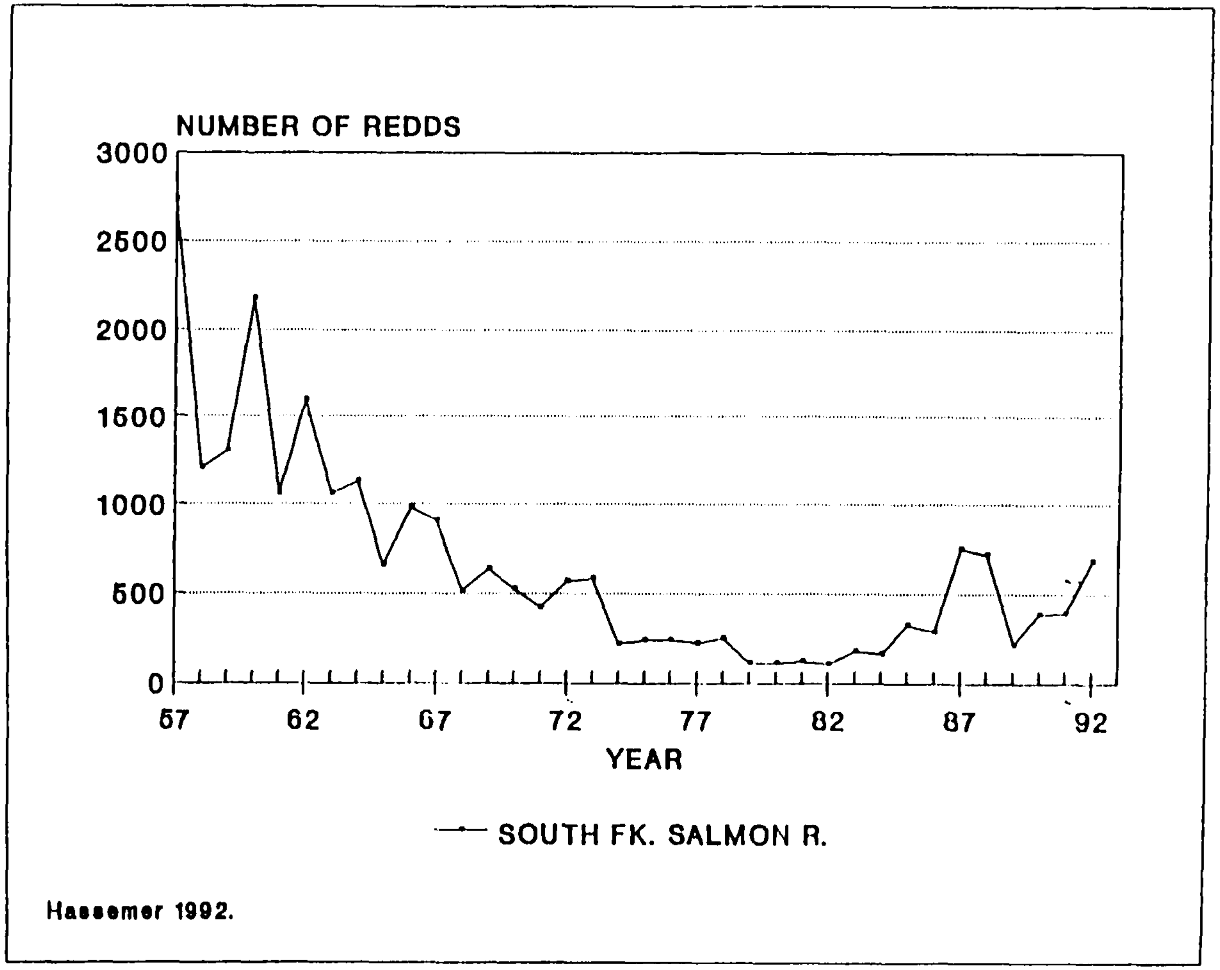


Figure 10. Chinook salmon redd counts, South Fork Salmon River.

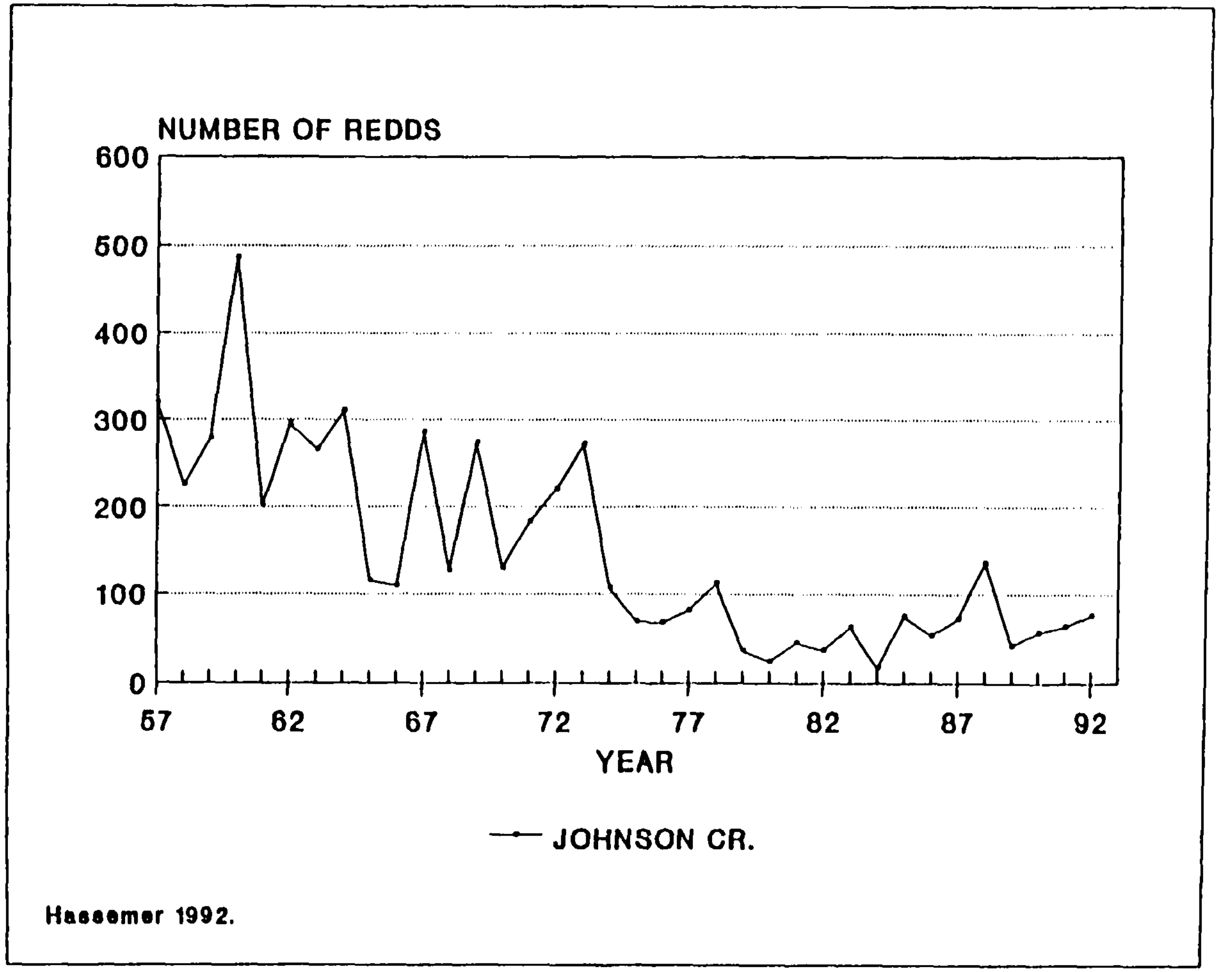


Figure 11. Chinook salmon redd counts, Johnson Creek (tributary to East Fork of the South Fork of the Salmon River).

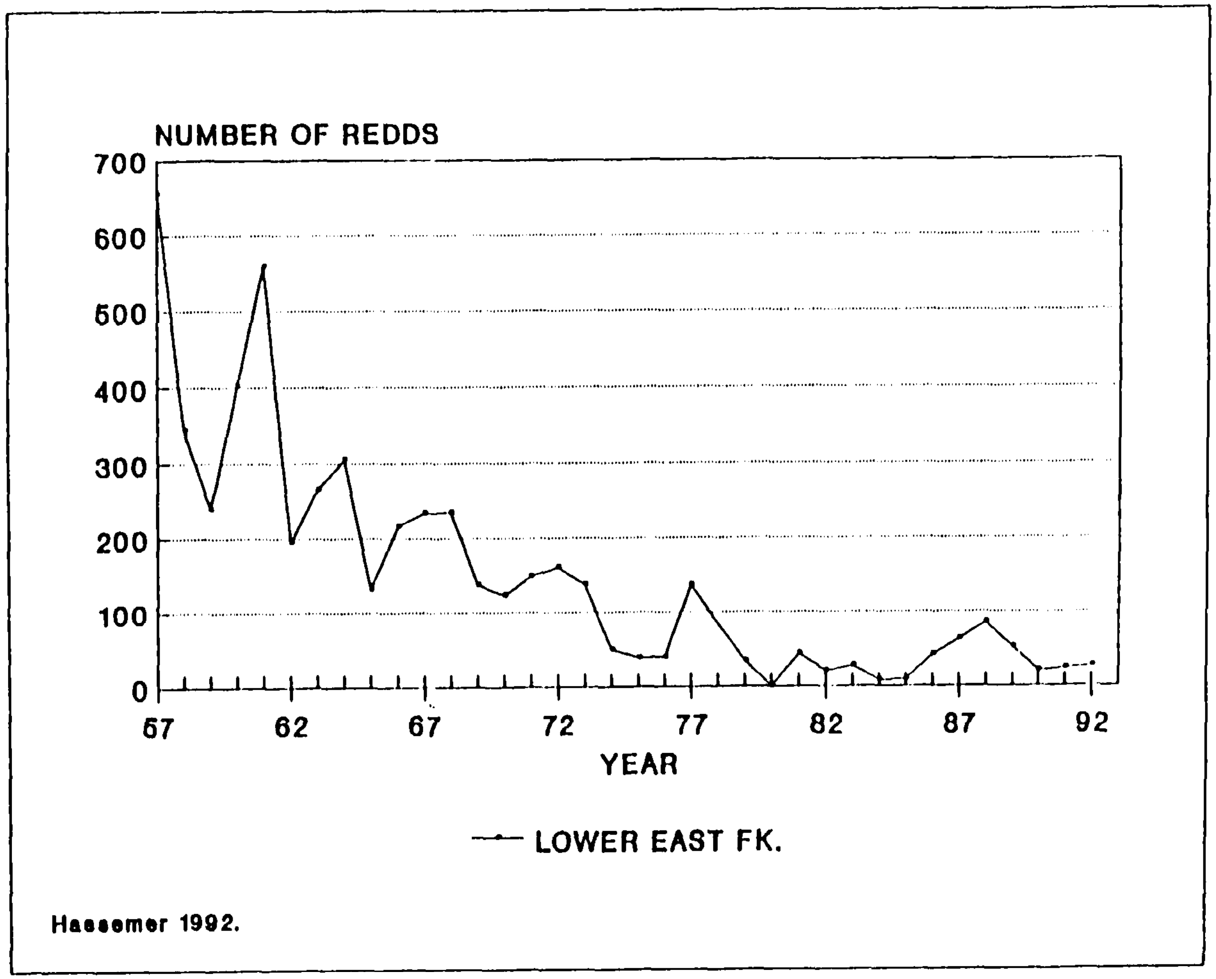


Figure 12. Chinook salmon redd counts, East Fork of the Salmon River.

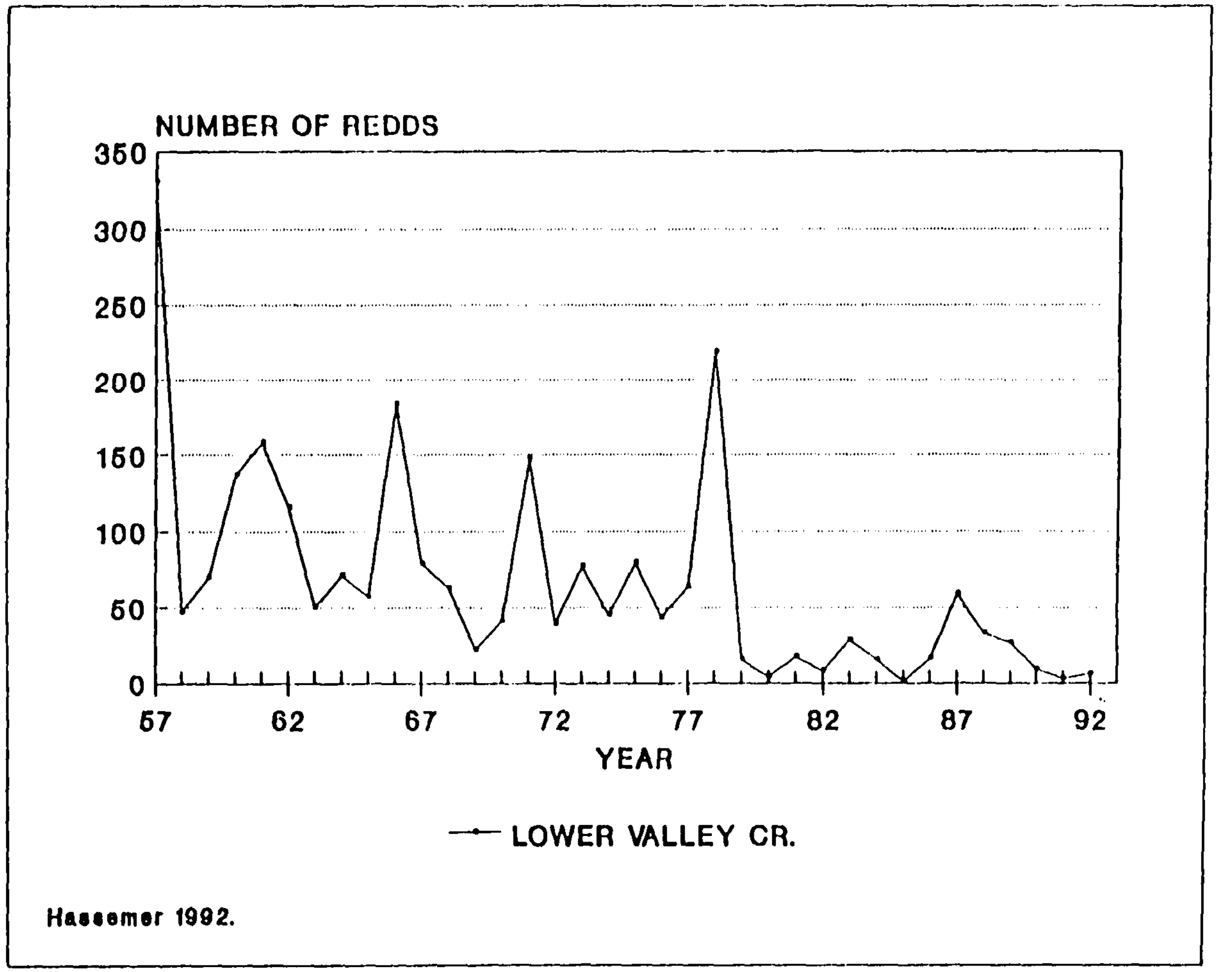


Figure 13. Chinook salmon redd counts, lower Valley Creek (tributary to Salmon River near Stanley, Idaho).

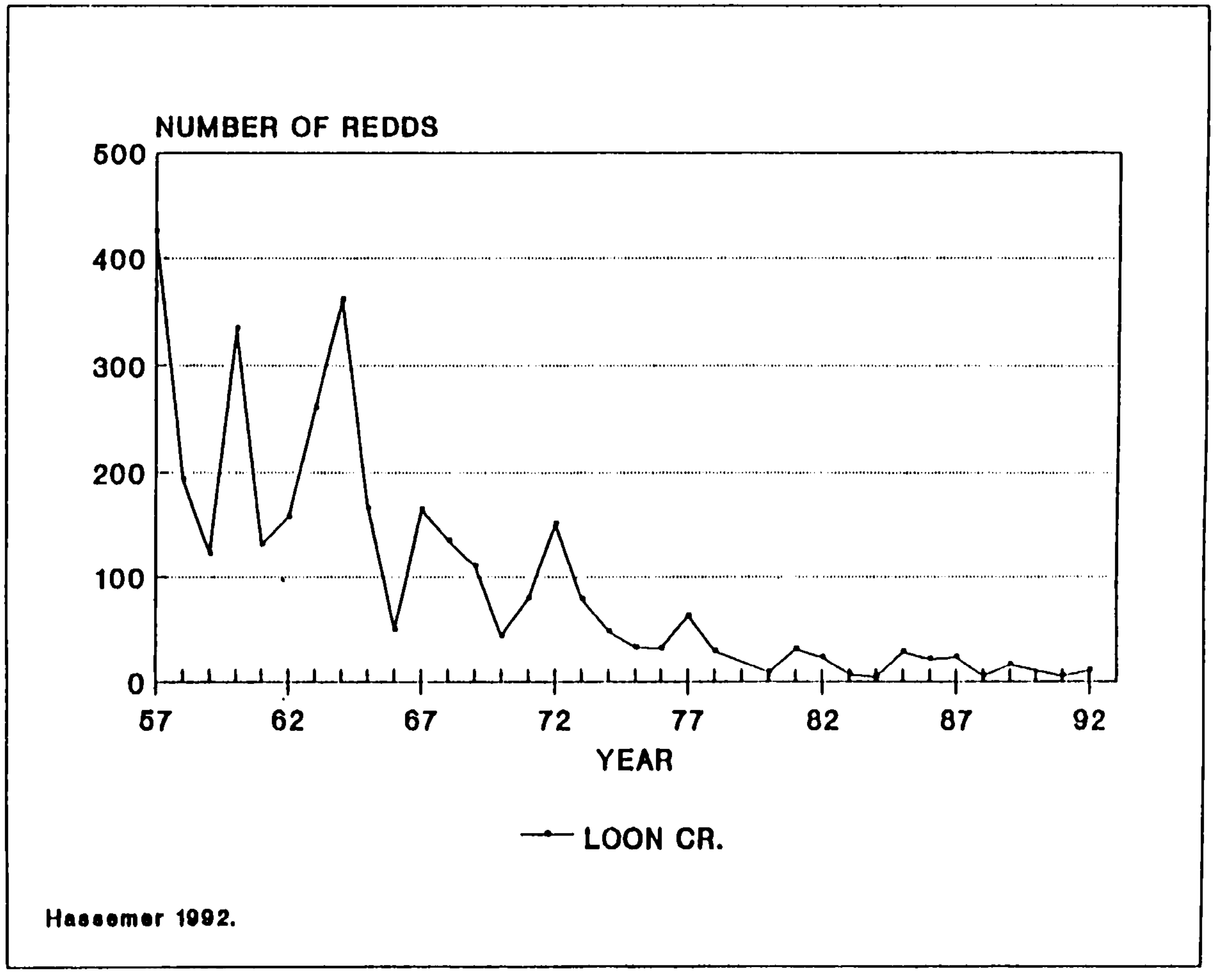


Figure 14. Chinook salmon redd counts, Loon creek (tributary to Middle Fork Salmon River).

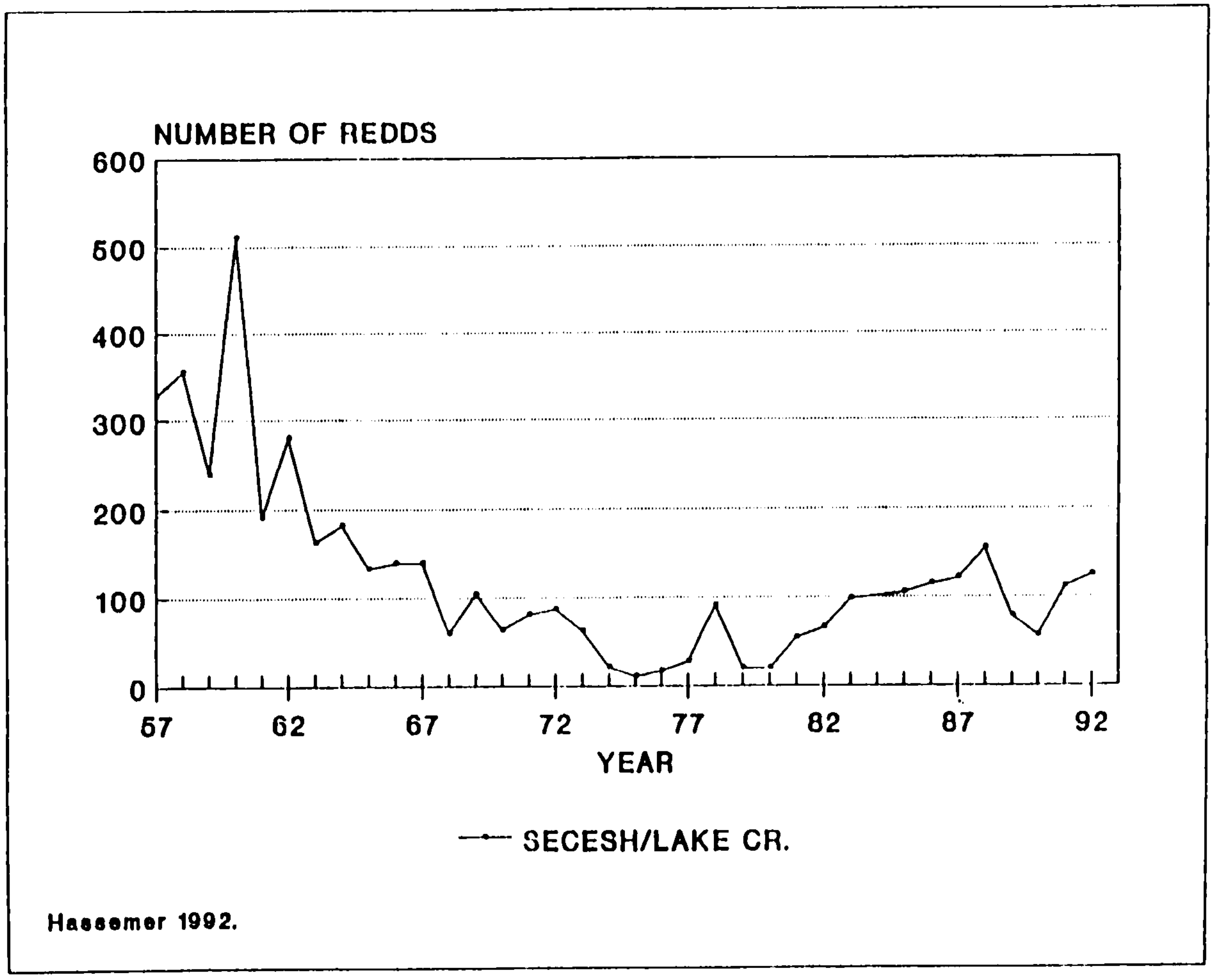


Figure 15. Chinook salmon redd counts, Secesh River/Lake Creek (tributary to South Fork Salmon River).

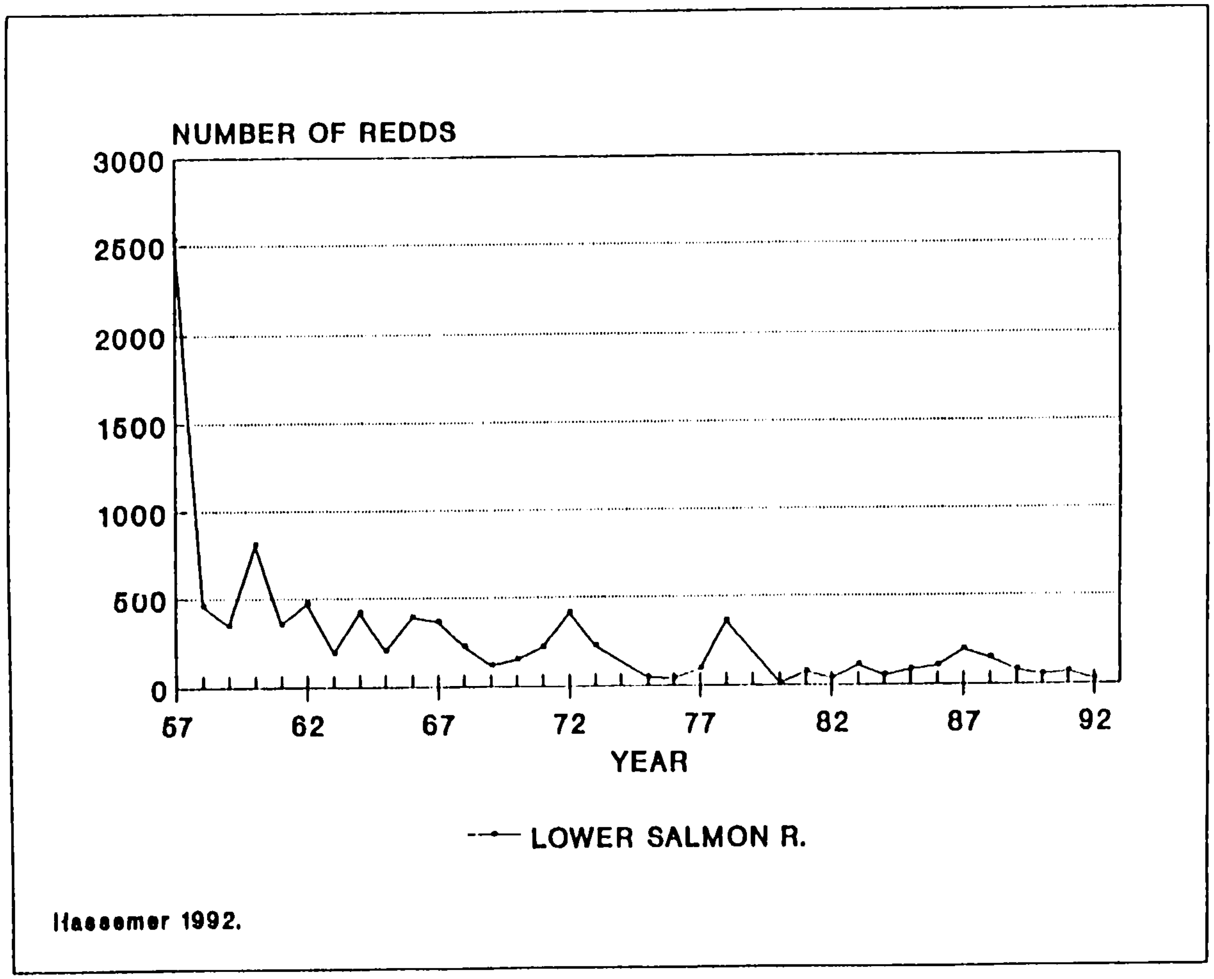


Figure 16. Chinook salmon redd counts, lower Salmon River (near Challis and Stanley, Idaho).

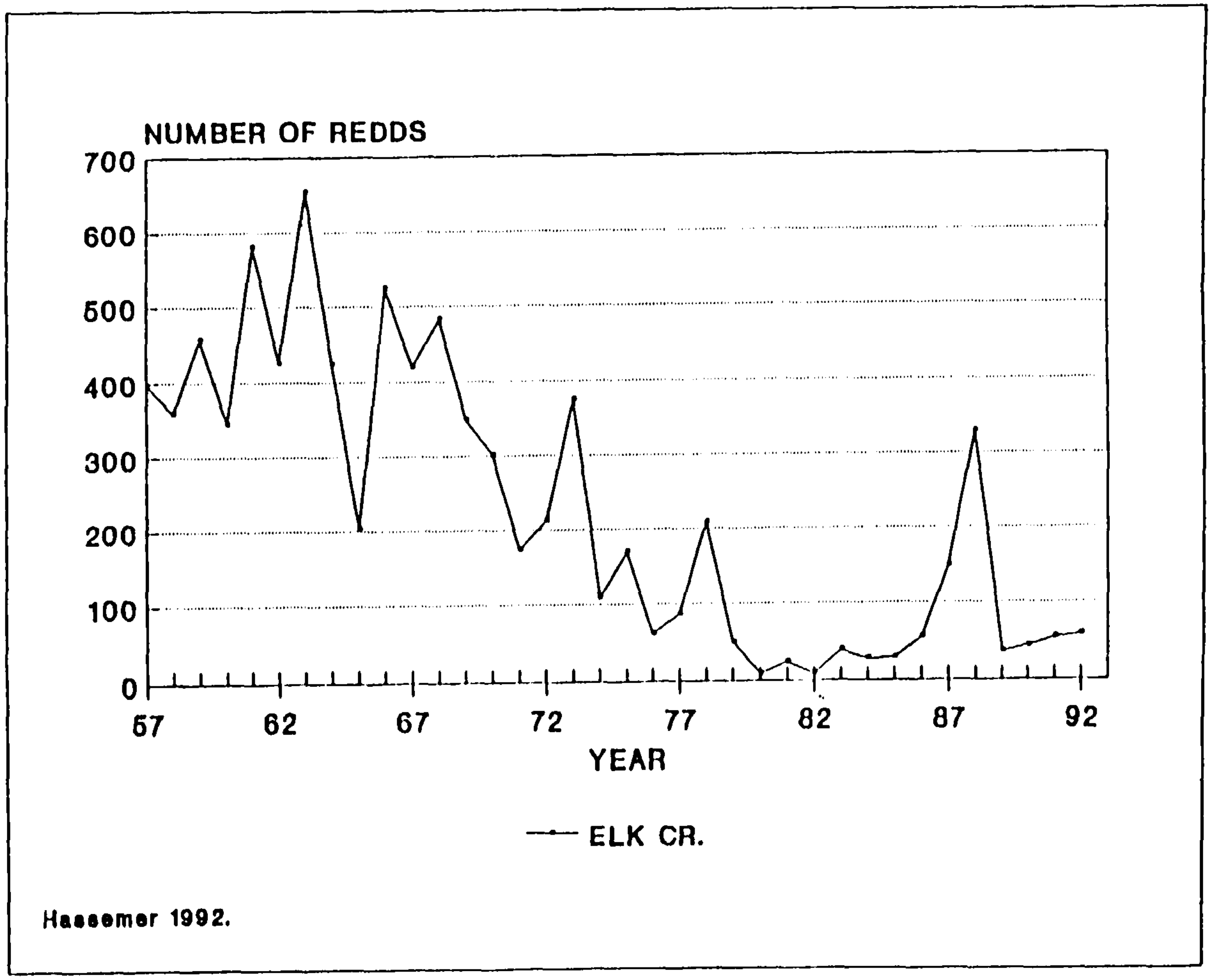


Figure 17. Chinook salmon redd counts, Elk Creek (tributary to Bear Valley Creek, Middle Fork Salmon River).

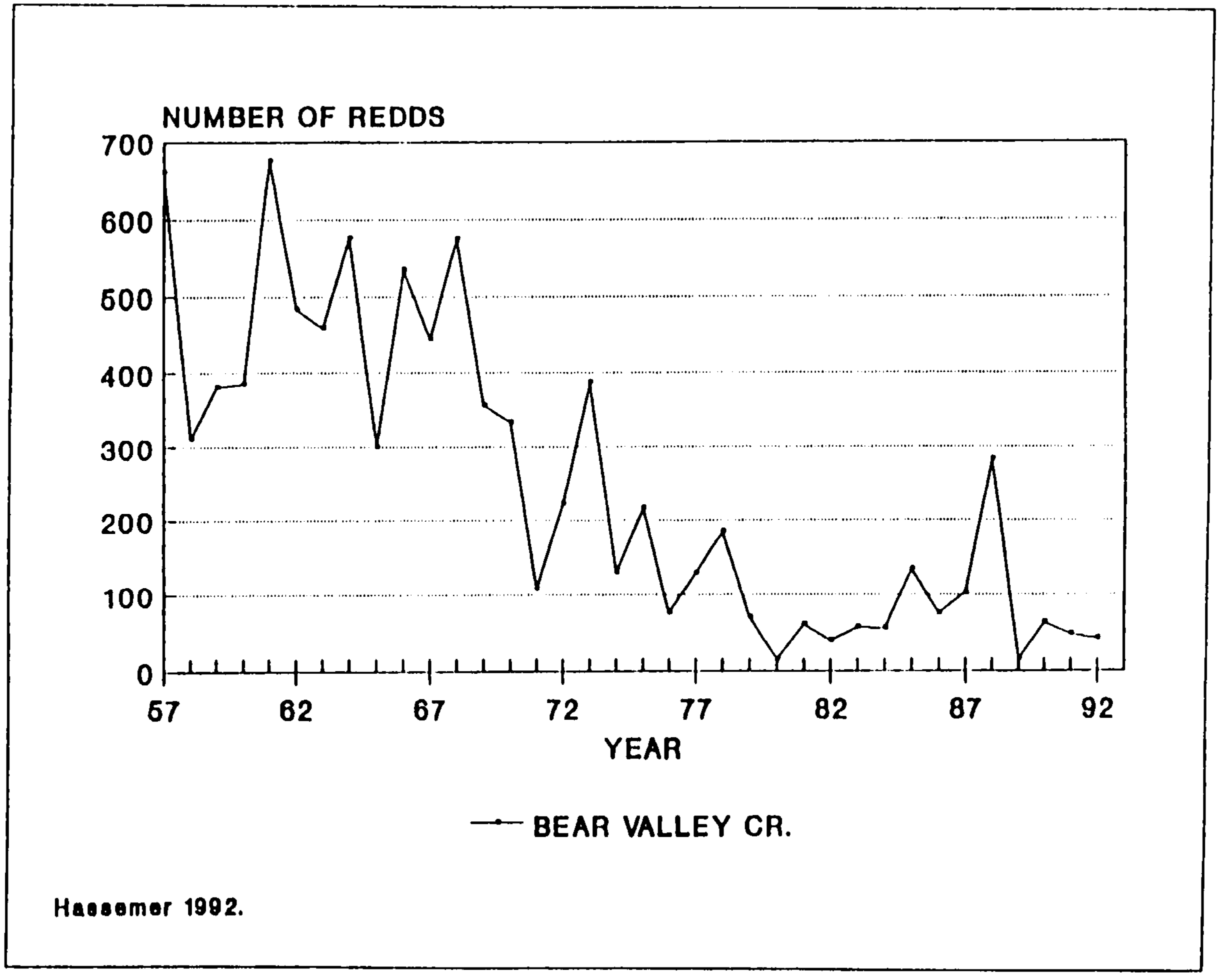


Figure 18. Chinook salmon redd counts, Bear Valley Creek (tributary to Middle Fork Salmon River).

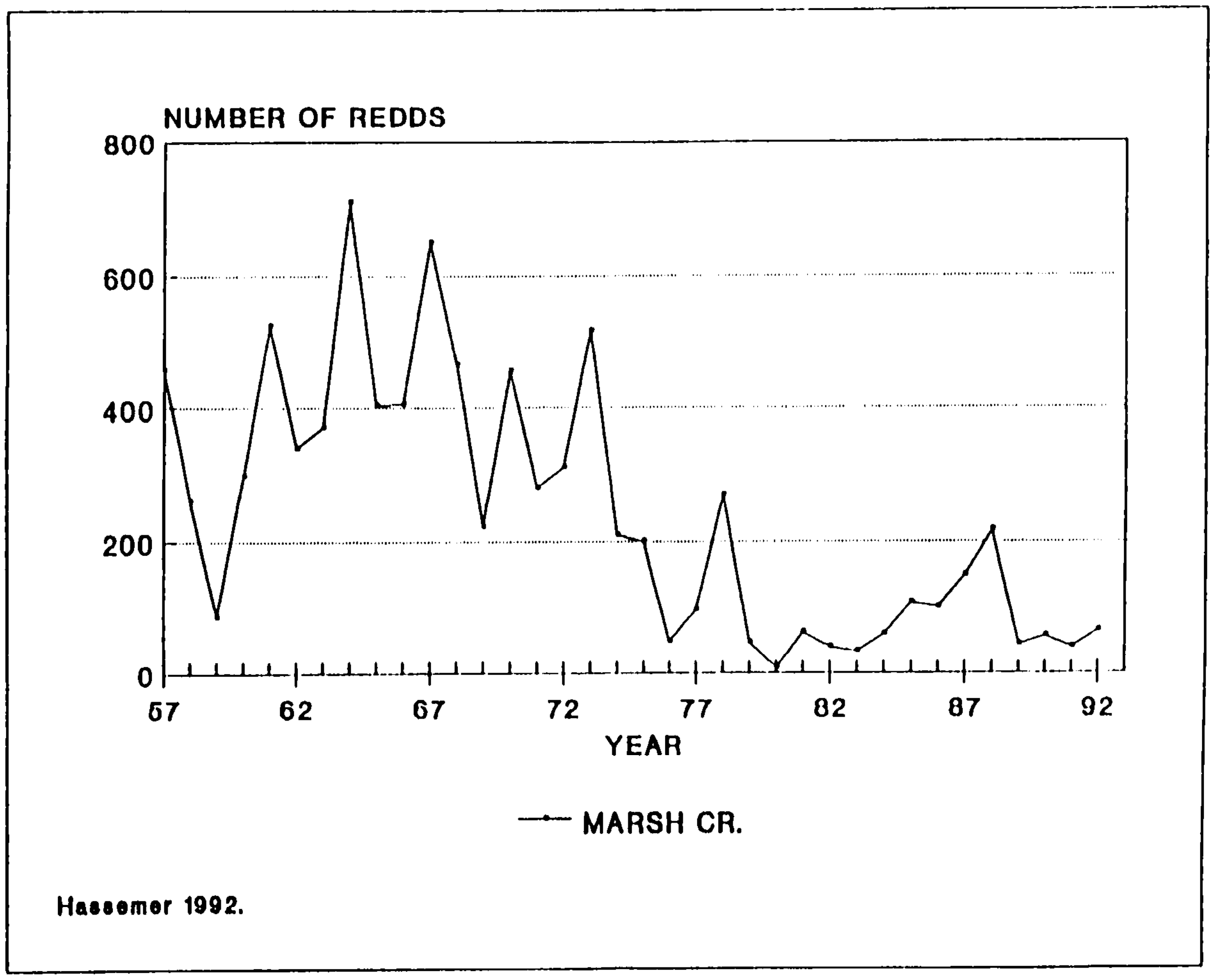


Figure 19. Chinook salmon redd counts, Marsh Creek (tributary to Middle Fork Salmon River).

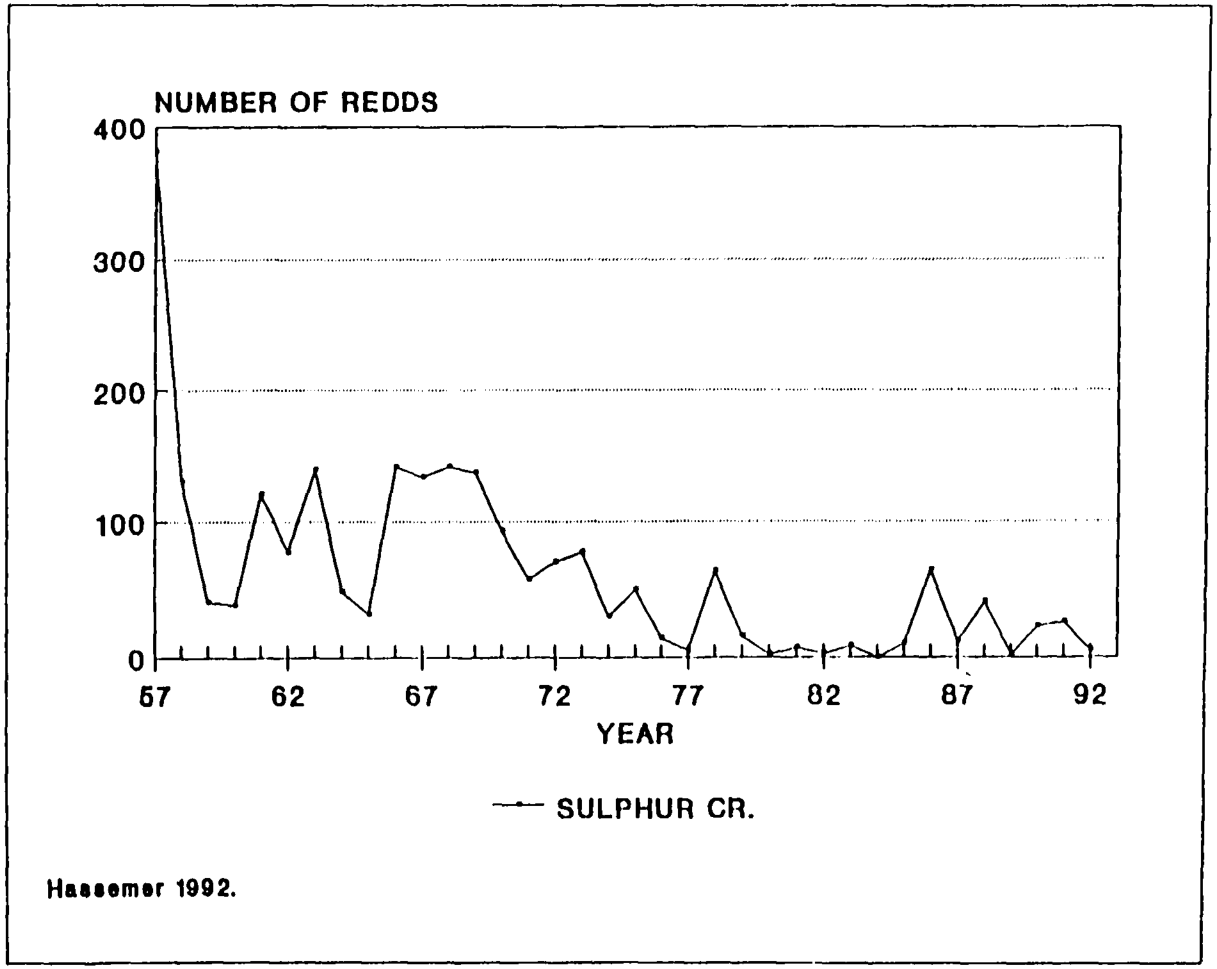


Figure 20. Chinook salmon redd counts, Sulphur Creek (tributary to Middle Fork Salmon River).

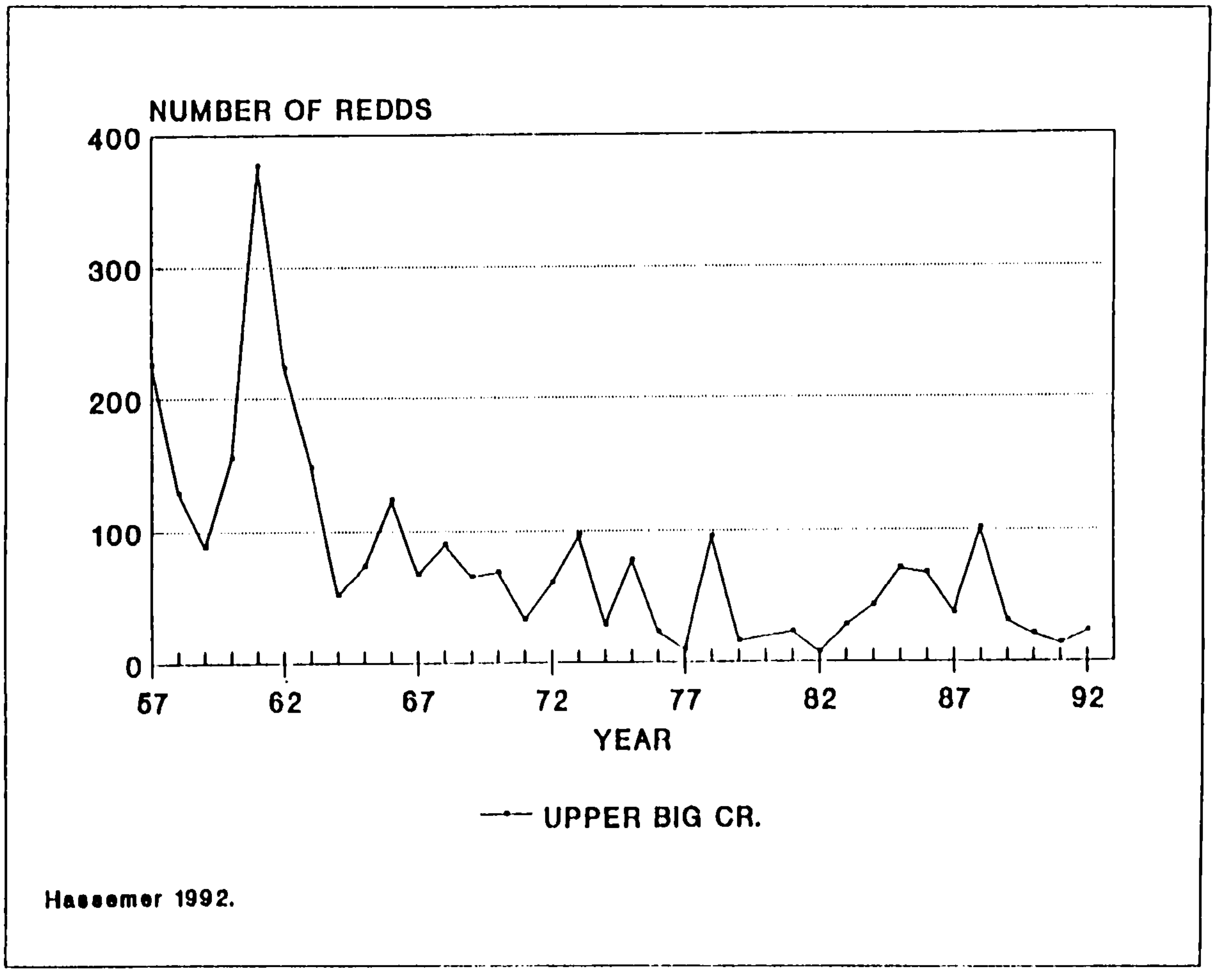
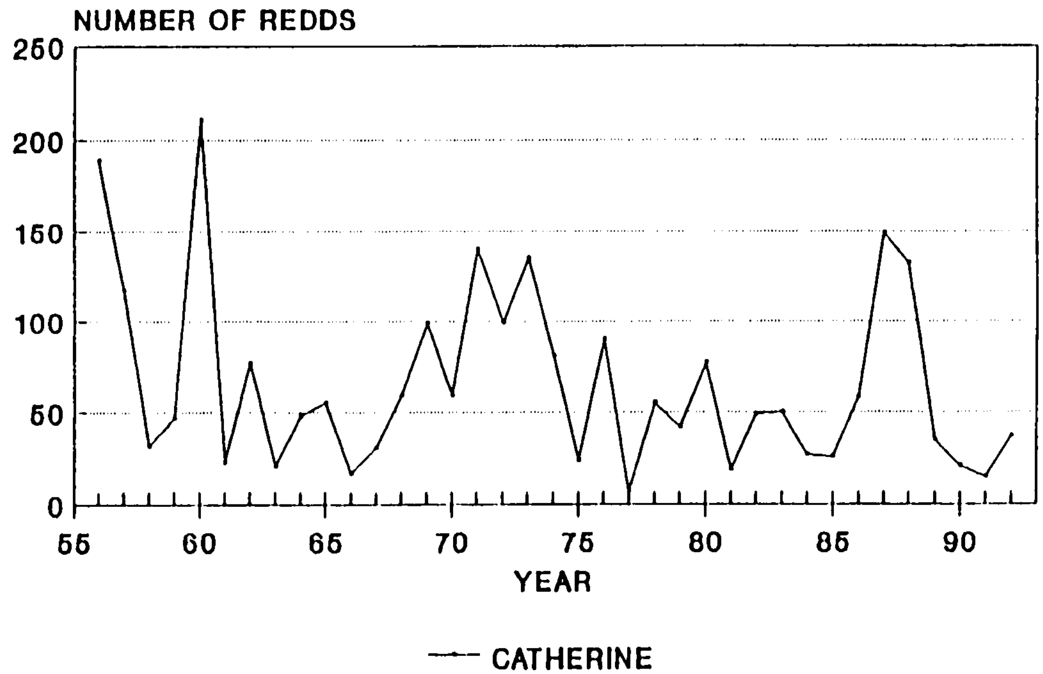
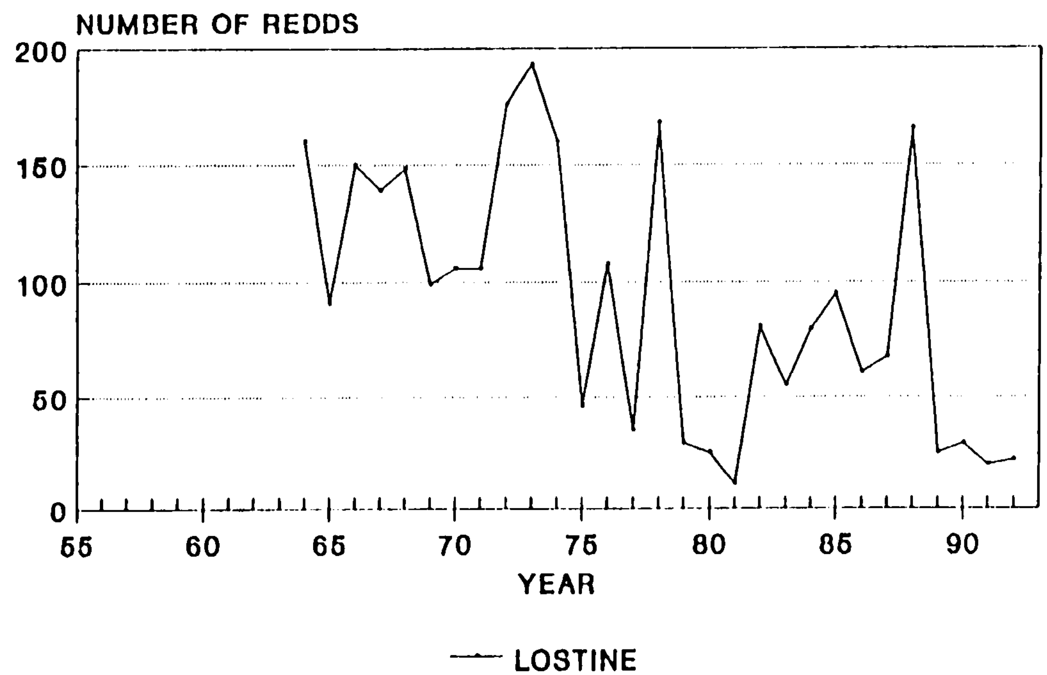


Figure 21. Chinook salmon redd counts, upper Big Creek (tributary to Middle Fork Salmon River).



ODFW (1990, 1992). Expansion factor 1.16 except for 1986-1992, when year-specific expansion was used.

Figure 22. Chinook salmon redd counts, Catherine Creek (tributary to Grande Ronde River).



ODFW (1990, 1992). Expansion factor 1.4 except for 1986-1992, when year-specific expansion was used.

Figure 23. Chinook salmon redd counts, Lostine River (tributary to Wallowa River).

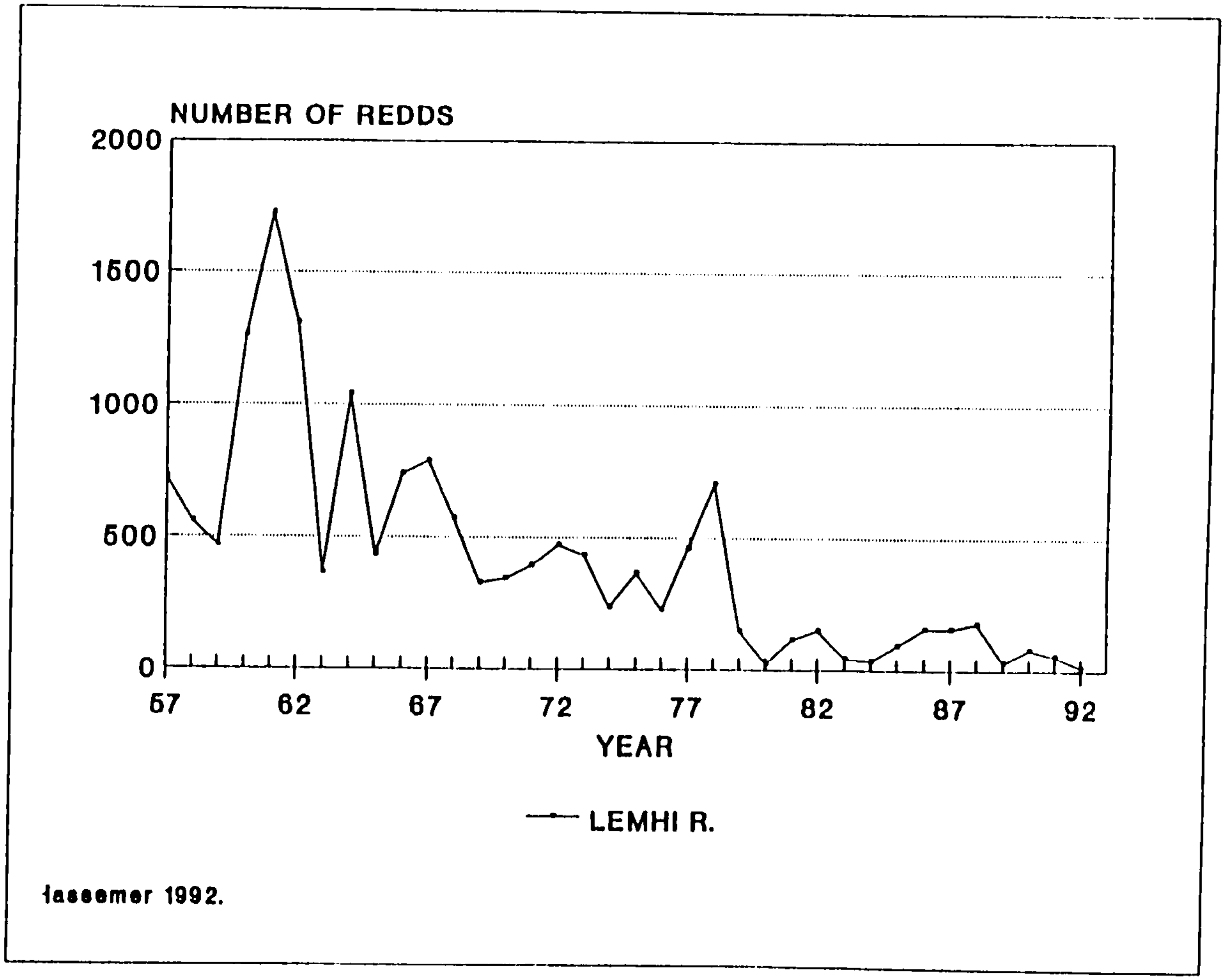


Figure 24. Chinook salmon redd counts, Lemhi River (tributary to Salmon River near Salmon, Idaho).

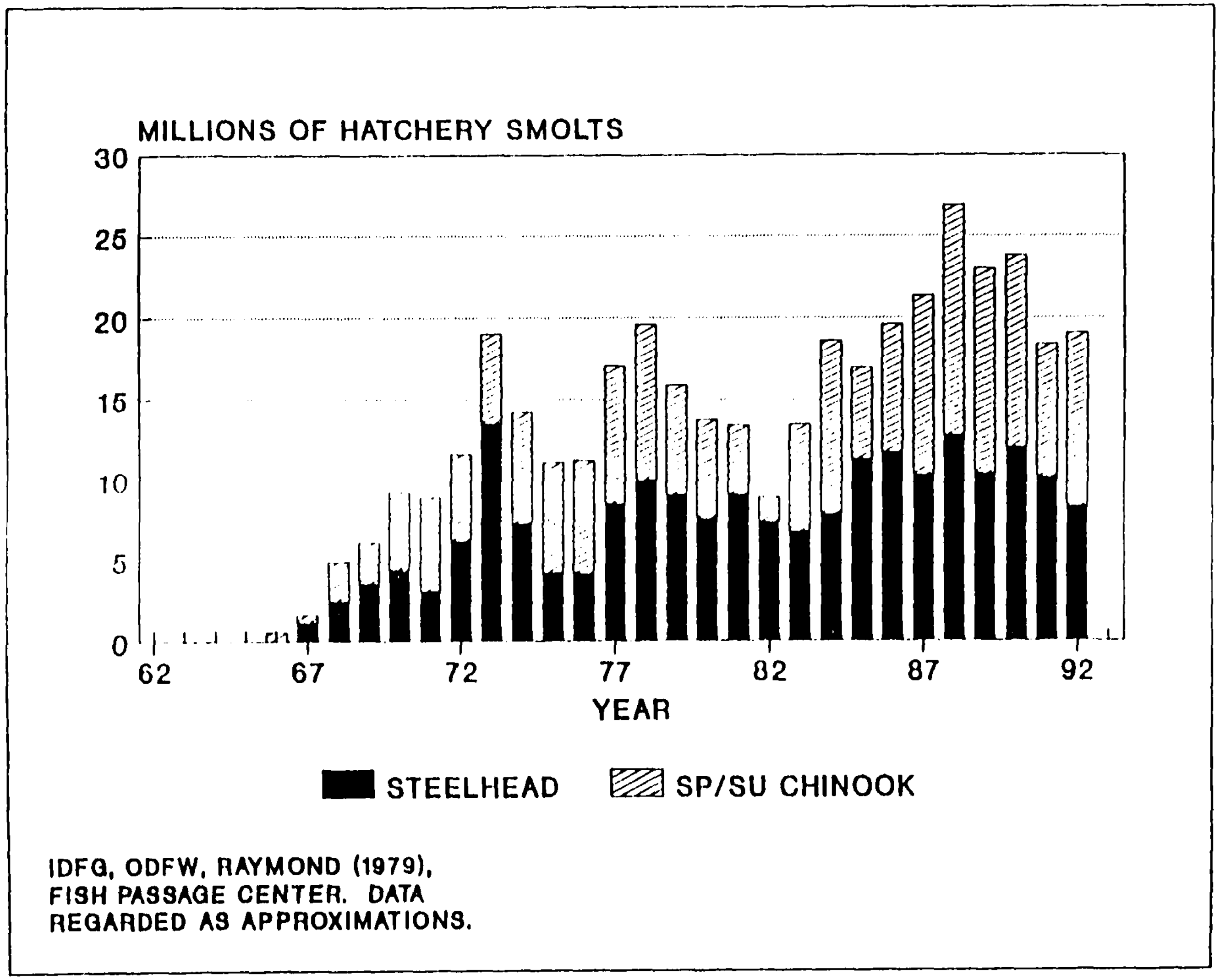


Figure 25. Number of spring/summer chinook and summer steelhead released in Snake River Basin upstream from Lower Granite Dam.

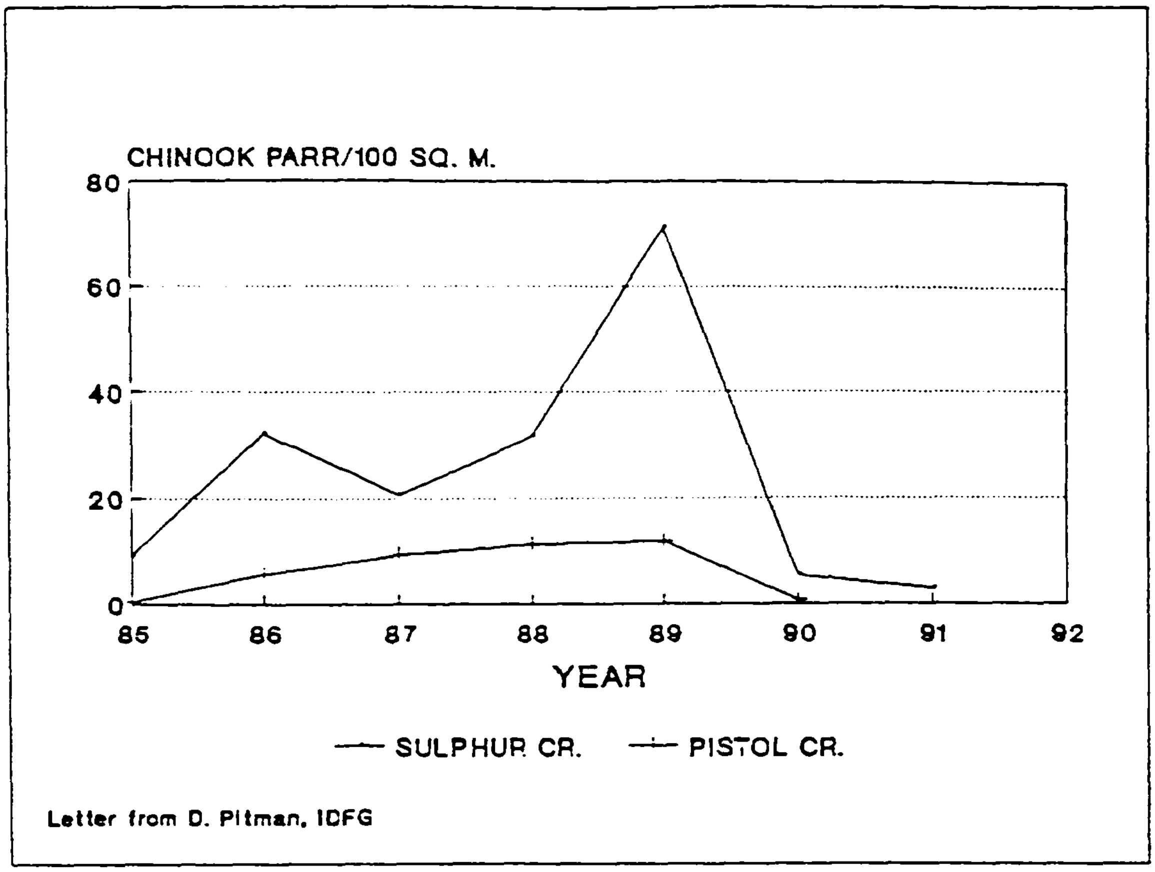


Figure 26. Snorkel-censused chinook parr per 100 sq. m. in Sulphur and Pistol Creeks (tributaries to Middle Fork Salmon River).

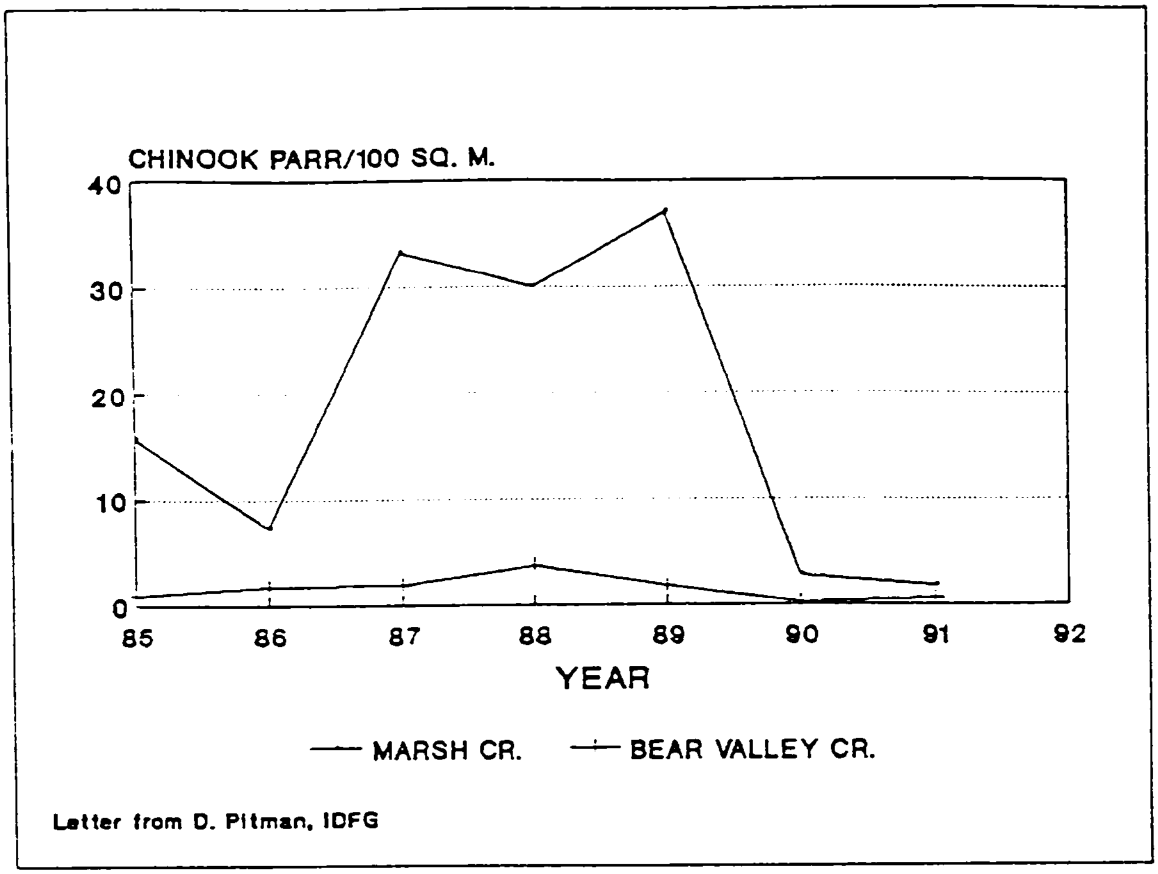


Figure 27. Snorkel-censused chinook parr per 100 sq. m. in Marsh and Bear Valley Creeks (tributaries to Middle Fork Salmon River).

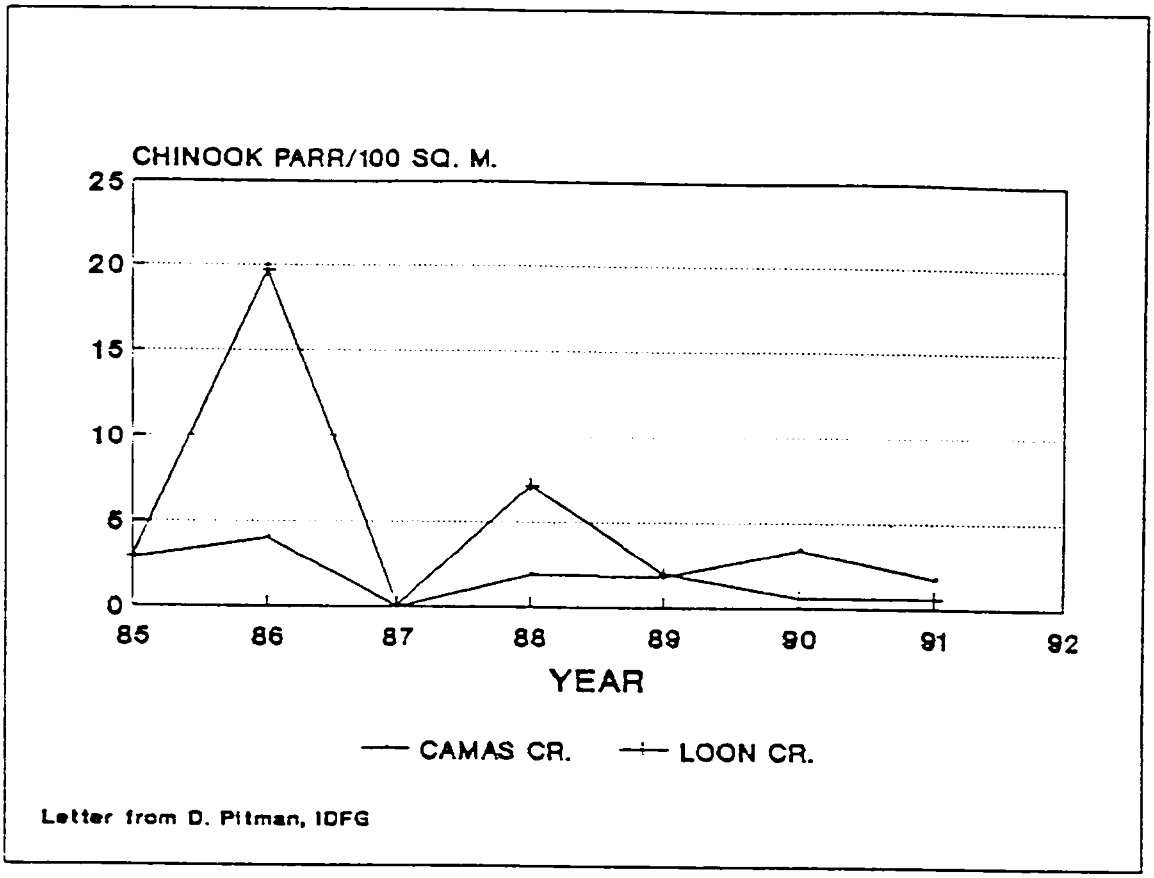


Figure 28. Snorkel-censused chinook parr per 100 sq. m. in Camas and Loon Creeks (tributaries to Middle Fork Salmon River).

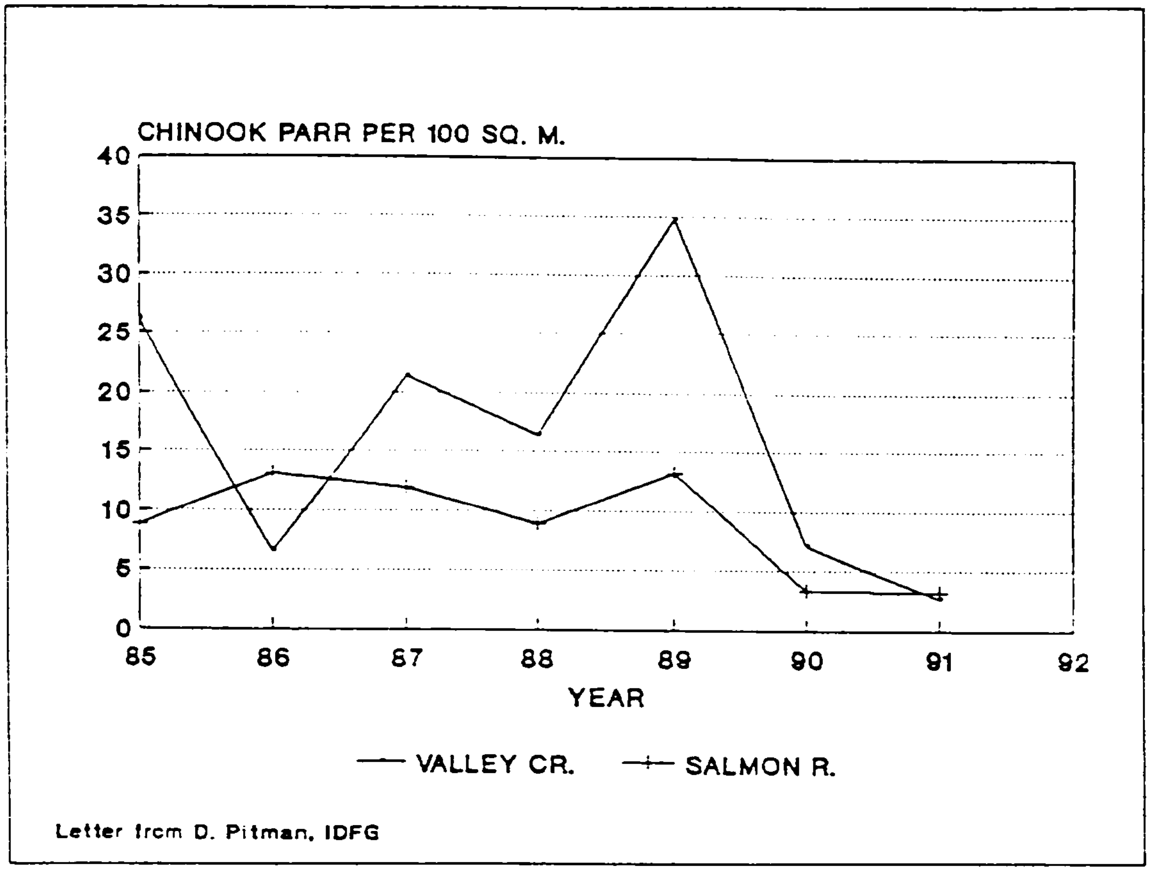


Figure 29. Snorkel-censused chinook parr per 100 sq. m. in Valley Creek and the Salmon River.

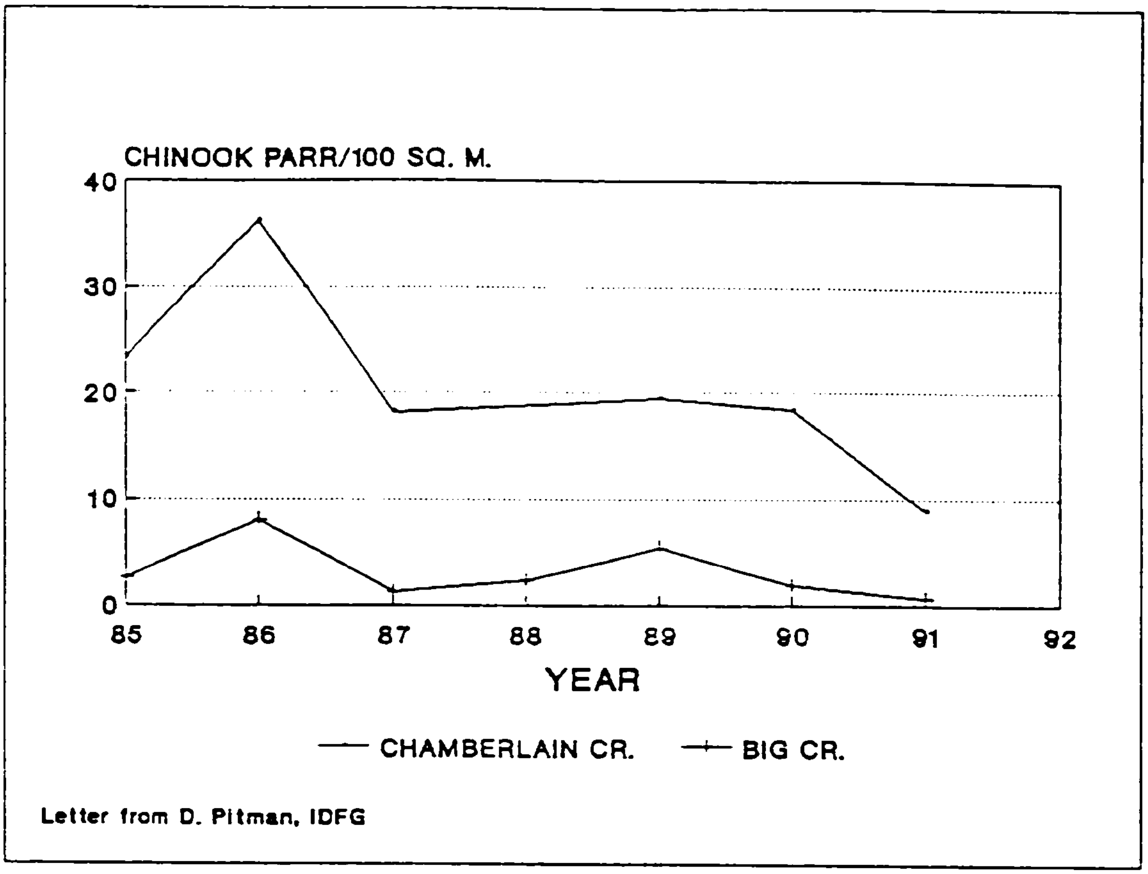


Figure 30. Snorkel-censused chinook parr per 100 sq. m. in Chamberlain Creek (tributary to main Salmon River, and Big Creek (tributary to Middle Fork Salmon River).

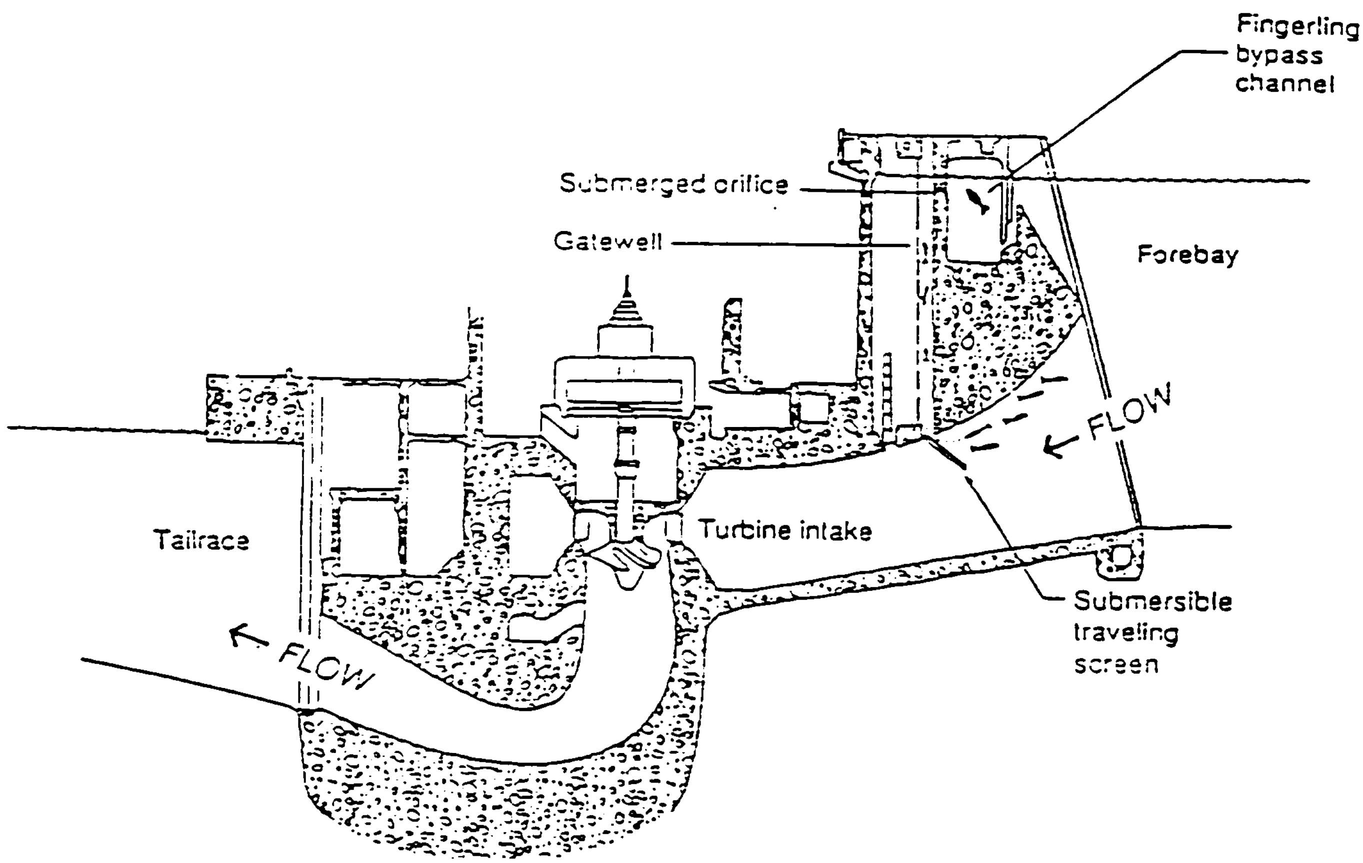


Figure 31. Cross-section of a typical hydropower dam on the Snake River.

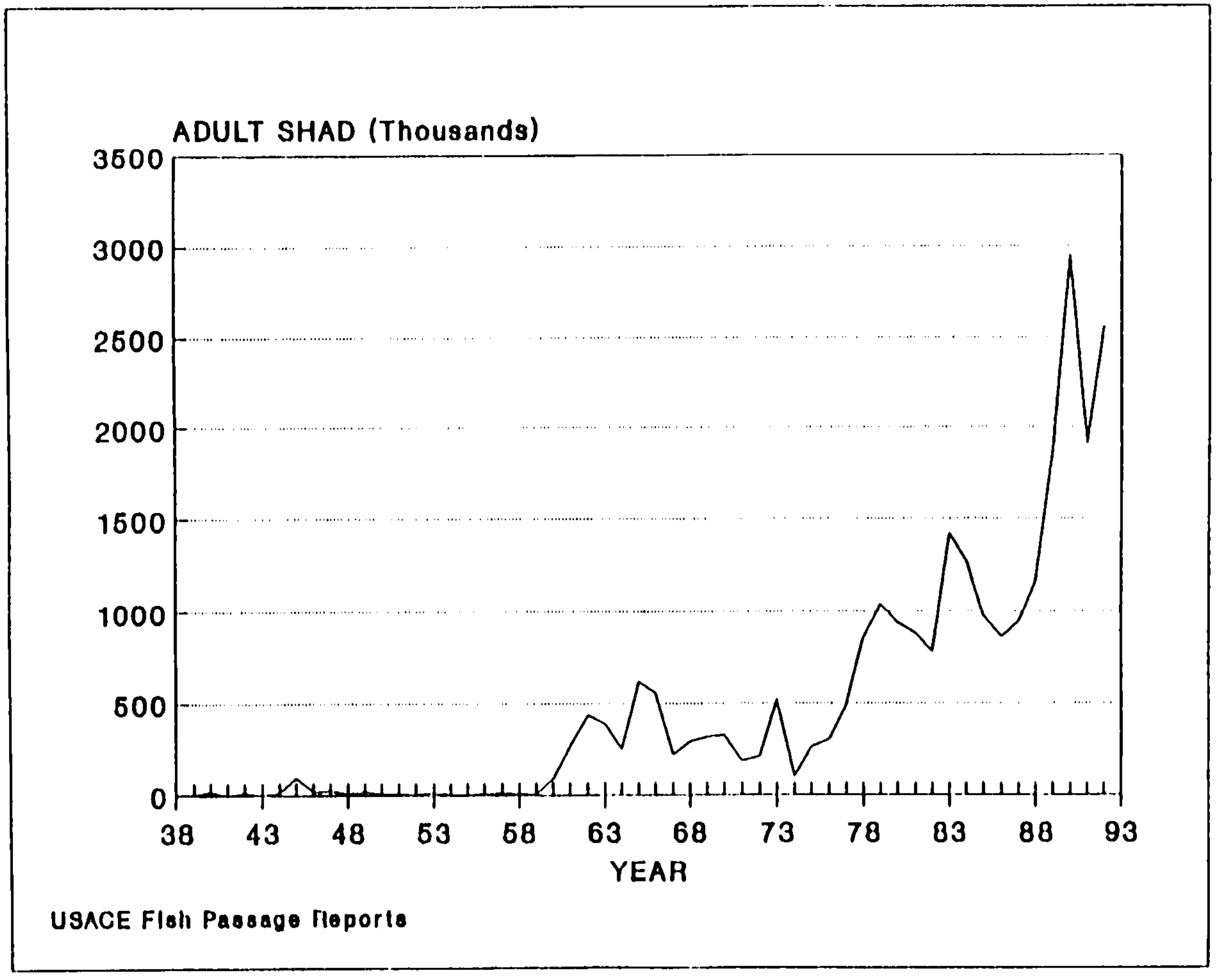


Figure 32. Fishway counts of adult shad at Bonneville Dam.

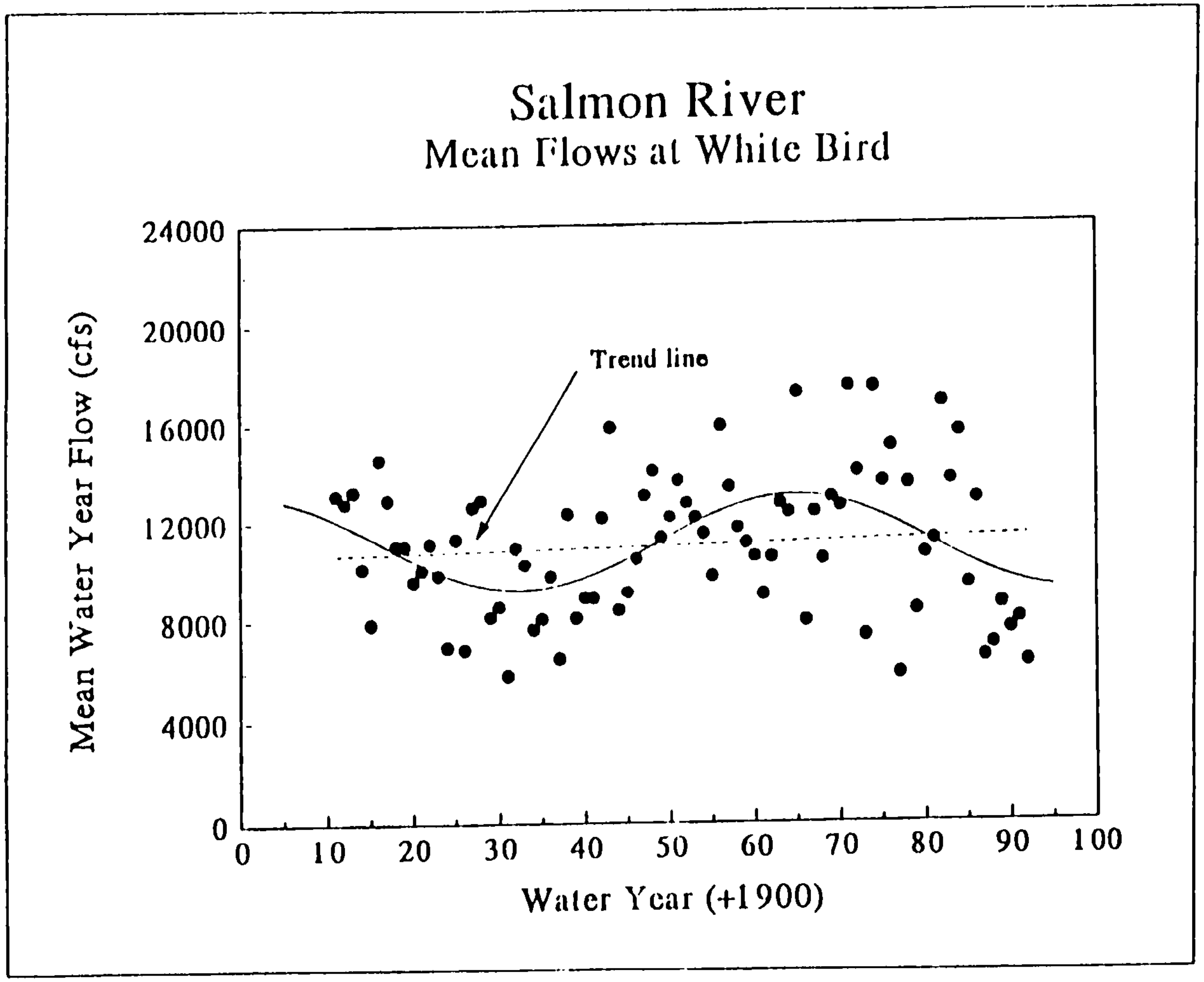


Figure 33. Mean discharge of the Salmon River at Whitebird, 1909-1992.