NOAA Technical Memorandum NMFS F/NWC-187

Status and Future of Spring Chinook Salmon in the Columbia River Basin--Conservation and Enhancement

Spring Chinook Salmon Workshop,
8-9 November 1989,
Sponsored by the
Coastal Zone and Estuarine Studies Division
Northwest Fisheries Center
National Marine Fisheries Service
Pasco, Washington

Donn L. Park, Convenor

August 1990

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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1. **The Question and Answer response on page 125 was for an abstract that was not received; it is unrelated to the preceding paper by R. W. Carmichael.**

STATUS AND FUTURE OF SPRING CHINOOK SALMON IN THE COLUMBIA RIVER BASIN--CONSERVATION AND ENHANCEMENT

SPRING CHINOOK SALMON WORKSHOP, 8-9 NOVEMBER 1989,
SPONSORED BY THE
COASTAL ZONE AND ESTUARINE STUDIES DIVISION
NORTHWEST FISHERIES CENTER
NATIONAL MARINE FISHERIES SERVICE

Pasco, Washington

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Coastal Zone and Estuarine Studies Division
Northwest Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
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INTRODUCTION

by Donn L. Park

The National Marine Fisheries Service (NMFS) sponsored the Spring Chinook Salmon Workshop because we believe urgent changes in priorities are required if a meaningful resurgence of the Columbia River Basin's once plentiful spring chinook salmon (Oncorhynchus tshawytscha) stocks are to be realized. Others share our concern for spring chinook salmon. About a week prior to the workshop we received a letter from the Idaho Chapter of the American Fisheries Society calling for additional protection of spring chinook salmon in light of potential endangered species listing. The letter states in part: "The protection of species native to the Columbia River system is a fundamental obligation we all share. Species preservation does not 'compete' with other uses of the river; it automatically takes precedence over them as a reserved right." The letter further states: "The Chapter regards the potential for extinction of wild chinook salmon with considerable dismay and is actively monitoring the status of this species within the Snake River watershed. We have notified the Regional Director, NMFS, and other State and Federal agencies (including the Bonneville Power Administration) and Indian tribes in the region that we will formally seek listing of these stocks pursuant to the Endangered Species Act if a material improvement in their status is not realized by 1992." Because of perceived mutual concerns throughout the Basin for spring chinook salmon we chose the theme Status and Future of Spring Chinook Salmon in the Columbia River Basin--Conservation and Enhancement.

The upriver stocks of spring chinook salmon have been in a general decline since 1970. Outmigrations from the Snake River alone produced approximately 100,000 adults annually as recently as 1975. These runs provided an abundance of naturally spawning fish and a harvestable surplus was used by commercial, tribal, and sport fishing interests. Notable depletion of spring chinook salmon have been cataclysmic in some years. The adult runs in 1979, 1980, and 1984 were approximately 9,000 fish counted each year at Ice Harbor Dam. Recently, the runs rebounded to more than 30,000 fish, only to collapse again in 1989. The fluctuating but low numbers of spring chinook salmon returning to Columbia Basin streams prompted the Columbia Basin Fish and Wildlife Authority to call for a status report on the stocks. The ensuing report prepared by the Columbia River fisheries agencies and tribes did not offer substantive alternatives for improving the runs. It did, however, attempt to explain why the run has been depressed and fluctuating.

Time may be running out for restoration of the valuable population of spring chinook salmon. We hope that the workshop can be a starting point for a revitalized restoration process.

The proceedings of the workshop include an abstract of each speaker's presentation as well as a condensation of the questions and answers that followed each presentation.

SESSION I

Stock Structure and Population Dynamics

Session Chair: J. D. McIntyre, U.S. Fish and Wildlife
Service, Seattle, Washington

SUSTAINABLE HARVEST RATES FOR SPRING CHINOOK SALMON IN THE UPPER COLUMBIA RIVER BASIN

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Knowledge of the spawner-recruit relation for a population is necessary to accurately estimate the harvest rates consistent with specific goals such as maximum recruitment or maximum sustainable yield (MSY). Spawner-recruit relations reflecting recent conditions in the Columbia River Basin have been estimated for two wild populations of spring chinook salmon in Oregon--the John Day River (Lindsay et al. 1986) and the Warm Springs River (Lindsay et al. 1989). I estimated these relations for wild fish from the Snake, Methow, Entiat, and Wenatchee Rivers.

For this analysis, I assumed that all hatchery fish returned to hatcheries, and I estimated the number of fish spawning in each river by subtracting the number of fish returning to hatcheries and taken in terminal fisheries from the total number of fish returning to a river (estimated from counts at dams on the Columbia or Snake River). Number of recruits was estimated by dividing the number of fish returning to each river by the proportion of upriver spring chinook salmon escaping the fisheries in the Columbia River (Zones 1-6). I assigned recruits to year classes by either using age composition data from spawning surveys for Snake River fish or adding half the recruits in year n + 4 and half the recruits in year n + 5 (because annual age composition data for wild fish were lacking) for fish from the Entiat, Methow, and Wenatchee Rivers.

Survival of smolts declined between 1964 and 1977 with the construction of mainstem dams in the Columbia and Snake Rivers, and increased after 1979 because of enhancement activities (Raymond 1988). To develop relations applicable to current conditions (assumed to be reflected by the survival of smolts migrating in 1982-84), I multiplied the number of recruits from each year class by $0.0237/s_n$, where 0.0237 was the mean survival for Snake River smolts migrating in 1982-84 and s_n was Raymond's (1988) estimated survival for Snake River fish of year class n.

Ricker spawner-recruit relations ($R = \alpha S e^{-\beta S}$, where R = recruits, S = spawners, and α and β are parameters of the model) were fitted by least squares linear regression of ln(R/S) on S (Table 1). I subjectively chose values for α that I considered more reasonable than the estimated values for three reasons: 1) the productivity parameter α is often substantially overestimated for stocks with low productivity (Walters and Ludwig 1981; Reisenbichler 1989); 2) estimated values of α for chinook salmon not exposed to numerous hydroelectric dams on their downstream and upstream migrations typically lie between 7 and 9 (Reisenbichler 1987); and 3) mortality of wild downstream migrants at and between dams may remain, on average, 12-15% per project (F. Young, Oregon Department of Fish and Wildlife, personal communication). I then calculated the corresponding values for β (Table 1).

Table 1.--Estimated parameters for Ricker spawner-recruit relations, $R = \alpha S e^{-\beta S}$, where R = recruits, S = spawners, α and β are parameters; μ_s is the harvest rate for maximum sustainable yield, and μ_m is the harvest rate for maximum recruitment.

Population	Year classes	Estimated		Subjective			
		α	β	α	β	μ_s	μ_m
Warm Springs River[a]	1975-81	5.2	0.00083	5.2	0.00083	0.64	0.48
John Day River	1970-79	1.1[b]	---	1.1	---	0.05	[c]
Snake River	1964-83	2.8	0.000025	2.2	0.000017	0.35	[c]
Wenatchee River	1968-83	7.9	0.00026	4.1	0.00015	0.57	0.34
Entiat River	1968-83	3.7	0.00057	3.4	0.00051	0.51	0.20
Methow River	1968-83	3.5	0.00023	2.9	0.00016	0.46	0.06

[a] Deschutes River drainage. Lindsay et al. (1989) did not account for prespawning mortality. I used the mean prespawning mortality for 1977-79 and 1983-86 (40%) to adjust their values.

[b] Geometric mean value for four areas in the John Day River system for 1970-79. Mean α = 6.1 for 1959-69, before completion of John Day Dam.

[c] Maximum recruitment occurs to the right of the replacement line with no harvest.

The Snake River population probably consists of a number of stocks with different productivities; consequently, the estimated harvest rate for MSY (35%) would probably deplete or eliminate some of the stocks. Furthermore, Reed (1979) showed that maximum sustained yields calculated from deterministic analyses (as above) are too high for randomly fluctuating (i.e., real) populations. For these reasons, and because the quality of the sport fishery (measured as catch per unit of effort) increases with the number of fish (e.g., Lindsay et al. 1989), managers would probably choose a harvest rate nearer 25% (Fig. 1).

Outplanting (releasing hatchery fish into natural areas to compensate for low numbers of naturally spawning fish) is expected to provide substantial increases in the number of adult fish produced from the Columbia River system. I used the model of McIntyre and Reisenbichler (1986) to estimate the appropriate harvest rate and the associated harvestable surplus when fry from hatcheries in the Snake River Basin are outplanted.

The expected hatchery production of spring chinook salmon smolts in the Snake River Basin is about 7 million per year (D. Herrig, U.S. Fish and Wildlife Service, personal communication). I assumed that 5,000 adults would be required to produce 7 million smolts, and that the smolt-to-adult survival rate for hatchery fish would be 0.2%, resulting in 14,000 returning adults. I also assumed that 1) hatchery fish are genetically, physically, and behaviorally equivalent to wild fish; 2) hatchery fish are outplanted as fry and are released throughout the available rearing habitat; and 3) a female spawned in the hatchery produces four times the number of fry that the same female would produce spawning naturally. When these data and assumptions about hatchery fish were applied, the model indicated the harvest rate consistent with a given escapement goal for naturally spawning fish (Fig. 2).

I repeated the analysis assuming that each adult spawned in the hatchery produced an average of 1.9 recruits rather than 2.8 recruits (as above). With 1.9 recruits per spawner (probably the more realistic expectation), the harvest rate for maximum catch was only slightly greater than that with no outplanting (Fig. 3). The allowable catch, of course, increases with the success of the hatchery program (measured in recruits per spawner), but it falls short of the catch from wild fish alone if the survival of downstream migrants is doubled (Fig. 3). One should realize that the assumptions for outplanting, such as no differences between hatchery and wild fish,[1] will probably not be met; hence, the allowable catch and acceptable harvest fractions are overestimated to an unknown extent.

Outplanting in the Methow River system would involve collecting wild adults each year, spawning them in a hatchery, and releasing their offspring back into the Methow River as smolts (W. Hopley, Washington Department of Fisheries, personal communication). I assumed that 1) no adults will be collected at escapements with less than 500 fish; 2) no more than either 1,000 or one-third of the returning adults (whichever is less) will be taken for the hatchery each year; 3) on average, each adult spawned in the hatchery would produce two returning adults; and 4) hatchery fish are genetically, physically, and behaviorally equivalent to wild fish. The results were similar to those for outplanting in the Snake River system (Fig. 4).

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[1] Indeed, the more general, implicit assumption that outplanting will produce any additional fish over an extended period of time remains to be verified.

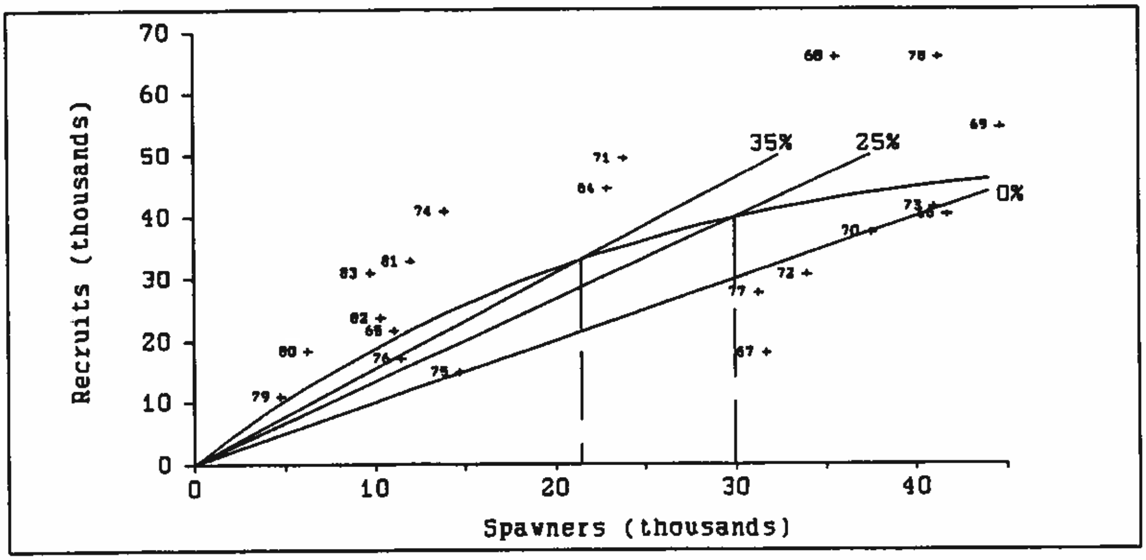

Figure 1.--Spawner-recruit relation for spring chinook salmon in the Snake River; $R = 2.2Se^{-0.0000178}$, where R = recruits and S = spawners. Solid lines indicate harvest levels of 0%, 25%, and 35%. Expected population levels are where the solid lines intersect the curve. Points are identified by year class.

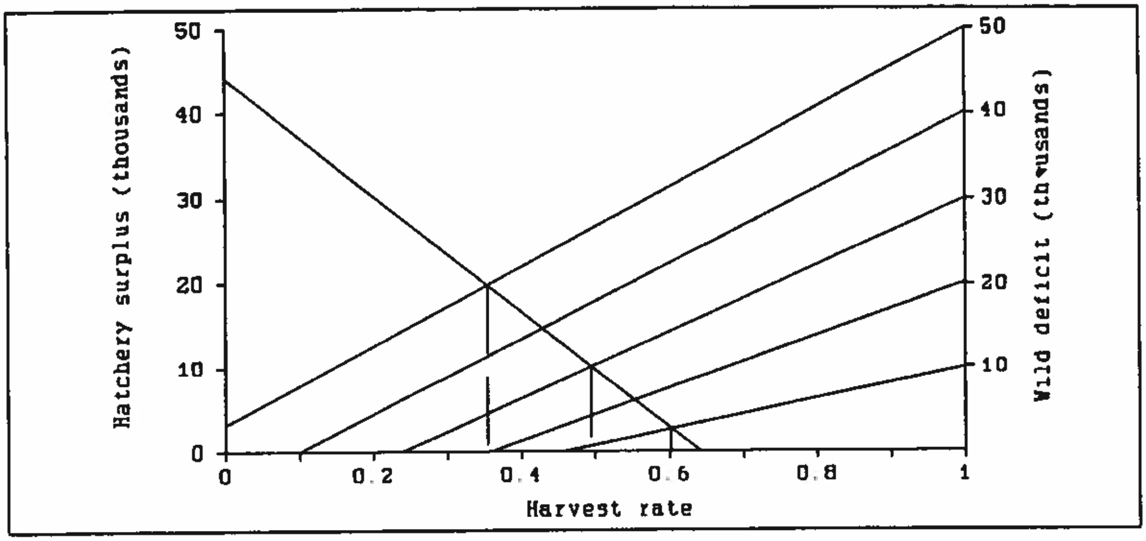

Figure 2.--Harvest rate, with outplanting, to achieve different escapement goals (values for wild deficit at harvest rate = 1) for spring chinook salmon in the Snake River when the hatchery programs produce 2.8 recruits per spawner.

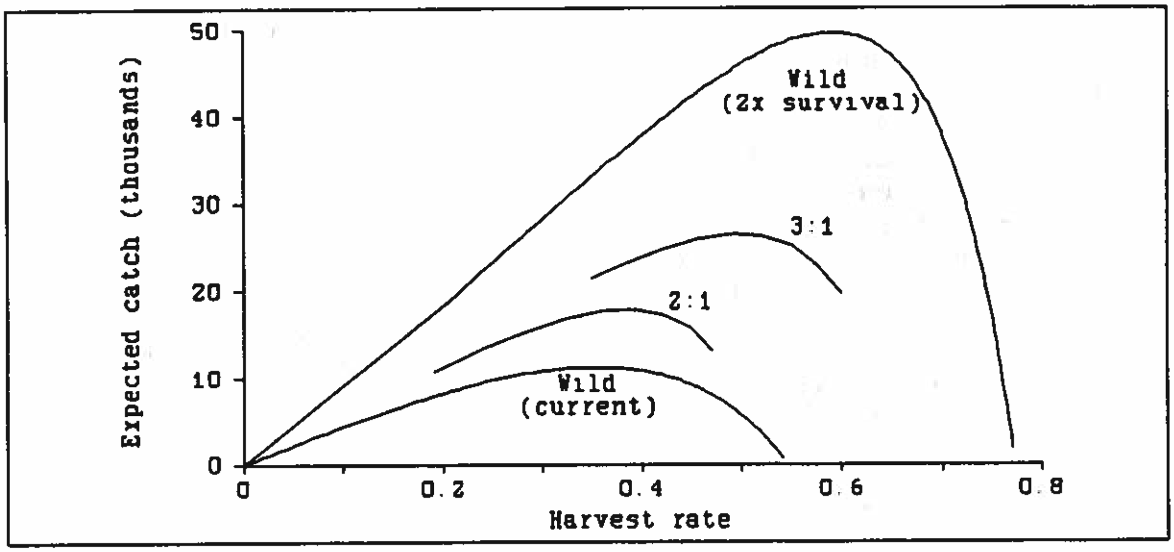

Figure 3.--Expected catch of spring chinook salmon from the Snake River at different harvest rates. Curves illustrate natural (wild) production under recent conditions (current) and when survival of downstream migrants is doubled, and natural and hatchery production with outplanting when hatchery programs produce 1.9 (2:1) or 2.8 (3:1) recruits per spawner.

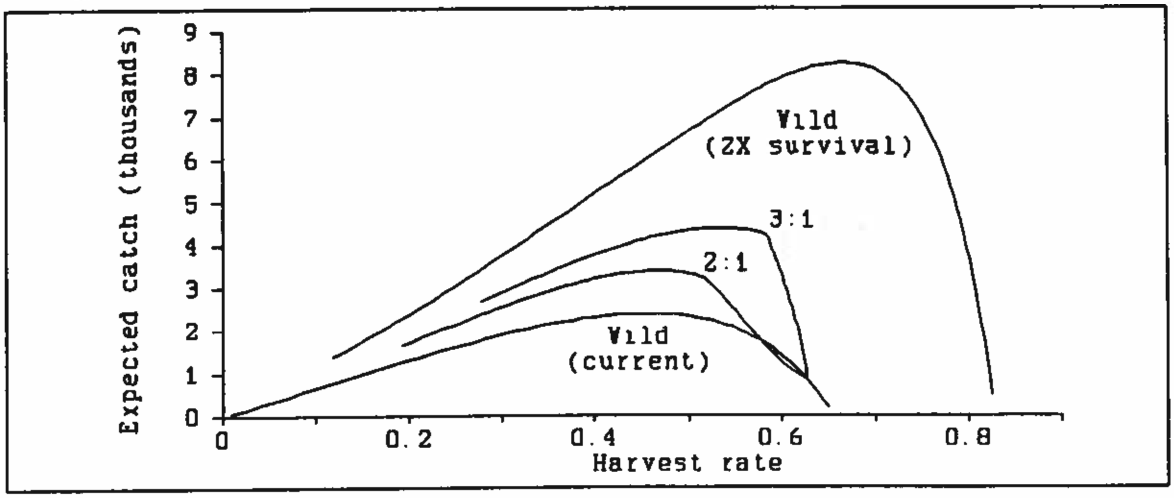

Figure 4.--Expected catch of spring chinook salmon from the Methow River at different harvest rates. Curves illustrate natural (wild) production under recent conditions (current) and when survival of downstream migrants is doubled, and natural and hatchery production with outplanting when hatchery programs produce two (2:1) or 3 (3:1) recruits per spawner.

Clearly, some populations can accommodate a higher harvest rate than others. The John Day River population may become extinct at a 10% harvest rate, and the 64% harvest rate estimated for MSY of Wenatchee River fish would deplete or eliminate the populations from the Entiat, Methow, and Snake Rivers. Accordingly, managers can allow only limited fishing in the main-stem Columbia River if each stock is to persist. This would require that there be almost no harvest below the John Day River until improvements in downstream migrant survival have substantially increased the productivity of the population and perhaps 25% harvest rate below the Snake River, even with successful (2:1) outplanting.

The estimates of population productivity given here, or anywhere else, may, of course, be wrong and may suggest harvest rates substantially different from optimum rates. For this reason, and because population productivity varies from year to year and among populations, minimum escapement goals should be established for each population in the system and escapements should be monitored to avoid both loss of populations from overfishing and generation of genetic problems resulting from small effective population size. Harvesting populations in their home tributaries, rather than in the Columbia or Snake Rivers, would allow for protection of the less productive populations, and would provide the greatest total catch.

Successful outplanting will increase production and allowable catch, although optimum harvest rates may change little. Outplanting programs should be planned and evaluated carefully because outplanting is not a proven technology; it can eliminate endemic populations, and may produce few or no additional fish over an extended period of years.

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QUESTIONS AND ANSWERS

Q: Were the stock recruitment and abundance numbers for the Snake River estimates to Lower Granite Dam?
A: Yes; we attempted to account for the harvest there at the same rate as for the rest of the system.

Q: Were outplanted fish counted as wild fish, for example in the Snake River?
A: Yes; this would inflate the production parameters.

Q: Would the higher acceptable harvest in the Snake River, compared to that in the John Day River, be due to local environmental conditions; would it be a bottleneck?
A: Yes, I meant to make this point. John Day River is an extreme example. If the problems can be solved there, one still might see differences. Perhaps stay out of the mainstem and tailor the harvest to the tributaries.
Comment: The problems at John Day Dam were passage problems, and there has been some correction of these problems.

Q: Do you believe that you can sustain the harvests that you indicated for the Snake River, especially since levels have been very low recently?
A: Yes; I feel comfortable because they meet the minimum levels for escapement, they are for average conditions, and they agree with Howard Raymond's data. I think they can be harvested at 25%. One sees a wide range in the production of the whole system.

Q: But you see harvest before you see escapement.
A: That is another reason why you should take the harvest out of the mainstem.

Q: What is your definition of "minimum escapement?"
A: I can't give numbers--it is the need to avoid substantial inbreeding problems. A manager needs to feel comfortable that he is conserving these stocks. One would need at least 200 fish, or maybe 150, in streams where maintenance of a viable stock is desired. This is complicated by the overlap of year classes.
Comment: A manager would decide subjectively and hope that his judgment is correct and that the fish will return at that rate. You gave the answer I expected, thank you.
A: There is actually a pathetic database, and it is hard to do otherwise. If you wanted 150 fish in each system, you would need to account for variable productivity in the different systems.

Q: With regard to the harvest rate, the management response has been to close the Wenatchee River--is this the wrong approach?
A: I do not see it as a management error. Smolt-to-adult survival rates had been very low. It is only recently that we have seen improved conditions as an effect of management actions. Will this continue? These are maximum estimates, intended only as guidelines. One still has to deal with environmental variables.

Q: Regarding the John Day River fish--it looked as if they were at particular risk, in that there was no "wiggleroom" for harvest. There are three dams involved here, while there are more dams at other systems. Are interdam losses factored into your numbers? With adverse flows, one may lose ground.
A: No, but the effect is included since the numbers here were of fish actually going past the dams. Yes, you would lose ground in years of adverse flows; note that most points from recent low flow years were below replacement levels.

Q: In calculating recruits, do you suggest that there is no ocean harvest? This may have changed in recent years, and could have an impact on your conclusions.

A: Yes; this was harvestable surplus in the river. Few spring chinook salmon are really taken in the ocean. A maximum estimate of marine harvest would be 5 to 10%. This will change our results, but not substantially.

Q: How far upriver would natural self-sustaining runs be possible, for more than a token fishery--to the Methow and Entiat? I would be skeptical, because one barely gets back adequate spawning stock. Maybe the Wenatchee River is the farthest upstream without supplementation?

A: Currently, I believe one could take some from the Methow--a meaningful fishery, even. It takes a lot to build these stocks. It is contingent on whether recent survival rates will hold. We need to see if outplanting works before leaping into it.

STOCK STRUCTURE AND GENE CONSERVATION IN COLUMBIA RIVER SPRING CHINOOK SALMON

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Three major races of chinook salmon, Oncorhynchus tshawytscha (spring, summer, and fall run fish), are recognized in the Columbia River Basin. These races are fairly distinct with respect to life history features, such as time of entry into fresh water and age and timing of outmigration, but somewhat less so if other characters are used. For example, Utter et al. (1989) found that fish from the same stream with different run times were typically more similar genetically than were fish of the same run time from different streams. They suggested that each race was probably polyphyletic, with life history divergence occurring within some streams after colonization by fish of a single run time.

Regardless of whether this hypothesis is true, considerable geographic structure can be identified among spring chinook salmon populations. Figure 1 shows a dendrogram of genetic relationships based on electrophoretic data for 15 polymorphic gene loci. Although it is easy to overinterpret such dendrograms, several points emerge from an examination of the figure. First, the major groupings fall out along geographic lines and generally are compatible with those identified by Schreck et al. (1986) using meristic, morphological, and genetic data. There is a major distinction between spring chinook salmon from west of the Cascades (group A, Willamette River and group B, lower Columbia River) and those farther east. Second, mid- to upper Columbia River stocks (group C) cluster very tightly together, as do those from the Snake River system (group D). It is interesting to note that Kooskia Hatchery, which is in Idaho but has been stocked with Carson fish, clusters with the Columbia River stocks rather than the other Snake River stocks. Finally, stocks in group C do not differ substantially from those in group D; this probably reflects the origin of the Carson-Leavenworth hatchery stock, which was started with upriver fish intercepted at Bonneville Dam.

Further insight regarding stock structure in spring chinook salmon is gained by considering average heterozygosity, a measure of overall genetic variability within individuals or populations. Winans (1989) reported much lower levels of heterozygosity in upriver spring chinook salmon than is found in lower river spring chinook or fall chinook from throughout the basin (Table 1). The cause of this pattern is not clear, but one possibility is that upriver spring chinook salmon stocks have experienced severe (or repeated) bottlenecks in population size during which homozygosity increased through inbreeding (matings between individuals of similar genotype). Low heterozygosity does not necessarily imply reduced fitness, as little detectable genetic variation has been found in a number of apparently healthy species. However, data for a variety of organisms provide evidence for a relationship between population bottlenecks, reductions in genetic variability, and increased susceptibility to disease (O'Brien and Evermann 1988). A plausible explanation for this relationship is suggested by the observation that immune and disease response systems in vertebrates are typically controlled by extremely polymorphic genetic systems; that is, a large

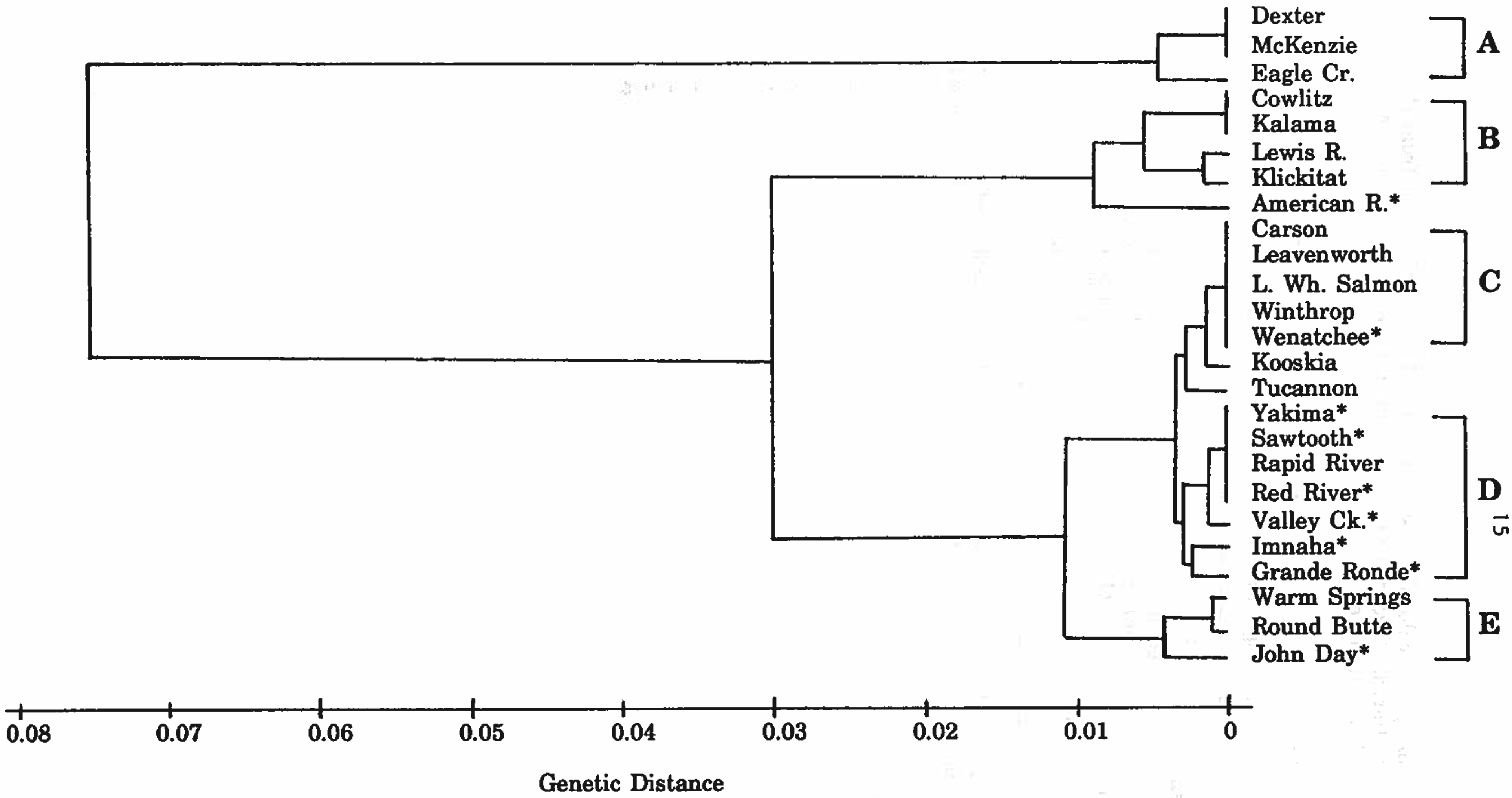

Figure 1.--Dendrogram of genetic relationships among 25 populations of spring chinook salmon. Dendrogram was constructed using electrophoretic data for 15 gene loci gathered by National Marine Fisheries Service, Seattle, and Washington Department of Fisheries, Olympia; clustering strategy was unweighted pain-group method analysis using Nei's (1978) genetic distance. A number of loci known or suspected to be monomorphic were not included in the analysis, so values shown are relative rather than unbiased estimates of true genetic distance. Major geographic groupings: A: Willamette River; B: Lower Columbia River (plus Klickitat); C: Mid- to upper Columbia River (Washington); D: Snake River (plus Yakima); E: Mid-Columbia (Oregon). Samples from wild/naturally spawning populations are indicated by an asterisk (*); others are hatchery samples.

Table 1.--Average heterozygosity values[a] for spring and fall chinook salmon from the Columbia River Basin. Regional values are means based on the number of stocks indicated in parentheses.

Region	Spring chinook	Fall chinook
Lower Columbia Basin	0.082 (3)	0.081 (5)
Willamette River	0.080 (4)	0.084 (1)
Mid-Columbia Basin	0.060 (5)	0.075 (3)
Upper Columbia Basin	0.061 (1)	0.088 (2)
Snake River Basin	0.045 (4)	0.077 (1)
Snake River Basin[b]		0.040 (3)[b]

[a] Based on data for 33 gene loci reported by Winans (1989). A number of loci known or suspected to be monomorphic were not included in the analysis, so values shown are relative rather than unbiased estimates of total heterozygosity.

[b] Excluding Kooskia Hatchery.

number of alleles occur in a population, with few individuals sharing any one genotype. Such a population is much less susceptible to decimation by a newly evolved viral or bacterial pathogen than is a largely monomorphic population. In this regard, it is interesting to note that problems caused by bacterial kidney disease are most severe in upriver spring chinook salmon, which have the lowest levels of genetic variability of any spring or fall stocks (Table 1).

This simple relationship by no means represents conclusive evidence for a causal relationship, but it does serve to illustrate the point that the erosion of genetic variability can have serious, and often unforeseen, consequences. In some respects, the extinction of rare alleles may be of more importance than the loss of heterozygosity per se (see Allendorf 1986). As shown in Figure 2, which depicts results from a series of computer simulations modelling the rate of loss of genetic variability from chinook salmon populations (Waples, in press), a substantial percentage of low frequency alleles can be permanently lost before there is an appreciable decline in heterozygosity. In chinook salmon, as in most species, rare alleles are more common than any other class of alleles (Fig. 3), so large numbers of rare alleles are subject to rapid extinction in small populations. It is not clear what immediate adaptive value this large class of rare alleles has, but it is certain that they represent the bulk of the raw material upon which natural selection might act. Permanent loss of a substantial portion of such alleles may compromise the ability of a population to respond to challenges presented by changing environmental conditions.

The rate of loss of genetic variability is a function of effective population size (N_e). If sex ratio of spawners is unequal or if the variance among families in reproductive success is large, N_e is less than the census number, and perhaps a great deal less. Given that spawning escapement to many upriver stocks is already seriously low (e.g., Williams 1989), reduced N_e is a very real concern for spring chinook salmon. Evaluating effective population size, however, is particularly difficult with Pacific salmon. Even if spawning is carefully monitored, smolt mortality after outmigration may be 99% or more, making it difficult to estimate the variance among families in number of progeny returning to spawn. Furthermore, because of the complex life history features of chinook salmon, it is not apparent what relationship the effective number of breeders each year (N_b) has to the more familiar concept of effective population size per generation (N_e).

To address these questions, a computer simulation model was developed that incorporates the pattern of overlapping year classes and one-time reproduction typical of chinook salmon. Results (Waples, in press) indicate that generation length in chinook salmon can be defined as the average age at reproduction and that effective population size per generation is equivalent to the generation length times the effective number of breeders per year. Thus, for a chinook salmon population with average age at spawning of 4 years, $N_e \approx 4N_b$. This relationship allows us to apply the large body of theory developed for population and conservation genetics directly to problems of concern to spring chinook salmon. A method has also been developed to estimate N_b from year-to-year changes in allele frequency, and this approach can be used to identify hatcheries (or wild populations) in which N_b is lower than expected; remedial actions can be taken before serious problems associated with inbreeding develop.

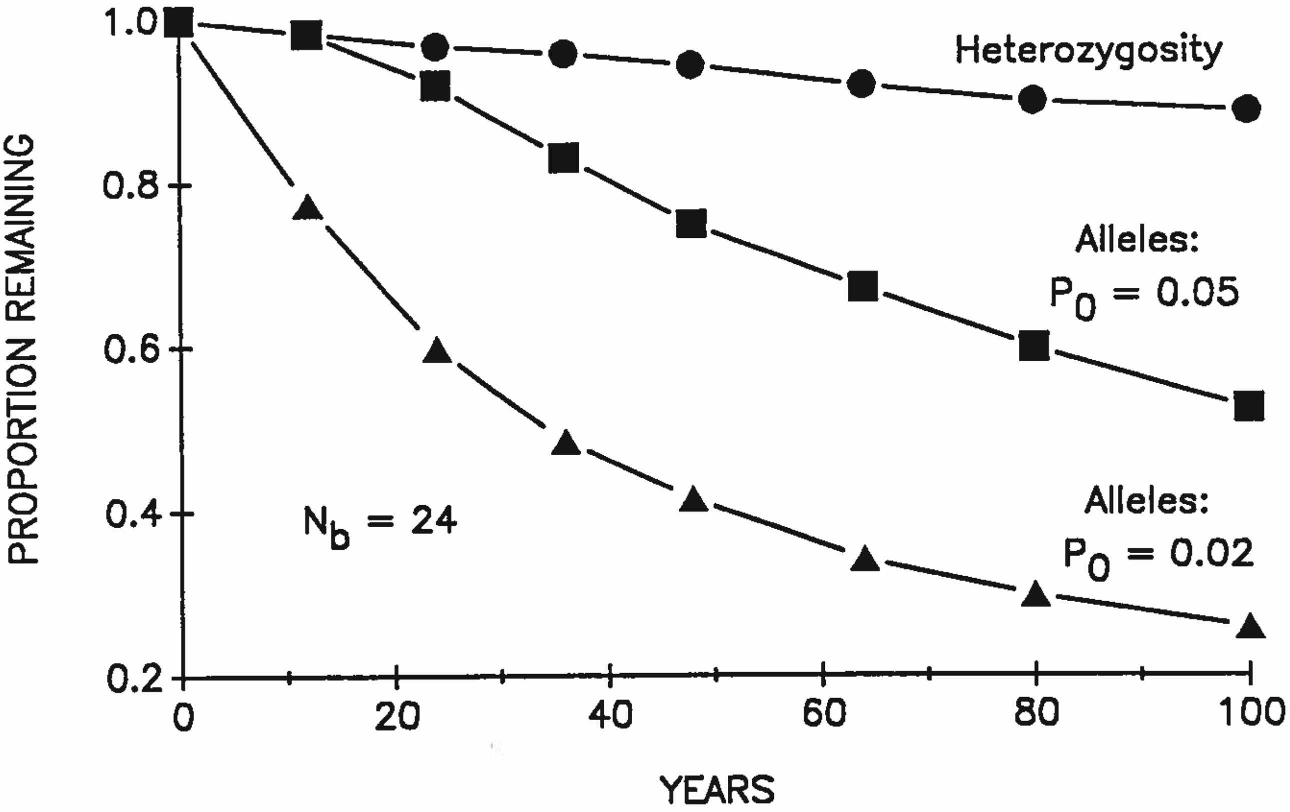

Figure 2.--Proportion of initial genetic variability remaining in a simulated chinook salmon population after periods of time up to 100 years. Large numbers of alleles with low initial frequency (P_0) can be lost before an appreciable change in heterozygosity is detected. N_b is the effective number of breeders per year.

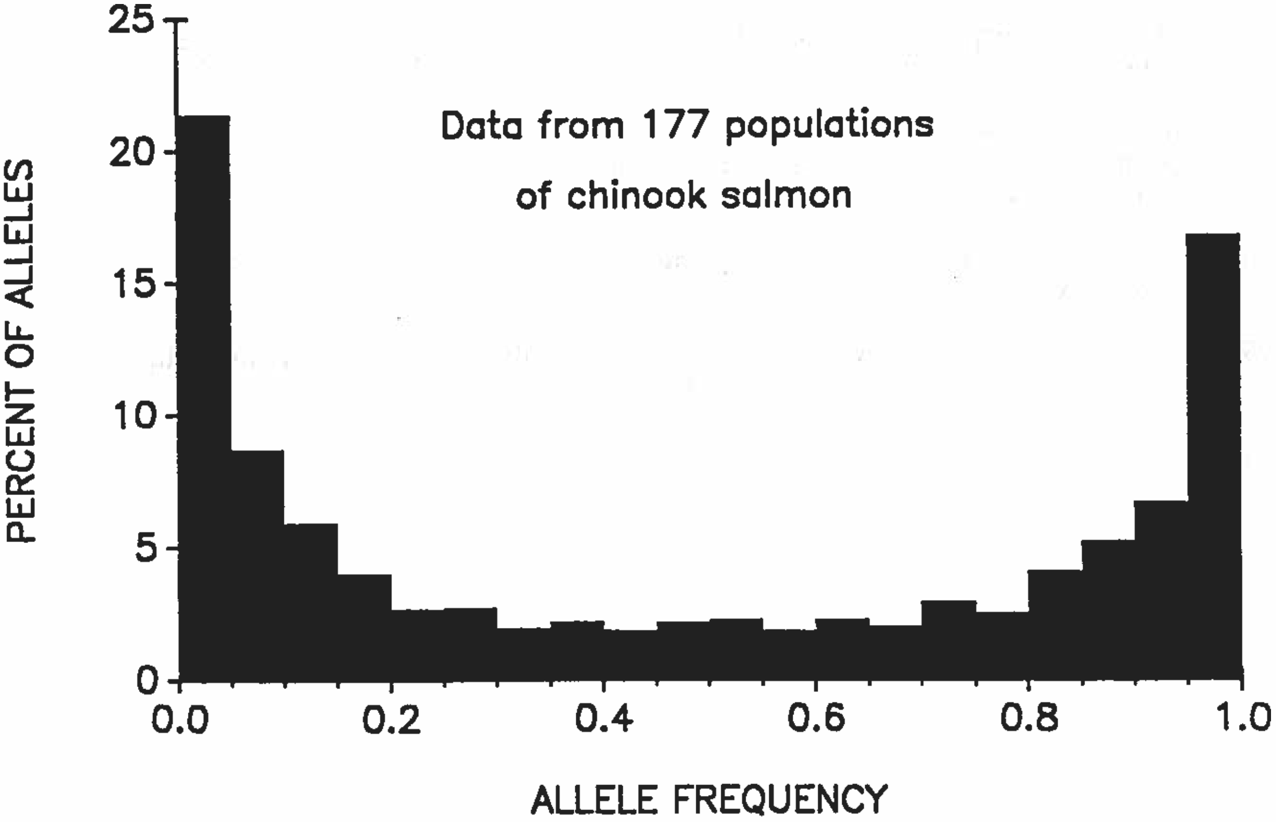

Figure 3.--Distribution of alleles at various frequencies found in samples from 177 chinook salmon populations in the Pacific Northwest.

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QUESTIONS AND ANSWERS

Q: How can you attribute changes to reduced numbers of breeders?
A: It is difficult to sort out genetic drift from rate of change of allele frequency. One needs to have a closed population--if you measure different parts of a run in different years, it is even more difficult. There would be a greater potential to see this in hatchery stocks. Preliminary data are available for 20-30 hatchery populations over many years. It seems that there is a much lower N_e than we would hope for.

Q: If heterozygosity of Snake River populations is low, what are we to do, and how are we to protect the integrity of Snake River stocks?
A: Some have suggested hybridization; this is a possibility but it is not recommended. This might result in the opposite of what is wanted. The wild fish have migrated for thousands of years, so one shouldn't interfere with their genetic makeup. We should leave them alone while not doing anything to further reduce this component. Some species, defined through electrophoresis, are doing even worse, although this does not imply reduced fitness.

Q: Might hatchery practices decrease genetic variability--for example, culling for disease?
A: Yes. Hatcheries might also take only one part of the run, or use a small number of males for a relatively large number of females. This would mean that a few individuals would have a large contribution to the subsequent population. Even females may show a disproportionate contribution; this should be discouraged. Bonneville Power Administration (BPA) has expressed interest in practical approaches for doing something about this.

Q: Were the stated heterozygosity values for hatchery or wild fish? And is there more life history variability, and therefore higher heterozygosity, in the lower river? We see some curious migration timing there.
A: Both hatchery and wild fish are included in the values. I don't know about life history variability in the lower river. It may be true that there has been loss of this variability in the Snake River, since there seems to be such a narrow window for migration timing.

Q: If life history behavior becomes less diverse, might the window be even further reduced?
A: Yes; good point.

EFFECT OF MAINSTEM SURVIVAL RATES ON SPRING CHINOOK SALMON PRODUCTION

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For the last several decades, mortality of juvenile and adult fish passing through the Columbia River hydroelectric system has been the major factor limiting and shaping the production of spring chinook salmon in the Columbia and Snake Rivers. Despite general acceptance of this point, it remains unclear how and to what extent passage losses affect spring chinook populations. Nonetheless, our ability to plan effective mitigation measures and the success of multimillion dollar efforts to rebuild spring chinook populations will ultimately depend on our understanding of the processes by which fish populations are shaped by the hydroelectric system.

The theme of this workshop is "The Status and Future of Spring Chinook Salmon in the Columbia River Basin." To contribute to this topic, I have examined how mainstem passage losses might act to limit production of spring chinook. This was done using a simple computer model. The model allowed manipulation of factors that would be impossible to do in the field. The purpose of the study was to gain insight regarding two questions: 1) How are natural spring chinook populations in the Columbia Basin presently limited by mainstem passage? and 2) What will be the effect of planned efforts to improve mainstem passage on spring chinook populations? It also provided an indication of the degree to which feasible subbasin and passage survival actions might mitigate the effects of hydroelectric development on production.

The study has indicated that natural spring chinook populations in the upper basin are, and will continue to be, severely limited by passage losses. Habitat measures appear to have a very limited ability to mitigate the losses caused by the dams. In this study, natural upriver spring chinook populations continued to be depressed even after improvements in passage survival and in subbasin survival and capacity.

Overview of the Analysis

Output for the study was the population size at the point of maximum sustained yield (MSY). Calculation of this point was done using the System Planning Model (MEG 1989). This permitted a variety of passage survival changes to be examined as well as modification of the subbasin production parameters. Density dependance in this model is based on the function described by Beverton and Holt (1957).

The model was used to place an identical, idealized spring chinook subbasin at four locations in the Columbia Basin. Study locations were as follows:

1. Below Bonneville Dam, River Mile 146, no dams below,
2. Above McNary Dam, River Mile 292, four dams below,

3. Above Lower Granite Dam, River Mile 400, eight dams below,
4. Above Wells Dam, River Mile 515, nine dams below.

At each location, four subbasin conditions were examined:

1. A baseline intended to simulate a moderate condition regarding juvenile survival and smolt carrying capacity,
2. The baseline condition with egg-smolt survival rate increased by 25%,
3. The baseline condition with the smolt carrying capacity increased by 50%,
4. The baseline condition with increases in both the egg-smolt survival and the smolt carrying capacity.

The baseline subbasin condition used data provided to the System Planning process (Columbia Basin Fish and Wildlife Authority (CBFWA) 1989) and represented mid-level values in regard to juvenile survival rates, carrying capacity, and fecundity. The other scenarios simulate feasible actions such as habitat improvement (increase the egg-smolt survival) and habitat expansion (increase the smolt carrying capacity).

The effect of each subbasin condition on the MSY was examined in light of five passage survival conditions:

Condition	Screens	TBR	Spill	Reservoir mortality rate
Baseline	Existing configuration	1.5:1	Minimal	0.0020/mile
Increased TBR	Existing configuration	2.0:1	Minimal	0.0020/mile
Full Screens	All projects, high FGE	1.5:1	None	0.0020/mile
Lower Reservoir Mortality	Existing configuration	1.5:1	Minimal	0.0015/mile
Max Passage Survival	All projects, high FGE	2.0:1	None	0.0015/mile

The baseline conditions simulated existing passage conditions while the other scenarios represent planned or possible changes in passage conditions. TBR refers to the transport benefit ratio which is the ratio in adult return rates between fish that were transported as juveniles and those that were not transported. FGE is the fish guidance efficiency, which indicates the proportion of fish approaching a turbine intake that are diverted into a bypass system.

Throughout the study, adult passage losses at the lower four projects (Bonneville through McNary) were assumed to be 10% per project, while losses at the upper projects in the Snake and mid-Columbia areas were set at 5% per project.

Harvest rates were set to zero for all combinations.

Results

The results from the study are summarized in Table 1. The effect of carrying capacity is linear in the Beverton-Holt relation, so that a 50% increase in capacity will result in a 50% increase in the number of fish. The effect of egg-to-smolt survival rate, however, is nonlinear and will vary with the scenario. In Table 1, the percent change of each scenario relative to the baseline subbasin condition (/1) is provided in the third, fifth, seventh, and ninth columns. Also shown is the percent reduction in the population at the maximum subbasin condition (/4) as a result of moving the subbasin to the locations above Bonneville Dam.

Discussion

The results of this study indicate the degree of reduction in spring chinook natural production in the upper Columbia Basin imposed by the hydroelectric system. They also indicate that extreme reduction in fish productivity will likely continue even after implementation of all presently available options for increasing passage survival rate. This point is reinforced in Table 2. Other results of the study are as follows:

1. Populations may be limited either by survival rate or capacity.

2. The limiting effect of survival rate on the population size increased as the subbasin was moved upriver. The population in the lower Columbia River area was largely limited by capacity.

3. Natural spring chinook populations in the upper Columbia Basin decreased substantially as a result of low passage survival rates.

4. Natural production of spring chinook in upper basin areas, particularly the upper mid-Columbia River area, remained low even under the most optimistic passage assumptions and optimum subbasin conditions.

5. In upper basin areas, the effectiveness of habitat improvement measures to increase the population size decreased because of the effect of main-stem passage survival rates.

6. At all locations, the effect of decreasing reservoir mortality by 20% was less than anticipated. This was because a seemingly large reduction in reservoir mortality resulted in a relatively small increase in reservoir survival rate.

7. Spring chinook productivity in the upper Snake River area was low but substantially greater than that in the upper mid-Columbia River area due to smolt transportation in the Snake River and the assumption of a positive transport benefit.

8. Productivity of natural spring chinook in the above Lower Granite area was increased by measures that increased the benefit of transport or the proportion of the migration affected by transport.

9. Production in the upper mid-Columbia River area was most benefitted by installation of efficient smolt bypass systems at all projects.

Table 1.--Maximum sustained yield of run size at four locations when passage and subbasin parameters are modified.

	Below Bonneville		Above McNary		Above Lower Granite		Above Wells	
Scenario	MSY Run size	% Change from /1	MSY Run size	% Change from /1	MSY Run size	% Change from /1	MSY Run size	% Change from /1
Base/1	3278	0.0	778	0.0	378	0.0	25	0.0
Base/2	3425	4.5	856	10.0	445	17.7	76	204.0
Base/3	4918	50.0	1166	50.0	566	50.0	37	50.0
Base/4	5137	56.7	1285	65.2	654	73.0	114	356.0
% Change from below Bonneville at /4				-75.0		-87.3		-97.8
Scrns/1	3278	0.0	878	0.0	459	0.0	202	0.0
Scrns/2	3425	4.5	971	10.6	527	14.8	255	26.2
Scrns/3	4918	50.0	1339	50.0	689	50.0	303	50.0
Scrns/4	5137	56.7	1457	65.9	790	72.1	382	89.1
% Change from below Bonneville at /4				-71.6		-84.6		-92.6
TBR/1	3278	0.0	834	0.0	582	0.0	39	0.0
TBR/2	3425	4.5	912	9.4	649	11.5	83	112.8
TBR/3	4918	50.0	1250	50.0	873	50.0	58	50.0
TBR/4	5137	56.7	1368	64.0	974	67.4	131	235.9
% Change from below Bonneville at /4				-73.4		-81.0		-97.5
Resv/1	3278	0.0	856	0.0	403	0.0	71	0.0
Resv/2	3425	4.5	935	9.3	461	14.4	117	64.8
Resv/3	4918	50.0	1284	50.0	604	50.0	107	50.0
Resv/4	5137	56.7	1402	63.8	705	74.9	182	156.0
% Change from below Bonneville at /4				-72.7		-86.3		-96.5
Max/1	3278	0.0	1047	0.0	735	0.0	302	0.0
Max/2	3425	4.5	1124	7.4	814	10.7	361	19.5
Max/3	4918	50.0	1570	49.9	1102	50.0	453	50.0
Max/4	5137	56.7	1687	61.1	1221	66.1	541	79.1
% Change from below Bonneville at /4				-67.2		-76.2		-89.5

Note: Coding of scenarios is Passage Condition/Subbasin Condition.

PASSAGE CONDITIONS

Base = Existing passage conditions
Scrns = All projects screened bypass systems.
TBR = Increased Transport Benefit Ratio.
Resv = Reservoir mortality rate decreased.
Max = All passage measures combined.

SUBBASIN CONDITIONS

/1 = Baseline subbasin conditions.
/2 = Egg-smolt survival rate increased.
/3 = Smolt carrying capacity increased.
/4 = Both capacity and survival increased.

Table 2.--Comparison of the change in spring chinook salmon run size for an idealized subbasin at four locations in the Columbia Basin under enhanced subbasin and passage conditions relative to the baseline condition.

Location	Existing passage conditions (%)	Enhanced passage and subbasin conditions (%)
Below Bonneville Dam	100	156
Above McNary Dam	24	51
Above Lower Granite Dam	12	37
Above Wells Dam	1	17

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QUESTIONS AND ANSWERS

Q: Regarding your third conclusion, that production can be described by main-stem passage losses--if stocks are genetically unique, and there are efforts to preserve this genetic diversity, how would you support water management strategy which is based on numbers of fish rather than specific stocks? This has been the approach in the Snake River. Spill management and water budget, for example, have not addressed the temporal separation of certain stocks.

A: That is the beauty of models, which don't have to deal with practical matters. In the Snake River, there are not too many water options. Information is being accumulated that may lead us to customize water use and better protect stocks. Up to now, this has been conjecture. I agree that this should be done, and to incorporate genetic data as well, in the decisions. This could lead to a very different management system.

Comment: Managers are confronted with the problem of whether to protect overall numbers of fish or particular stocks. This hasn't been addressed.

Q: Have you run the model with other races or species with smolts outmigrating later in the spring, especially in regard to predation?

A: A model to relate residence time with flow doesn't exist now. Predation was less than I expected, but it is still significant. Predation would be a greater factor in the summer, with higher temperatures, etc.

Q: Regarding changes in survival, I am optimistic about the increases that you noted--but what about population levels today?

A: Yes, if you look at percentage changes, for example 700%, this is dramatic. But if you look at populations, in some this means that a 300% increase comes from only three fish! Can these co-exist with downriver populations? We need to temper our actions and look at a broader perspective.

Q: In the model, you enhanced particular factors, but what about increased flows? Is this not an option or perhaps not a benefit?

A: The effects of flows may be felt in the predation aspect. How the decrease actually occurred may be due to flow enhancement.

AN ASSESSMENT OF ADULT LOSSES, PRODUCTION RATES, AND ESCAPEMENTS FOR WILD SPRING AND SUMMER CHINOOK SALMON IN THE SNAKE RIVER

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In recent years, increased numbers of adult spring and summer chinook salmon have returned to the Snake River. This rebound in abundance follows a period around 1980 when adult production had fallen to about 10% of the numbers 20-30 years earlier. Reported herein are summaries of an assessment of potential adult losses related to dams, production rates by wild fish, and present wild fish spawning escapements versus those in earlier years.

Adult Losses Between Dams

Counts of upstream migrating salmon entering the Snake River were begun in 1962 with the completion of Ice Harbor Dam. Additional upstream dams were completed and counting of migrants started in 1969 at Lower Monumental Dam, 1970 at Little Goose Dam, and 1975 at Lower Granite Dam. The discrepancy in counts between Ice Harbor and Lower Granite Dams during the 1975-89 period has averaged 15.1% for spring chinook, 0.01% for summer chinook, and 11.8% for both groups combined. The runs have averaged about 30,000 fish during the period and thus about 3,000 more fish, on average, have been counted at Ice Harbor Dam than at Lower Granite Dam. Some of the lost fish entered the Tucannon River (probably less than 1,000 annually) and some probably died between the dams. The loss per dam for the three dams and reservoirs upstream from Ice Harbor would average about 3 to 4%, about the same rate as has occurred between Ice Harbor and Lower Monumental Dams for the 1969-89 period.

Losses Between Dams and Spawning Grounds

In addition to adult salmon counted at the dams, the redds of spring and summer chinook salmon have been counted in many Snake River tributaries, some since the early 1950s. These redd counts provide an index of spawner abundance that can be compared with counts of adults destined to spawn naturally at the dams to determine if loss rates during the final portion of their upstream migration have changed since the early 1960s. The number of fish that were destined to spawn naturally in the Snake River Basin and that crossed Ice Harbor Dam was determined by accounting for wild and hatchery fish upstream from Ice Harbor Dam, assigning each group its share of the lost fish, and determining the proportion of fish counted at the dam that were wild or hatchery in origin for any given year. This number was then compared with estimates of fish that actually spawned (based on redd counts) to determine the proportion that survived to spawn.

From 1962 to 1968, when Ice Harbor Dam was the only dam in the lower Snake River, I estimate that about 55% of the wild fish survived to spawn (Fig. 1). Since the completion of the three other dams, the estimated survival rate between Ice Harbor Dam and the spawning grounds has been about 46%. The lower rate in recent years could be due to losses at the most recent dams rather than increased mortality between the dams and the spawning ground.

Production Rates of Wild Fish

The separation of the Snake River spring and summer chinook into wild and hatchery components for the 1962-88 period provided an opportunity to evaluate production of the wild segment using a parent-recruit model. I assumed that spring and summer chinook salmon had a 4-year cycle and employed a 5-year running average to evaluate trends in production rate. During the 1960s, the production rate for spring and summer chinook salmon combined was about five recruits per parent (Fig. 2). By the late 1970s, the production rate had declined by about 80%. Production rates for recent brood years have risen to levels equal to that of the 1960s.

The number of adults crossing Ice Harbor Dam that were destined to spawn naturally has declined during the last 27 years from an estimate of about 17,000 (not including losses) in the 1960s to less than 4,000 fish for the 1980-84 brood year 5-year average (Fig. 2). The increase in production rates of recent brood years coincided with the smallest spawning escapements of wild fish in the last 30 years. If the Snake River spring and summer chinook salmon populations have dynamics similar to those of models such as the Beverton-Holt parent-recruit relation, increased production rates would have been expected with small numbers of spawners. The questions then become: Have the production rates increased to expected levels? and Are the increases due to improvements in conditions that caused the lower rate or merely a response to small numbers of spawners? To evaluate the recent increases in production rate, I used a Beverton-Holt curve fit to the parent and recruit numbers for the brood years of the 1960s, and compared the expected production rates based on the parent-recruit curve (Fig. 3) with actual rates. Brood years in the 1960s had actual production rates that were similar to the expected rates (Fig. 4) because the parent-recruit curve was based on data for those brood years. In subsequent years, expected production rates increased as the number of wild spawners declined, and the actual production rates decreased until after the 1978 brood year, when they began to increase. The recent increases in production rate probably signal an improvement in conditions that caused the earlier declines, but the rates are still lower than expected, an indication that problems still remain.

Spawning Escapements for Wild Fish

The number of spawners needed to provide optimum or even full seeding in the natural production areas of spring and summer chinook salmon in the Snake River Basin has not been well defined because of the lack of intensive studies in a variety of types of streams. During the 1970s, we monitored the number of juvenile spring chinook salmon produced in Marsh Creek, a tributary of the middle fork of the Salmon River, and related the number of migrants to the number of redds from the preceding fall. During the 8 years of monitoring, numbers of redds ranged from about 20 to 350, and the number of age-0 fish migrating downstream after rearing in the stream during the summer and fall ranged from about 10,000 to nearly 130,000 (Fig. 5). Although there is variability and not as much data as we might like, I would infer that there is

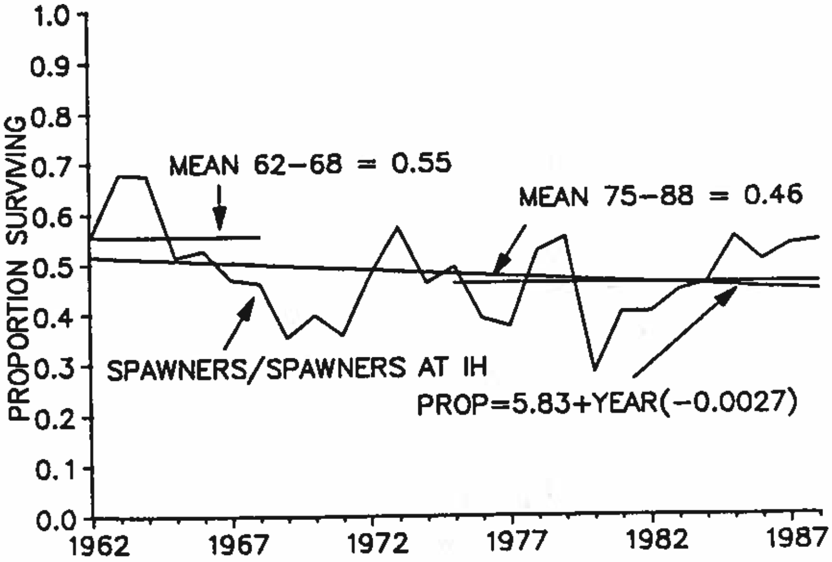

Figure 1.--The proportion of wild spring and summer chinook salmon passing Ice Harbor Dam from 1962 to 1988 that survived to spawn in the Snake River Basin. During the 1962-68 period, Ice Harbor Dam was the only dam present in the lower Snake River. After 1975, all four of the present dams were in operation.

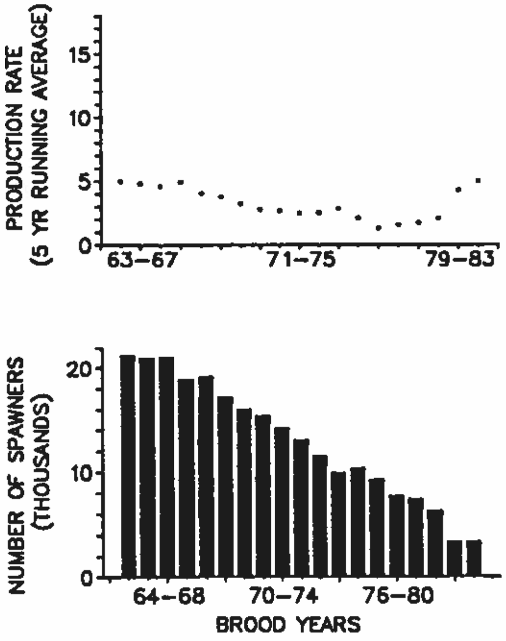

Figure 2.--Production rates (recruits per parent) for wild spring and summer chinook salmon in the Snake River Basin based on a 4-year cycle (upper), and estimated number wild spawners from 1962 to 1988. Data are smoothed with a 5-year moving average to observe trends.

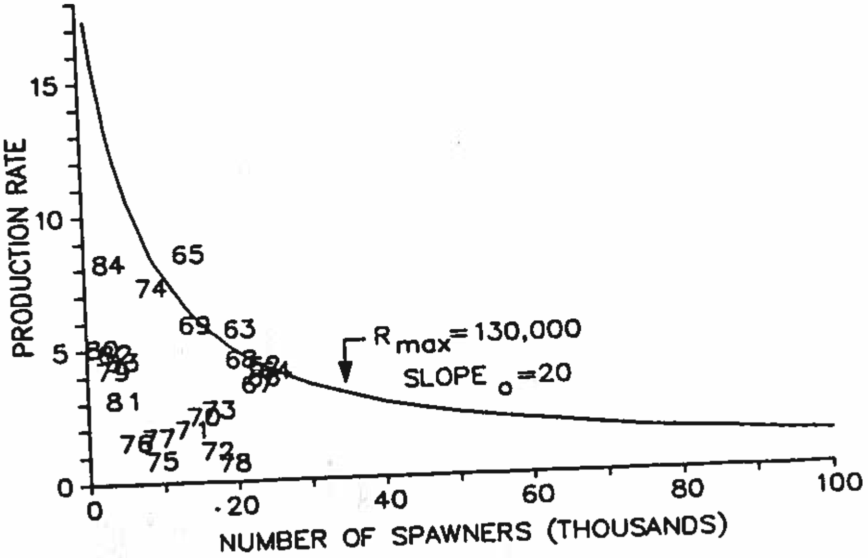

Figure 3.--Production rate of Snake River spring and summer chinook salmon versus number of spawners for the brood years from 1962 to 1984, and the expected production rate curve with a Beverton-Holt relation with parameters as listed next to the curve.

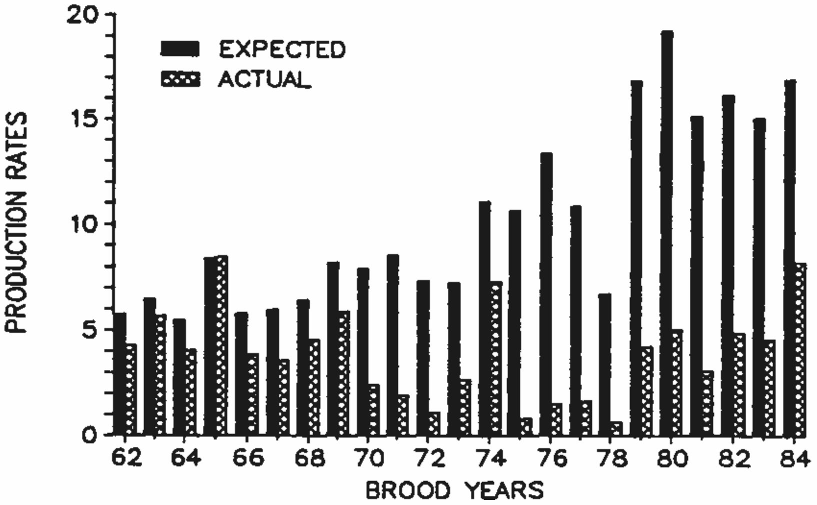

Figure 4.--Expected and actual production rates for the 1962-84 brood years, spring and summer chinook salmon in the Snake River.

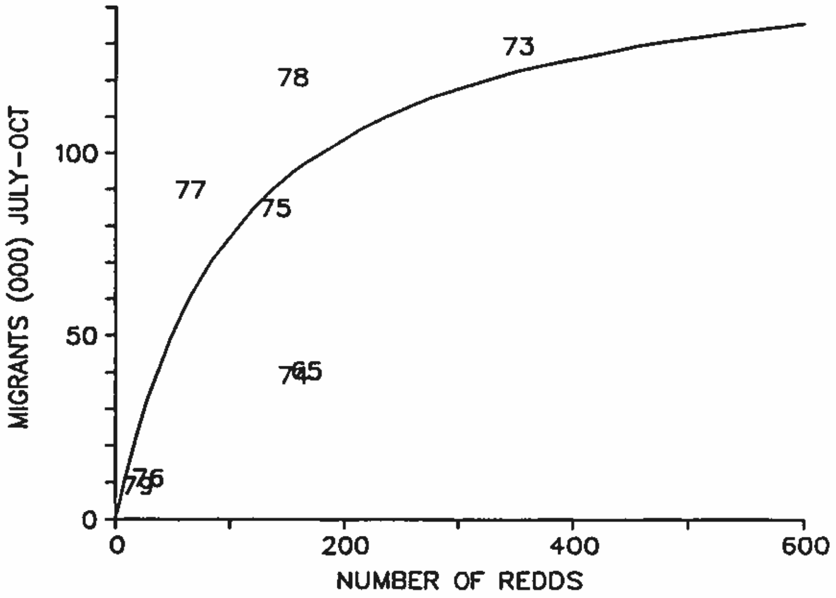

Figure 5.--Number of redds counted and number of age-0 spring chinook salmon leaving Marsh Creek in late summer and fall for eight brood years, and my inference of the asymptotic relation.

evidence of an asymptotic relation between redds and age-0 migrants, and that about 400 redds would come close to fully seeding the Marsh Creek drainage upstream from Capehorn Creek. If the foregoing is accepted, then we can relate redds in Marsh Creek to the estimated number of wild spawners passing Ice Harbor Dam (Fig. 6) to obtain an estimate of the escapement of wild spring chinook salmon needed at Ice Harbor Dam for nearly full seeding. If 400-500 redds provides nearly full seeding in Marsh Creek, and the other spring chinook stocks have a similar relation, then we could suggest from the relation in Figure 6 that we need about 20,000 wild spring chinook salmon spawners (not including losses) over Ice Harbor Dam for the remainder of the Snake River Basin.

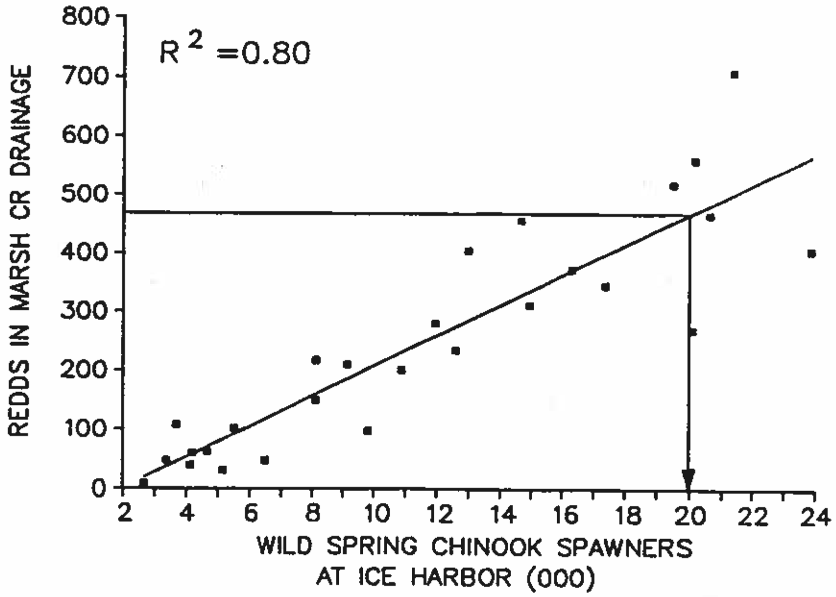

Figure 6.--Estimated number of wild spring chinook salmon passing Ice Harbor Dam that survived to spawn, and number of redds counted in the Marsh Creek drainage from 1962 to 1988. The arrow represents an estimate of escapement needed for nearly full seeding based on Figure 4.

QUESTIONS AND ANSWERS

Q: Have you taken into account the effects of ocean conditions?
A: I have assumed that ocean harvest is negligible.

Q: If ocean harvest rates decreased recently, would this give the results you show?
A: The early segments of the graph would show an increase, and they don't.

Q: In estimating numbers of wild spawners, was this based on observed redds in all basins, or expanded from a few observations?
A: The estimate is based on actual counts, but we did expand the number of spawners to assume that we saw only 90% of the redds.

Q: Do you think you might have underestimated the counts recently? Since you have observed the redds and the returns to hatcheries, it appears that there are a number of fish disappearing because of mortality, or you have not accounted for all of the redds.
A: I believe that our redd counts have been accurate. We included adult counts from Ice Harbor Dam.

Q: How much residual can be explained by saying that all fish are 4-year-olds and invoking the ocean environment?
A: We have looked at age structure by 5-year segments and 5-year averages, and this doesn't change the conclusions. We probably don't have age structure data for all tributaries. Using age structures may sharpen the conclusions, but not dramatically. Ocean conditions are just part of the variability. With flows, for example, not much of the variability was due to this at times. Maybe the same applies at times to ocean conditions.

Q: Did you account for removal of the Lewiston Dam and the addition of the Clearwater River as spawning area?
A: Yes, all of the redds are in this relationship--all of the Clearwater River drainage.

Q: In expanding Marsh Creek to Ice Harbor Dam, you assumed all above Ice Harbor Dam were equal to Marsh Creek--is that a supportable assumption?
A: This would vary from stream to stream. Other examples are not markedly different, 24 vs. 20 for some streams. The carrying capacity varies by stream.

Q: In estimating wild spawners at Ice Harbor Dam, did you look at rack returns and subtract the Ice Harbor Dam numbers and use this?
A: I did that for all hatchery fish I could account for.

Q: In hatcheries, some fish do not come back, i.e., they are strays. The early years show less "residual" (expected vs. actual) numbers when there were few hatcheries. How would this affect your conclusions?
A: We don't know the straying rate--it seems to be low, less than 5%. If it is higher, then it would show up as redds. The same would apply to hatchery fish put into streams to spawn.

Q: There have been millions of salmon coded-wire-tagged in Idaho hatcheries on the Salmon River--have you recovered any of these in the Middle Fork of the Salmon River?
A: No.

SESSION II

Stock Status and Carrying Capacity

Session Chair: D. W. Chapman,
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STATUS OF SNAKE RIVER IDAHO SPRING CHINOOK SALMON STOCKS

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The status of spring chinook salmon originating above Lower Granite Dam and those stocks of Idaho origin are examined. Abundance of adult salmon is compared to abundance just prior to and after the serious decline following completion of the mainstem Columbia and Snake River hydroelectric system in 1975 and to goals for run and stock restoration established in the aftermath.

Raymond (1979) documented the magnitude of the impact of the hydroelectric system on Snake River spring chinook and noted with optimism that steps taken in 1975 to alleviate some of the juvenile fish passage problems resulted in higher survival of smolts and subsequent higher return of adults. He further stated that with safe passage and guaranteed in-stream flows, upriver runs of salmon and steelhead to the Snake River could be restored to former levels. Prior to hydroelectric system impacts, Snake River spring chinook salmon contributed to commercial, sport, and tribal fisheries in the ocean, Columbia River, and Snake River main stem and tributaries. Bjornn (1960) estimated that 45% of the 443,000 spring and summer chinook entering the Columbia River on average each year from 1954 to 1959 originated in Idaho. Horner and Bjornn (1981) reported that, statewide, Idaho sport anglers harvested an average of 23,000 spring and summer chinook annually prior to 1961 and the Ice Harbor Dam construction. By 1965, the first statewide salmon fishing closure occurred due to limited escapement. Tribal fisheries declined to limited areas and numbers. The Pacific Salmon Treaty and Columbia River Management Plan limited ocean and river catches of Columbia and Snake River spring chinook to incidental harvest.

Snake River Spring Chinook Run

Chinook salmon counted annually at Ice Harbor and Lower Granite Dam before 11 June and 17 June, respectively, are considered spring chinook. Sizes of spring chinook adult runs increased during the 1985-88 period to near the sizes of 1964-78 annual runs. A major decline occurred in 1989.

The Snake River spring chinook run is comprised of various stocks. From the management perspective of the Idaho Department of Fish and Game (IDFG), the spring chinook run may be divided into three major stock groups--hatchery stocks, natural stocks spawning naturally but influenced by hatchery production, and wild stocks.

Hatchery Stocks

Hatchery stock abundance has increased with hatchery construction and increased smolt production. Annual variation has occurred in adult returns from smolt releases. Without exception, adult returns have not achieved the anticipated returns of mitigation planning. Returns have been an order of magnitude less than expected. In 4 of the 8 years since 1982, adult returns have been lower than the adult brood requirement for hatchery smolt production.

These deficiencies have had biological and socioeconomic implications. Implementation of the natural stock restoration program has been delayed by deficiency of brood fish. The high expectations of fishermen for hatchery-returning salmon have intensified conflicts between allocation and resource demands.

Natural Stocks

Natural stock abundance is indicated by long-term spawning redd counts in standard index areas of the Salmon River (White and Cochnauer 1989). Increases in redds from 1985 through 1987 were followed by decreases in 1988 and 1989. A rebuilding trend is not apparent.

The average redd count for the current 5-year period, 1984-88 (307 redds), was approximately 13% of the pre-1969 5-year averaged redd counts. The current average is approximately 18% of the averaged redd counts during the two 5-year periods from 1969 to 1978.

Wild Stocks

Wild spring chinook stock abundance is also monitored by a long-term Salmon River redd count index program. The Salmon River redd count bottomed out in 1980 at 38 redds and then began a gradual increase to 972 redds in 1988. Wild stocks declined in 1989 when less than 150 redds were counted (IDFG preliminary data).

The average annual redd count for the 1984 through 1988 period was 28% of those counted on average during 5-year periods from 1959 to 1968. Redds counted during the low escapements of 1979-1983 averaged 8%. The 1989 redd count approximates that average.

Discussion and Summary

Raymond (1979) expressed optimism for spring chinook salmon stocks, but the status of Idaho stocks has changed little. Juvenile passage and flow provisions have not allowed restoration of stocks to former levels. Hatchery stocks are more abundant, but they are not replacing their predecessors at anticipated levels. To reach those levels of returning adult abundance given the smolt-to-adult returns demonstrated since 1980, either 10 times the number of smolts will need to be grown or their survival rates must improve. It is doubtful whether a tenfold production increase is practical or realistic.

Natural stocks have not increased, but wild stocks have shown rebuilding. Dependency on the hatchery program for supplementation and interception of natural escapement to provide and supplement hatchery brood collection may be affecting natural stock status. The 1989 collapse of the Salmon River wild stock points out the tenuousness of its restoration.

Petrosky (IDFG unpubl. data 1989) estimated recruitment and percent smolt to adult returns (SAR) to two Idaho wild spring chinook tributaries for smolt migration years 1972-85. Recruitment of wild chinook ranged from 0.03 to 15.25 recruit redds per spawner redd. Recruitment was generally below replacement (1.0) when mean flow at Lower Granite Dam during smolt migration was less than 85,000 ft^3/s. He estimated further by simulation modeling that SAR for a brood/smolt migration year is correlated positively with mainstem flows during the smolt migration period ($p < 0.001$). At 85 kcfs minimum flow the predicted SAR was 0.36% compared to 1.28% at 115 kcfs. At 0.36%, SAR spawning escapements are predicted not to be met. At 1.28%, SAR spawning escapement would be met, and, in addition, a 50% terminal fishery harvest rate could occur. Coded-wire-tag returns from summer chinook hatchery stock at McCall Hatchery demonstrated SAR and flow relationship similar to the wild spring chinook analyses.

Provision of guaranteed and suitable flows during the juvenile migration period is the single most effective action capable of restoring hatchery, natural, and wild stocks of Idaho-origin spring chinook salmon to productive status. Improved survival would bring actual adult returns closer to anticipated returns. In turn, supplementation life stages would be available for natural stock development. Improved survival would minimize future supplementation needs as selfsustaining natural production occurred. Finally, wild stock rebuilding would occur and be secure when faced with periodic environmental stress. Given healthy status of each stock group, management needs for resource management and fishery allocation could be satisfied.

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QUESTIONS AND ANSWERS

Q: Regarding your observations on flow vs. percentage of adult return--are the wild smolts in the river from 15 April to 15 May during periods of Water Budget flows?

A: We do not know, but we are interested in PIT-tag studies to show exactly what stocks are in-river at what times, and what a water budget of 5 or 9 days, for example, would accomplish. We could see how water is used and try to provide minimum needed flows for 80% of the years, to keep the appropriate genetic integrity of stocks. Also keep in mind that when we report total redd counts of 134, for example, we often found only one or two redds in the transects--there is not much to work with.

Q: Dr. Bjornn did not show a good relationship of survival to flow. You emphasized flows as the major factor to improve the lot of wild fish during outmigration, while Dr. Bjornn suggested more transportation--how do you reconcile the differences?

A: I don't know if I can--one needs to compare the 15 April-15 May dates in the two sets of data and look at the flow vs. transport program. One saw 95% losses at the Lower Granite forebay in 1977 and 1987; they never arrived at the collector dam to benefit by transportation.

Q: What program does Idaho envision for irrigation and hydropower to deal with the needed flows?

A: We are trying to muster interest and hope that we are not forgotten out there. Idaho has a significant portion of the potential production area--5,000 miles of pristine environment. We just need to get back sufficient broodstocks. Fish have equal status with flood control and power--the general public has to be aware of the problems.

Q: NMFS's PIT-tagged wild fish outmigrated in late May--would you move the water budget to later, and also release hatchery fish later?

A: We want to accomplish this, and it is the direction we are going. There is a social element for the reasons. We cannot ignore the hatchery fish; however, if it came down to protecting the wild fish, we would do that. Our priority is first the resource, then the allocation.

STATUS OF CHINOOK SALMON STOCKS IN THE MID-COLUMBIA

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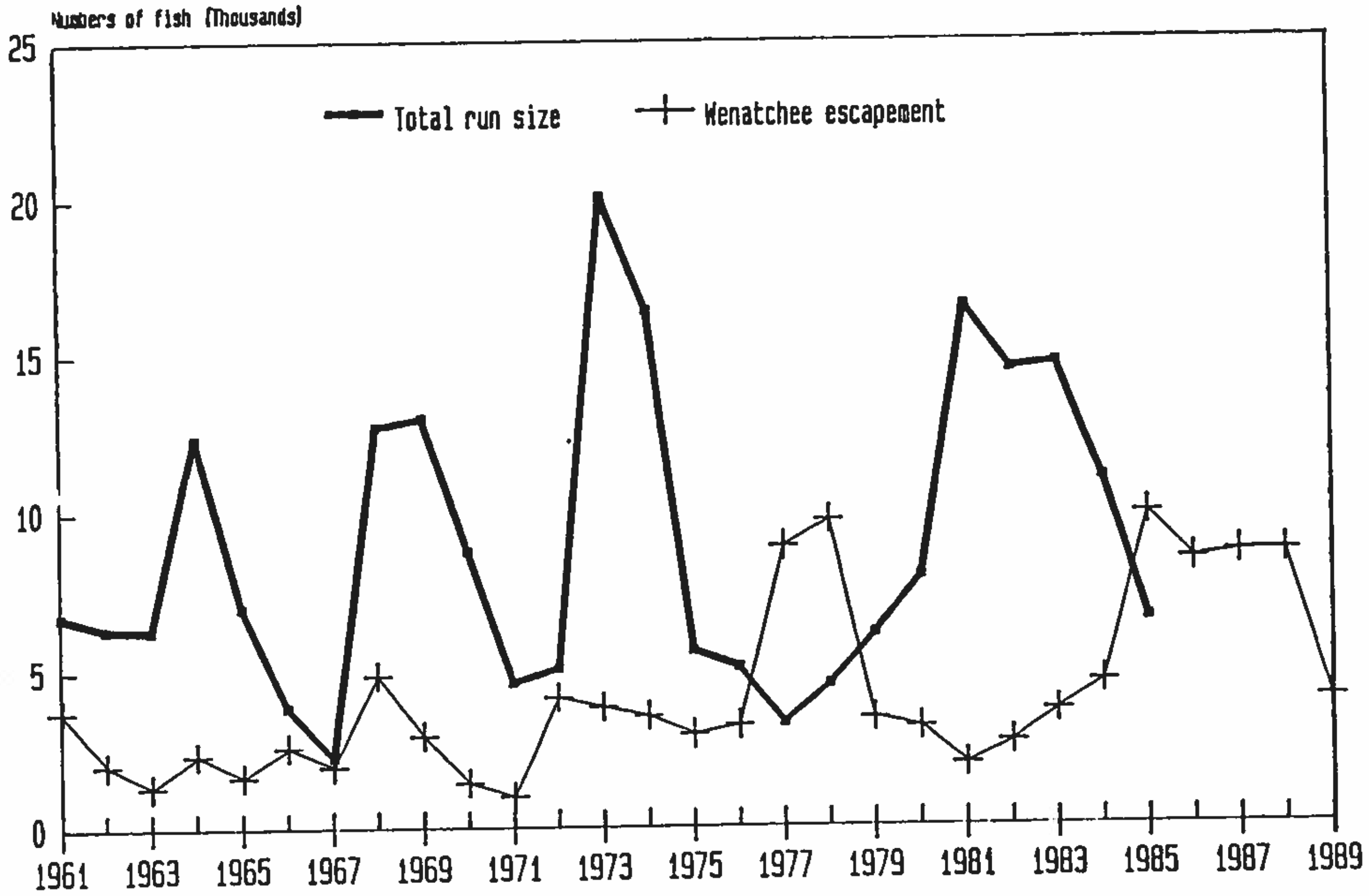
It is widely believed that chinook salmon stocks in the mid-Columbia River are severely depressed. Here I develop a paradigm that demonstrates that populations are stable and that the streams in this region now rear chinook salmon at carrying capacity.

The Wenatchee, Entiat, and Methow Rivers support wild spring chinook salmon. Leavenworth National Fish Hatchery (NFH) releases about 2.4 million spring chinook salmon yearlings annually to Icicle Creek, a tributary of the Wenatchee River. Entiat and Winthrop NFHs release about 1.0 million yearlings to the Entiat and Methow Rivers.

I assessed escapements to the Wenatchee, Entiat, and Methow Rivers as the differences between adult counts at appropriate dams. Wild adult escapement equaled interdam count less fish that returned to hatcheries or were harvested. I divided spawner/redd ratios of 2.4 (Kohn 1988 for the Methow River; Hollowed 1983 for the Yakima River) and 3.1 (Meekin 1967 for the Methow River) into interdam counts of wild spring and summer/fall chinook salmon, respectively, to account for prespawning mortality. I used an egg deposition of 4,600 per spring chinook salmon female (12-year average at Leavenworth NFH) and 5,240 per summer/fall female (Mathews and Meekin 1971). Annual losses of stream salmonids are universally high (Alexander 1979), and I assumed 50% overwinter mortality for age-0 chinook salmon.

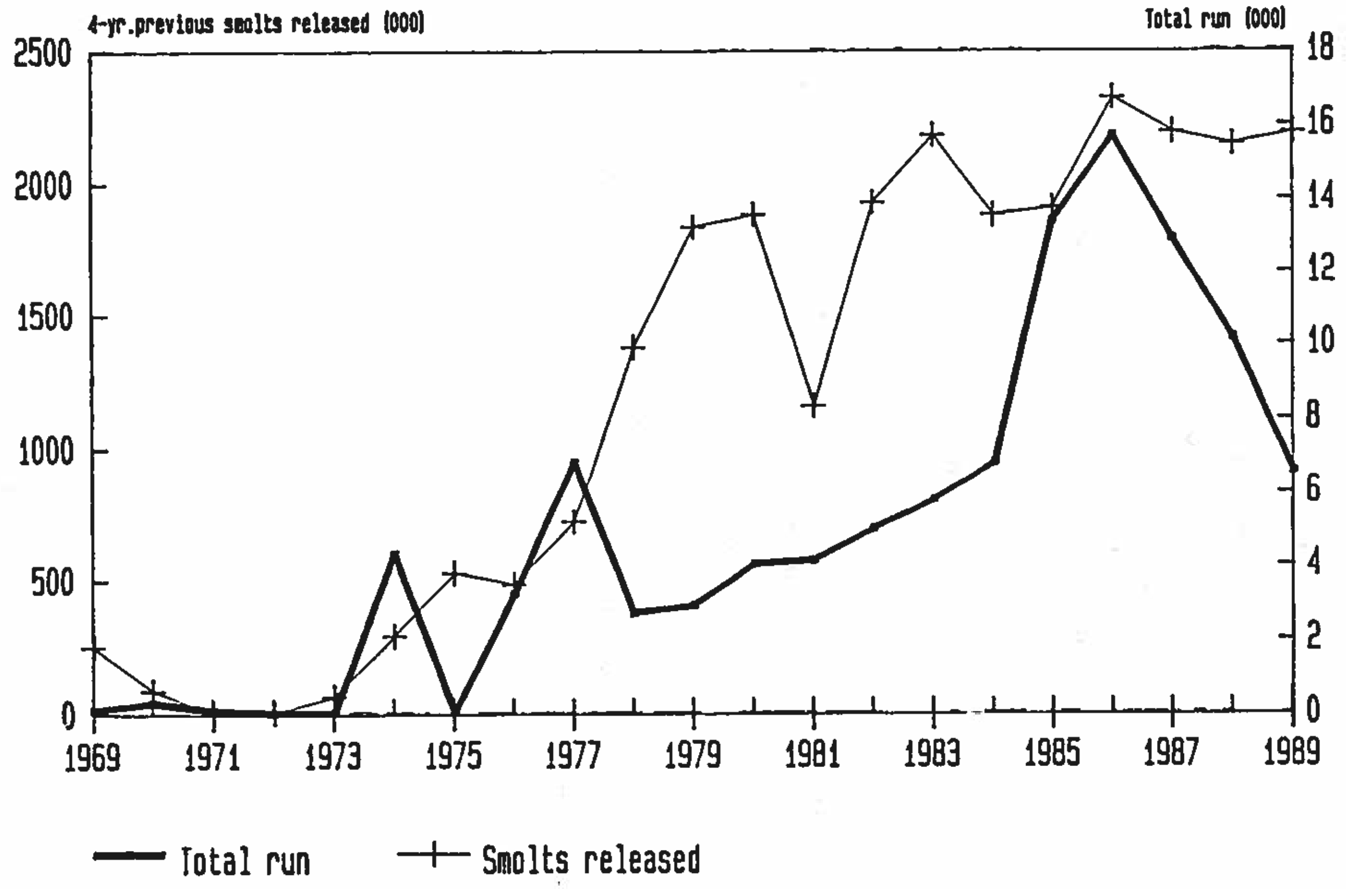
About half of the area used by anadromous fish in the three drainages has been physically measured. Samples were expanded to account for total wetted area (1,476 ha) at low flow in September. Fish densities were assessed by snorkelers (Schell and Griffith 1984), sodium cyanide census (Wiley 1984), or both, in 2.1% (31.3 ha) of the area, 1983-87. Snorkel counts of juveniles were calibrated against cyanide censuses (Hillman et al., in press). Sampled fish habitat was ranked with Binns' (1982) Habitat Quality Index (HQI), which rates late summer flow, annual flow variation, water temperature, food, cover, water velocity, nitrate nitrogen, and stream width with an index of nonsalmonids substituted for bank erosion.

A mean of 8,431 naturally-produced spring chinook salmon returned to the Wenatchee (4,465), Entiat (1,247), and Methow (2,719) Rivers 1967-87. I assumed mean per-project adult loss of 5% (Northwest Power Planning Council 1986), then calculated mean adult abundance at the Columbia River mouth as 12,600. In-river catch averaged 20% (3-39%, Oregon Department of Fish and Wildlife and Washington Department of Fisheries 1988), which should increase adults to 15,750. A 10% correction for ocean harvest (Northwest Power Planning Council 1986) yields a total run of 17,400. I found suggestions of an inverse relationship between spawning escapement and total run 4 years later (Fig. 1). Hatchery spring chinook salmon abundance fluctuated in much the same manner, which suggests the ubiquitous importance of ocean survival (Fig. 2).



Escapement to the Wen. R. (yr.N)
compared to total run size 4 yrs. later
(yr.N-4).

Figure 1.--Spawning escapement, natural spring chinook salmon to Wenatchee River.



Spring smolts (yr.N) compared to total run size 4 yrs. later. See text for information on estimating total run.

Figure 2.--Leavenworth hatchery releases of spring chinook salmon.

I extrapolated rearing densities for the total drainage rearing areas by HQI ranking, and produced a range in late-summer or early-fall population estimates (Table 1). For example, I multiplied a homogenous stream reach area, with HQI of 20, by the poor density value (2.5 age-0 chinook/100 m^2) and the fair value (3.8 age-0 chinook/100 m^2). Egg-to-fall fingerling survival of naturally produced spring chinook salmon thus ranged from 2.7 to 13.3%; and smolt-to-adult survival from 1.6 to 8.1%. Mean hatchery smolt-to-adult survival ranged from 0.16 to 0.55%, 1976-88. Naturally produced smolts were about 10-80 times as viable as hatchery smolts (Table 2).

Spring chinook salmon typically ascend to headwaters during high water in spring, and their offspring rear there for a year or more before smolting (this produces a stream-annulus on scales). Ocean-annulus chinook salmon usually return in summer and fall and spawn downstream from spring chinook salmon, and their offspring leave these milder climes at age 0. Stream fish are less common at sea and apparently distribute widely there. The more common ocean-annulus chinook salmon occur more frequently in coastal waters (Mullan 1987).

Mean escapement to the Wenatchee (12,012), Entiat (100), and Methow (3,385) Rivers for naturally-produced chinook salmon with ocean-type first annuli from 1967 to 1987 was 15,497. Corrected for 5% interdam loss, incidental in-river catches of 9%, and ocean harvest of 75% in 1967-84 (Northwest Power Planning Council 1986) and more recent harvests of about 40%, total run size was about 88,600 naturally-produced ocean-type chinook salmon (Wenatchee--68,600; Entiat--570; Methow--19,350). Although ocean harvest data are not specifically available for all years, it is apparent that the trend in escapements to the Wenatchee River in the past 27 years was relatively stable. This suggests that the habitat was fully seeded even at low escapements (Fig. 3).

I estimated juvenile migrants with three different statistics (Table 3). I adopted an estimated output of about 20 smolts per 100 m^2 because most summer/fall chinook habitat ranks poor to fair in summer but good to excellent in spring, when shoreline vegetation floods. Estimated egg-to-migrant survival for wild summer/fall chinook salmon ranged from 4.8 to 15.2%, excluding a 45% aberrant value for the Entiat River (Table 3). The Entiat River is at best marginally suitable for summer/fall chinook salmon (Mullan 1987). Most probable migrant-to-adult survival was 2.2 to 14.2% (Table 3).

Temporal variation in abundance causes problems in population estimates based on standing crop (Hall and Knight 1981). The range in age-0 chinook salmon densities (0.6-21.2/100 m^2) during September 1985-88 in an experimental section of Icicle Creek was 100% of mean abundance (10.5/100 m^2) (Mullan 1989, unpublished). Hillman and Chapman (1989) observed only a small difference between age-0 chinook salmon densities in the Wenatchee River in September 1986 (1.4/100 m^2) and 1987 (1.1/100 m^2). The mean density observed by snorkeling was higher in late August 1985 (2.4/100 m^2). This range in standing crop encompasses the variation (Table 1) used in estimating chinook salmon abundance.

Survival rates in Table 3 lie within bounds of those reported by others. Major and Mighell (1969) estimated that 5.4-16.4% of potential spring chinook egg deposition survived to smolt in the Yakima River. Fast et al. (1988) reported 4.2-6.5% egg-to-smolt survival in the Yakima system.

Runs of adult stream chinook salmon in the undammed Fraser River average only 19,000 to 31,500 (U.S.-Canada 1984), compared to 17,400 for the mid-Columbia. The

Table 1.--Average (weighted) densities (number of fish/100 m^2) of age 0 chinook salmon, agej 0 steelhead trout, steelhead trout, steelhead trout parr, and total salmonids (exclusive of mountain whitefish) according to habitat quality indexing (HQI) of poor, fair, average, good, and excellent for mid-Columbia River tributaries.

Habitat quality index rating		Number of stations	Area (m^2)	Densities (No. fish/100 m^2)			
				Age 0 chinook	Age 0 steelhead	Parr steelhead	Total* salmonids
11-20	poor	19	65,060	2.5	1.3	1.1	5.4
21-40	fair	53	160,897	3.8	2.3	1.3	9.7
41-60	average	26	30,239	9.8	8.7	3.6	23.5
61-80	good	28	43,908	11.6	8.7	6.2	29.5
81-100	excellent	14	12,779	19.9	30.1	9.8	71.4
	TOTAL	141	312,883				

* Includes rainbow/steelhead >200 mm, cutthroat trout, eastern brook trout, bull trout, and hatchery coho salmon.

Table 2.--Life table for spring chinook salmon in mid-Columbia River tributaries.

Item	Wenatchee River drainage	Entiat River drainage	Methow River drainage
Spawning area (ha)	244	102	397
Number redds/ha	7.7	5.2	2.9
Number eggs/ha	35,088	23,475	13,096
Rearing area (ha)	732	102	642
Number of fall fingerlings (000)	227.7-365.3	74.6-111.4	302.4-690.5
Egg-to-fall fingerling survival	2.7-4.3%	3.1-4.7%	5.8-13.3%
Fall fingerling-to-smolt survival	50%	50%	50%
Number of smolts (000)	113.8-182.7	37.3-55.7	151.2-345.3
Average run size (1967-87)	9,215	2,573	5,611
Smolt-to-adult survival	5.0-8.1%	4.6-6.9%	1.6-3.7%
Average hatchery smolt-to-adult survival 1976-08 (range)	Leavenworth 0.55% (0.21-0.70%)	Entiat 0.16% (0.07-0.27%)	Winthrop 0.20% (0.02-0.28%)
Viability of naturally produced smolts vs. hatchery smolts	12-24X	26-32X	10-80X

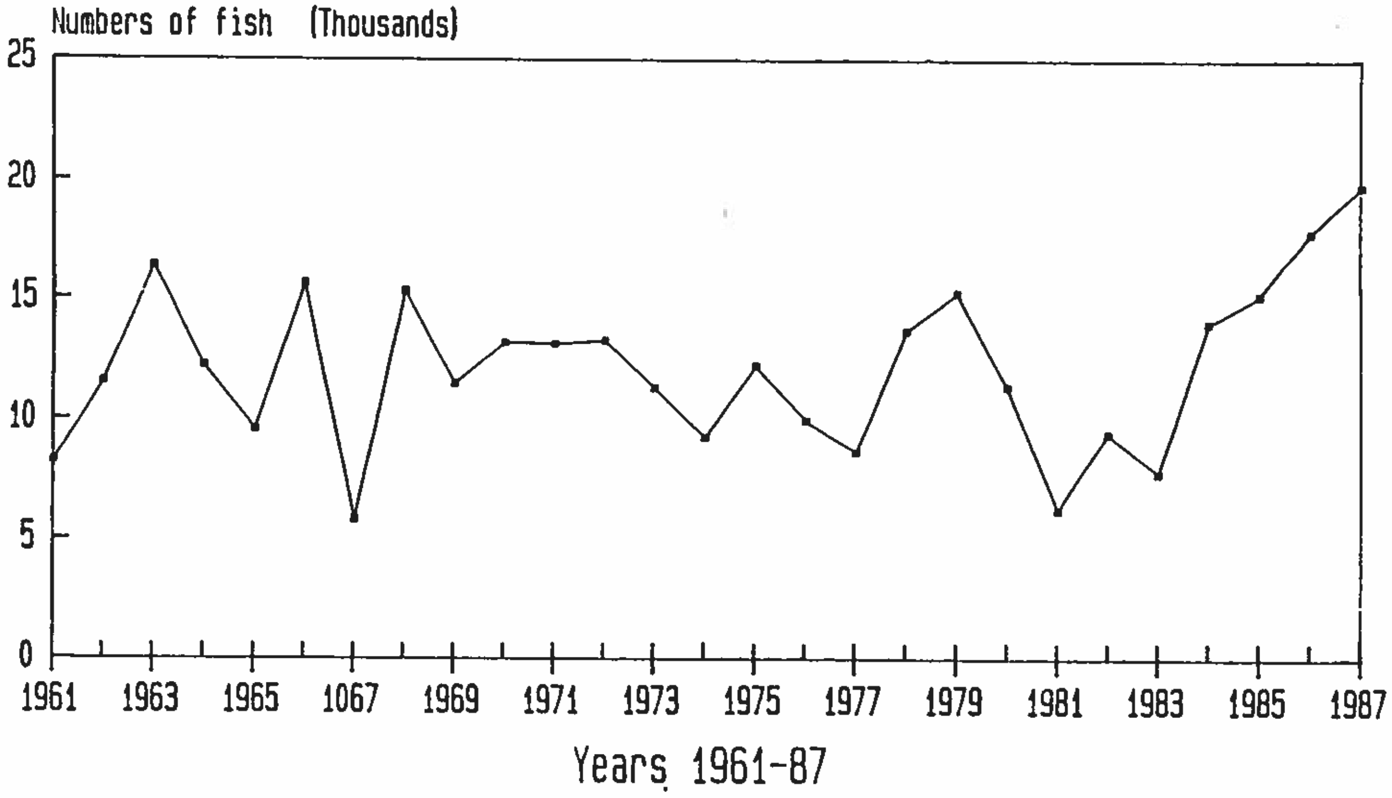


Figure 3.--Interdam escapements of summer/fall chinook salmon to Wenatchee River.

Table 3.--Life table for summer/fall chinook salmon in mid-Columbia River tributaries with migration estimates from three sources.

Item	Wenatchee River drainage	Entiat River drainage	Methow River drainage
Average run size (1967-87)	68,600	570	19,350
Spawning area (ha)	488	22	245
Rearing area (ha)	same	same	same
Number eggs deposited	20,300,000	169,000	5,700,000
Number migrants[a] (1 g yield/m^2; 5 g mean wt.)	976,500	43,700	490,700
Egg-to-migrant survival	4.8%	25.8%	8.5%
Migrant-to-adult survival	7.0%	1.3%	3.9%
Number migrants[b] (19.9 fish/100 m^2)	971,000	43,500	488,200
Egg-to-migrant survival	4.8%	25.9%	8.5%
Migrant-to-adult survival	7.1%	1.3%	3.9%
Number migrants[c] (35.2 fish/100 m^2)	1,718,563	76,951	863,556
Egg-to-migrant survival	8.5%	45.5%	15.2%
Migrant-to-adult survival	4.0%	0.7%	2.2%
	Summary of above		
Number migrants (000)	482.4-1,718.6	21.6-77.0	242.4-863.6
Egg-to-migrant survival	4.8-8.5%	25.9-45.5%	8.5- 15.2%
Migrant-to-adult survival	4.0-7.1%	0.7- 2.6%	2.2- 8.0%

[a] Observed from experimental section of Icicle Creek, 1986-89.
[b] Estimated from Table 1, density according to HQI rating of excellent.
[c] Wenatchee R. June densities minus July densities (Hillman and Chapman 1989).

Wenatchee, Entiat, and Methow Rivers contribute only 2% of the average flow of the mid-Columbia River, and there is no evidence that these streams ever produced more fish than they now do (Mullan 1987).

Low returns of hatchery chinook salmon (Mullan 1987) seem to lie outside the purview of fish health and genetics. This is not to say that diseases and genetics are unimportant, but I see hints that the behavior of chinook salmon in hatcheries is conditioned--like that of Pavlov's famous dogs--differently from that of wild fish. For example, large age-0 and yearling spring chinook salmon released to Icicle Creek do not orient to cover, remain at the water surface, and drift downstream in the channel regardless of season. They have no apparent social structure and frenzy when hit by light at night (Hillman and Mullan 1989). Recently-hatched fry released to Icicle Creek, by contrast, quickly remove themselves from strong currents and mimic the behavior of naturally-produced chinook as described by Hillman et al. (1989a, b). Exceptions to low hatchery returns almost invariably involve chinook salmon least exposed to hatchery life (Heard 1987).

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QUESTIONS AND ANSWERS

Q: Did you allow for 20% of broodstock trapped at Priest Rapids?
A: Yes, but I was not talking about either Okanogan or Rocky Reach Dam.

Q: Are you suggesting that we increase hatchery outplants?
A: No; we can spend the next 30 years on IHN virus or genetics and it wouldn't change a thing. The problem is in chinook salmon behavior. Wild fish and hatchery fish behave very differently. Hatchery fish cannot be raised to act like wild fish. In the Great Lakes there is a 17% return, which is now equal to the historical capacity, and therefore the system is full.

Q: Is no one going to challenge that?

Q: Are the summer and fall chinook salmon using the Wenatchee system to the historical extent?
A: These runs were wiped out at the time Grand Coulee Dam was built. In the 1930s, Washington Department of Fisheries maintained that there had never been a run of summer chinook in the Wenatchee River. They wanted the Bureau of Reclamation to provide water at Dryden Dam, and said that the Grand Coulee project had introduced exotic races. The Bureau of Reclamation went through all the records at the time, and that is what was used. There is not much historical evidence.

Summer chinook salmon are confined to the Wenatchee River, and in some years there are 2,000 redds in 50 miles of stream; the capacity is at maximum right now. Rocky Reach was severely depleted to about 2,000 fish by overfishing. I cannot find records of more than the present numbers of fish, although I may have missed something.

Q: Then what is the baseline to compare with your present numbers?
A: If one considers like habitat, these streams are doing as well as any.

Q: How did you arrive at your figure of 50% for fingerling-to-smolt survival?
A: This was based on the world literature.

Q: There are indications that some streams in Idaho are not at full capacity, so why do you believe that these three upper Columbia streams are at full capacity?
A: This is for spring chinook salmon, where smolts are at capacity, not adults produced. This is not the case for coho salmon, which I have not mentioned--coho salmon were important in the Methow River, but they are now extinct there.

Q: What about the fact of dams now, and the related survival problems--wouldn't we see more fish without these problems?
A: Yes, we would; no one would deny that they don't kill fish. There is, however, as much production of smolts as before. Therefore, there is also no room for outplanting.

ESTIMATING SPRING CHINOOK PARR AND SMOLT ABUNDANCE IN WILD AND NATURAL PRODUCTION AREAS

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The Idaho Department of Fish and Game (IDFG) began in 1984 to monitor the abundance of chinook salmon and steelhead trout (Oncorhynchus mykiss) juveniles in the Salmon, Clearwater, and upper Snake River subbasins. Status and trends of wild and natural anadromous fish populations in Idaho were monitored through three programs.

The first, a parr density and physical habitat monitoring program, was established in 1984 to determine benefits of Bonneville Power Administration (BPA) habitat improvement projects implemented in Idaho as off-site mitigation for downstream hydropower development on the Snake and Columbia Rivers under the Northwest Power Planning Act. A parallel IDFG-funded monitoring program was established in 1985 to index parr densities in the remainder of the wild and natural production areas not sampled by the BPA project. Together, these two programs form a data base that includes a total of 236 monitoring sections sampled annually. The third program, begun in 1986, is a BPA-funded research study to define the numerical relationships between spawning escapement and numbers of parr and smolts produced for two natural production areas, the upper Salmon River and Crooked River.

Juvenile chinook salmon monitoring in Idaho provided data with several levels of resolution and applications. Parr densities were compared among years, populations, drainages, habitat conditions, redd densities, and with carrying capacity ratings developed for subbasin planning by the Northwest Power Planning Council (NWPPC). Total parr abundance (standing stock) estimates and redd counts were used to estimate egg-to-parr survival in different streams and habitats. Where hatchery chinook salmon fry were stocked into vacant habitat above BPA barrier removal projects, total abundance and fry-to-parr survival were estimated.

The upper Salmon River and Crooked River research studies monitored adult escapements past weirs, estimated escapements by redd counts, and estimated total parr abundance and smolt production (yield). Smolt production was estimated from migrant trapping at weirs, and the tagging and recovery of PIT tags (passive integrated transponder; Prentice et al. 1986). Recapture and interrogation of PIT-tagged juveniles at the weirs and at Snake and Columbia River dams provided data on migration characteristics and parr-to-smolt survival.

Parr density estimates were obtained in most streams by visual counts made by snorkeling in established sections during the summer low flow period (July-August). We compared estimates obtained by visual counts and electrofishing removal in 1986 in five stream sections of different size and conductivity. Predepletion estimates were obtained by snorkeling 1 day before electrofishing. On day 2, we block-netted section boundaries and removed fish in three passes (Seber 1982). We then snorkeled a second time before releasing catches and removing block nets. Consistent with Hankin and Reeves (1988) findings for coho salmon (O. kisutch), visual estimates of chinook salmon abundance were similar to electrofishing estimates in four of five tests. Contrary to

Hankin and Reeves, who consider electrofishing more accurate, the fifth electrofishing estimate accounted for only 18% of the total number of parr that were estimated visually before and immediately after depletion. The bias was due to inefficient electrofishing in low conductivity water (40 µmho/cm).

Monitoring of chinook salmon parr density during 1984-88 documented the depressed status of wild and natural populations of spring and summer chinook salmon in Idaho (Petrosky and Holubetz 1989). Densities were highly variable and reflected habitat conditions and escapements. Highest densities occurred in low gradient C-channels (Rosgen 1985) of both wild and supplemented streams. Mean densities of wild chinook salmon in the Middle Fork Salmon River increased during 1984-88, and reflected the general rebuilding trend for the period. On the other hand, parr densities in some streams remained at extremely low levels. We have not documented presence of spring chinook salmon parr in Snake River tributaries of Hell's Canyon since monitoring began in 1985.

Chinook salmon parr density correlated (r = 0.75) with redd density the previous year in Salmon River streams. Redd densities in the wild and natural index areas were low, ranging from 0 to 8.9 redds/ha. By contrast, the 1960s mean for the Marsh Creek drainage (Middle Fork Salmon River tributary) was 18.7 redds/ha.

We inferred chinook salmon carrying capacity from annual monitoring, the literature, fry outplants specifically designed to test carrying capacity in different habitats, and NWPPC subbasin planning estimates. Fry outplants in 1987 fully seeded stream reaches in undisturbed habitat in portions of the upper Lochsa River drainage. C-channels supported a density of chinook salmon parr (108/100m^2) that averaged 60% higher than in B-channels (67/100 m^2). Sekulich (1980) estimated a similar potential parr density for low gradient streams in the Idaho batholith (120/100 m^2). We calibrated the NWPPC smolt capacity ratings to IDFG estimates of chinook salmon parr carrying capacity. The calibrated habitat capacity ratings in terms of parr were excellent = 108/100 m^2; good = 77/100 m^2; fair = 44/100 m^2; and poor = 12/100 m^2.

We estimated seeding level as the observed density divided by the carrying capacity estimate. Overall, the mean 1984-88 seeding levels (unweighted mean, all monitoring sections and years) for wild spring, natural spring, wild summer, and natural summer chinook salmon were 11.5, 17.4, 11.4, and 19.0% of estimated carrying capacity, respectively (R. J. Scully, IDFG, unpubl. data). Estimated mean seeding levels in C-channels (21.0%), which included the major spawning areas, exceeded those in B-channels (5.5%) nearly fourfold.

Total parr abundance estimates and redd counts in upper Salmon River and middle fork of Salmon River streams were used as the basis to estimate and compare egg-to-parr survival rates in streams with different sediment levels and riparian degradation. The Shoshone-Bannock Tribes (Richards and Cernera 1987) provided data for Bear Valley and Herd Creeks for this analysis. Egg-to-parr survival estimates ranged from 1.2% in Bear Valley Creek, a highly sedimented stream, to 29% in two cleaner streams. Percent survival correlated strongly (r = -0.97) with percent surface sand.

We estimated total parr abundance in the vicinity of outplant sites where chinook salmon fry were introduced into vacant habitat using systematic stratified sampling. Fry-to-parr survival rates averaged 20% (range, 11-30%). Based on 75% green egg-to-fry survival in hatcheries, estimated egg-to-parr survival for outplanted fry was 15% (range, 8-22%), similar to estimates for natural spawning.

PIT tagging and outmigration monitoring of spring chinook salmon began in the upper Salmon River in 1987 (Kiefer and Apperson 1989). Total parr abundance was estimated in July-August using stratified sampling. Parr were PIT tagged in August with assistance from National Marine Fisheries Service (NMFS) personnel. Field observations, live-box tests and studies by NMFS indicate that mortality due to the tagging operation is low. A scoop trap was installed at the Sawtooth Hatchery weir to estimate total outmigration and to tag and recapture migrants. Peak outmigration occurred in September-October and March-April (R. B. Kiefer, IDFG, unpubl. data). An estimated 73% of the summer parr population migrated past the weir, most during the fall (67%). Parr-to-smolt survival for fish that overwintered in the study area was conservatively estimated as 26%. PIT-tag recaptures will be analyzed to determine parr-to-smolt survival for fall migrants and for the total summer parr population. During the poor migration flow years of 1988-89, approximately 2-4% of the PIT-tagged parr were detected as smolts at Lower Granite Dam. An irrigation diversion that dewatered the upper river until mid-September reduced the survival of fall migrants.

PIT tagging and outmigration monitoring of Crooked River spring chinook salmon began in 1988 using similar methods as in the upper Salmon River. An estimated 47% of the summer parr migrated past the Crooked River weir, predominately during the spring. Estimated parr-to-smolt survival of juvenile chinook salmon that overwintered in Crooked River was 31%. Less than 2% of the PIT-tagged parr from Crooked River were detected at Lower Granite Dam in spring 1989.

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QUESTIONS AND ANSWERS

Q: What is your feeling about the low estimated parr-to-smolt survival based on the NMFS's PIT-tag data?
A: I am surprised at the apparent low survival to Lower Granite Dam.

Q: Could this be attributed to the tagging process?
A: We saw about 30% overwintering survival, which was lower than we expected. Maybe it is worse in the winter than we expected. We need to look at this more carefully; the PIT tag can give us data on groups leaving vs. groups staying, but it is too soon to tell much about this.
Comment: (by E. Prentice) There have been extensive tests to evaluate the PIT tag. The apparent low survival is probably not a result of the tagging. We tag 1.3 g and larger fish and find 98-99% survival. We did note, though, that Lower Granite Dam was inadvertently in the bypass mode early in the season, and therefore a lot of fish were bypassed and not interrogated.

Q: Did you have PIT-tag data from Little Goose Dam to compare with data from the other detector sites?
A: Yes; Little Goose Dam was 30% and McNary Dam was 10% of the Lower Granite Dam values.

Q: You said you were surprised at the overwintering survival--what did you expect?
A: I thought it would not be very different from the steelhead survival, based on size, especially the 1- to 2-year-old fish. This has been about 60% overwintering survival from August smolts. But there are key missing pieces, and the PIT tag may provide that information.

Q: In estimates of smolt carrying capacity, it appears that for some streams (e.g., Bear Valley Creek) you indicate only fair to good production, but they continue as viable producing/spawning areas--might the fish be overwintering somewhere else?
A: In Bear Valley Creek, there are indications of a lot of early outmigration after emergence. The egg-to-parr survival is very different from that in cleaner streams, and therefore some must leave. We do not find them in the summer.

Q: If there is outplanting at a given point, one sees poor outmigration of juveniles. I note great ranges (2.5 to 15%) for egg-to-smolt survival in good habitat--is that the correct range?
A: Yes.

Q: The subbasin plans are using higher survivals than that--do you agree?
A: If you approach the carrying capacity, the literature suggests that this declines to about 6%. In the subbasin plans, the egg-to-smolt survival is indicated as 20-25%.

Q: What if you separate overwintering survival from the egg-to-smolt survival?
A: That would compare favorably with a 20% egg-to-smolt survival at low density.

Q: How would this differ from the estimates from the Yakima River?
A: The Yakima River gets 4% egg-to-smolt survival, based on 50% mortality from the headwaters to Prosser.
Comment: In the John Day system, where there is apparent low abundance, one sees 4-10% egg-to-smolt survival.

EFFECTS OF HATCHERY BROODSTOCK WEIRS ON NATURAL PRODUCTION

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Sufficient direct information does not exist to definitively show that hatchery broodstock weirs placed on spring chinook salmon streams deleteriously affect natural production. However, inferences based upon limited knowledge suggest that weirs will, at a minimum, decrease natural production through both direct and indirect means. In addition, although effects may occur separately, the process for decrease in stock viability most likely occurs through some collective interaction. Long-term operation of weirs also jeopardizes the survival of wild fish above the weir. Finally, massive releases of hatchery fish may also jeopardize overall spring chinook salmon survivals.

The greatest direct effect of hatchery weirs occurs initially when 100% of the adults removed for hatchery production depletes natural production on a one-to-one basis. Subsequently, with continual removal of fish at the weir for hatchery egg take, unless only hatchery-produced fish are removed, a decrease in natural production will also occur. But since most hatchery fish are unmarked, origins of adult returns are generally unknown, and thus the proportion of hatchery to wild removed or released above a weir is also unknown. Although a small decrease in natural production might seem reasonable if expectations are high for hatchery success, subtle unrecognizable effects from this strategy are potentially insidious and, via a number of pathways, may lead toward further large decreases in natural production and, potentially, overall production as well. These effects fall into two broad categories: 1) consequences of decreased natural population size, and 2) consequences as a result of hatchery practices.

Potential Consequences of Decreased Natural Population Size

Spring chinook salmon from the Snake River Basin already have low genetic diversity compared with other Columbia River salmon stocks (Winans 1989). Additional removal of wild fish from headwater river stretches with low populations may eventually reduce the size of the effective breeding population above a weir to a point where further decreased genetic diversity would limit the long-term viability of that segment of the natural population (see abstract by Waples in Session I). Another possible effect from decreases in the number of spawners may occur if the nutrient load to the upper reaches of streams decreases (Cederholm et al. 1989). It certainly decreases nutrients for predators in the ecosystem, and it may also affect aquatic invertebrate fauna. Since nearly all aquatic invertebrates have some relation to trout and salmon and most are eaten to some extent by fishes (Shapovalov and Taft 1954), changes in nutrient loads, although potentially only subtle, may affect the quality or condition of fry and parr during their freshwater rearing and thus their potential long-term survival.

In addition to removal of wild spawners at weirs, two additional deleterious effects could occur as a result of hatchery fish releases above the weir. First, hatchery fish may not migrate far enough upstream of the weir to take advantage of available spawning habitat. Over time with continual removal of wild fish and replacement by hatchery fish, all spawning activity except in the near vicinity of the weir could cease. This would lead to underutilization of previously productive habitat, possibly replaced by less successful production from less favorable habitat.

Secondly, transmission of hatchery diseases to wild fish could occur. For example, in 1988 the incidence of bacterial kidney disease (BKD) infection in spring chinook salmon adults at Sawtooth Hatchery was 95% (Pascho and Elliot 1989). Some of these fish had much higher BKD infection levels than others. If hatchery-origin adults released above the weir have high BKD levels, they may spawn with wild fish, pass on the high BKD levels, and thus potentially lower offspring fitness levels.

Outside of problems related to which adults are taken at weirs, another major problem area relates to the increased number of smolts produced as a result of hatchery practices. Between 1964 and 1968, when four dams existed on the lower Snake and Columbia Rivers, 1.3-2.0 million Snake River wild spring chinook salmon smolts produced 50,000-80,000 adult fish (Raymond 1988). Snake River hatcheries now produce upward of 10 million spring chinook salmon smolts. If historical population sizes were related to the carrying capacity of the freshwater environment, then the massive increase in migrating smolts, which feed during the river migration, will, at best, tax the river's carrying capacity, but more likely create severe food competition between smolts, decreasing their overall chance of survival. Other problems also occur with increasing fish density. Shapovalov and Taft (1954) found that as the density of salmonid smolts increased, their survival decreased. They speculated this resulted from an increased susceptibility to predation with increased fish concentrations. Murphy and Shapovalov (1951) and Fagan and Smoker (1989) additionally argued that density-dependent factors operate on stocks during early ocean entry. Fagan and Smoker proposed further that large hatchery releases cause fluctuations in stocks they seek to enhance. They extended the modelling results of Schaffer et al. (1986) and suggested that large-scale, high-production hatcheries can expect many years in which returns are virtually nil.

Whatever the mechanism, past experiences with hatcheries and weirs indicate that wild stock survivals and overall production are lowered with increased hatchery production. Chinook salmon production was low from Oregon coastal streams between 1930 and 1960 when many chinook hatcheries were in production. Because of lack of hatchery success and low production, hatcheries switched to coho salmon. Since the early 1960s, wild stocks of chinook salmon from Oregon coastal streams have rebounded and overall chinook salmon production has increased (Jay Nicholas, pers. commun.)[1].

Finally, speculations regarding problems of removals at weirs for hatchery production from unknown adult stock origins presume that hatchery fish contribute significantly to returning fish populations. If wild fish dominate the returns, however, then maintenance of hatchery production would be at the expense of the wild stock it was designed to supplement, and at times when conditions are favorable for wild stocks to potentially increase, recovery of the stocks in hatchery-influenced areas might not occur. Based upon Idaho Fish and Game index redd counts (White and Cochnauer 1989), it appears this scenario possibly exists. Between 1959 and 1963, the average number of spring chinook salmon redds on what are now classified as wild and natural

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[1] Jay Nicholas, research biologist, Oregon Department of Fish and Wildlife, Corvallis, OR 97333. Pers. commun., September 1989.

streams was 1,656, and on what are now classified as hatchery-influenced streams was 2,494. Between 1979 and 1983, the average number of redds in both classification areas dropped substantially to 134 and 360, respectively. However, during the recent rebound in spring chinook salmon returns between 1984 and 1988, the average number of redds in the wild/natural areas increased by 350% to 463, which was 27% of historical levels; whereas the estimated average number of redds in hatchery-influenced areas decreased further to 341, which was only 14% of historic levels. Greater increases in redd counts should have occurred in hatchery-influenced areas if hatcheries were truly supplementing wild stocks.

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QUESTIONS AND ANSWERS

Q: You say that we shouldn't place weirs to collect wild fish--what options are there to obtain hatchery broodstock?
A: You should determine if you really need these fish for hatchery production.

Q: Many wild stocks cannot meet demands for harvest rates (both commercial and sport)--what then might the options be?
A: It is possible to release 10 million fish and the returns may be low; to add more to it may cause it to get even worse. If you need hatchery fish at one hatchery, get them from another hatchery.

Q: We have used nonendemic stocks and it hasn't worked. Therefore, we have gone to endemic stocks, but do you imply that this may be a dead end?
A: Yes; you can see this in Waples's data for certain groups. You can move hatchery fish to a nearby hatchery.

Q: Is there really 5% survival of Cowlitz stock at Ringold?
Comment: It is 2.5-3%, which is very good.
Comment: Cowlitz stock are not upriver spring chinook salmon. You don't see this in upriver stocks. One needs to select hatchery sites very carefully. The Rapid River site has produced substantial numbers of returns over the years, in a terminal non-endemic production area. This is an ideal hatchery strategy, and has worked out well.

Q: In 1968, the Cowlitz wild spring chinook were introduced to the basin, and there was a 5% return--the returns for the Cowlitz River were probably not much higher, based on counts at Mayfield Dam. Why were there such dramatic differences in Idaho?
A: I have no idea. The Sawtooth Hatchery may be unique in its low returns. In the case of spring chinook salmon, with the long outmigration, perhaps as distance increases there is a greater probability of problems. When you look at the 5 billion chum salmon released by the Japanese and the 4 billion chum salmon released by the Soviets, you don't see this. The Cowlitz stock may do well, and some others do well, too. But some need to go a long way, and this may lower the chances of all fish traveling along with them.

Q: The carrying capacity of other areas (e.g., mid-Columbia) may provide ideas for outplanting densities, so that they may not be exceeded. Should we not stop this altogether, just stay within limits?
A: Yes, one should go slowly. In the Middle Fork, there were 1,600 redds, then one saw 400 redds. Therefore, that should have a greater potential. But as we supplement more and more, we have to consider the whole system when there is a long migration time. It is an ecological problem that needs to be dealt with. Barging fish to the estuary within 24 hours may help. One should use caution and not consider adding great numbers over what there is now.
Comment: Scales from Sawtooth Hatchery and McCall Hatchery fish were looked at and apparently there was a difference between the scales of hatchery and wild fish. These scales have been sent to the Oregon Department of Fish and Wildlife (ODF&W) for further analysis. It looks as if more than 80% of the fish were hatchery returns to the Sawtooth weir.
A: I hope so.

Comment: It is believed that much of the difference can be explained by the higher mortality in CWT/freeze-branded fish than in CWT fish alone, both of which show higher mortality than unmarked fish.
A: Perhaps it would be better not to mark fish.
Comment: It is the high incidence of BKD in hatchery fish that is the problem here, since the handling and tagging triggers the vastly higher mortality. The tag may be a trigger, but the problem is BKD. Maybe a lower rearing density should be used.

Q: Whether the fish are tagged or not (and about one-third are tagged), only 20-80% arrive at the first downstream dam--why?
A: That has to be a rhetorical question. Fewer releases may lead to better quality fish. High numbers of releases seem to have suppressed both hatchery and wild fish.

Q: What is the release strategy at Sawtooth Hatchery? Is it a true supplementation (if so, it is different from past practices) or a conventional culture/release? In the conventional mode I would expect survival to be poor.
A: The system is already overburdened, so the results would be the same in either case.

Q: It has been said that there is not full seeding, so why wouldn't there be room for supplementation?
A: I would say proceed very cautiously with very low numbers. Take into account the status and capacity of individual systems, but go slow.
Comment: One alternative would be to reduce our expectations!

CONVERSION OF WEIGHTED USABLE AREA TO POTENTIAL FISH PRODUCTION IN THE YAKIMA RIVER BASIN

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This paper describes a model developed to estimate potential fish production in the Yakima River Basin. During the past 30 years, planners have addressed the costs and benefits of enhancing fish habitat in the Yakima River Basin. Recently, the Fish and Wildlife Service conducted a flow study on the river system using the Instream Flow Incremental Methodology (IFIM). Concurrently, the Bureau of Reclamation developed a computer program that simulates flow in each of 31 river reaches for a 52-year period (assuming a repeat of historical flows) for the Yakima Irrigation Project. The challenge facing project planners was to combine the IFIM output (Weighted Usable Area (WUA) vs. flow) with the operations program to estimate potential fish production for various operational scenarios.

Many investigators have reported fish densities in various macrohabitat types such as pools or riffles, although few have assessed fish densities at the microhabitat level. Everest and Chapman (1972) evaluated chinook salmon densities in various microhabitats. They reported fish density in preferred habitat and the mean density in utilized habitat as 6.5 age-0 chinook/m^2 (0.6/ft^2) and 1.8 age-0 chinook/m^2 (0.17/ft^2), respectively. In IFIM terminology, these data suggest that in preferred habitat where the Joint Preference Factor (JPF) is 1.0 (i.e., ideal depth, velocity, cover, etc.) a square foot of habitat supports an average of 0.6 fish. I assumed a linear relation between JPF and fish density, and concluded that the mean JPF for utilized habitat was 1.8/6.5 = 0.28. A more descriptive way of defining WUA is that a unit of WUA is a unit of optimum equivalent habitat or, in the above case, the area required to support 0.6 fish. It takes 1 square foot of preferred habitat to support 0.6 fish and 3.5 square feet (i.e., 6.5/1.8) of marginal habitat with a JPF of 0.28 to support 0.6 fish. However, in each case a single unit of WUA is being described. Thus, for the calculations made in establishing parameter values for our computer model, we used 0.6 fish per unit of WUA as the conversion factor.

The above-derived ratio of fish per unit of WUA is for age-0 juveniles during July and August. Approximately 30% of these August age-0 juveniles survive to the smolt stage (McIntyre 1983, Lindsay et al. 1986). Fast et al. (1985) estimated the egg-to-migrant survival for this species in the Yakima River as 5.6%, and Lindsay et al. (1986) reported survival for the same period as 6.3%. Information verified through spawning surveys in the Yakima Basin indicates that 2.9 spring chinook salmon escape into the upper watershed for every redd constructed. However, with the ongoing improvements to fish passage facilities it is expected that the spawners per redd ratio will likely decrease to 2.5. The fecundities of the Naches stock and the upper Yakima stock were evaluated by Major and Mighell (1969) and reevaluated by Wasserman[1], who reported that the weighted mean fecundity for spring chinook in the Yakima Basin is 4,870 eggs per female.

We then developed habitat ratios (Bovee 1982) to determine if rearing or spawning habitat limited production. Using the above information, the rearing WUA for spring chinook was converted to spawner equivalents as follows:

$$1 \text{ Unit WUA}_{\text{rear}} = 0.6 \text{ fry} \times \frac{0.30 \text{ smolts}}{\text{fry}} \times \frac{100 \text{ eggs}}{5.6 \text{ smolts}} \times \frac{1 \text{ redd}}{4{,}870 \text{ eggs}}$$

$$1 \text{ Unit WUA}_{\text{rear}} = 0.00066 \text{ equivalent redds} \quad \underline{\text{or}}$$

$$1 \text{ Unit WUA}_{\text{rear}} = 0.00066 \text{ redds} \times \frac{2.5 \text{ spawners}}{\text{redd}}$$

$$= 0.00165 \text{ equivalent spawners} \qquad (1)$$

We also calculated potential production from the $\text{WUA}_{\text{spawn}}$ by considering that the average size of a spring chinook redd, including disturbed area and protected territory is 176 square feet (Burner 1951). Thus:

$$176 \text{ Units WUA}_{\text{spawn}} = 1 \text{ redd}$$

$$1 \text{ Unit WUA}_{\text{spawn}} = \underline{0.00568 \text{ equivalent redds}} \quad \underline{\text{or}}$$

$$1 \text{ Unit WUA}_{\text{spawn}} = 0.00568 \text{ redds} \times \frac{2.5 \text{ spawners}}{\text{redd}}$$

$$= 0.0142 \text{ equivalent spawners} \qquad (2)$$

A fully seeded unit of $\text{WUA}_{\text{spawn}}$ would produce enough fry to fully seed nine units of WUA_{rear} (i.e., 0.0142/0.00165). This is the "Habitat Ratio" of Bovee (1982).

The Bureau of Reclamation operations model yielded mean monthly flow in cubic feet per second. The first step in converting mean monthly flow to potential fish production was to create a subroutine containing the WUA vs. flow (Q) functions for the various reaches and then to allow the model to convert the monthly flows to WUA for spawning and for rearing. The model, with a 52-year period of analysis, permitted us to analyze time-series to track limiting life stages for each water year and year class.

We estimated fish production based on rearing for any given reach by averaging the WUA available during July, August, and September. Production in the Yakima Basin can be limited by severely low flows <u>or</u> by severely high irrigation flows during

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[1] L. Wasserman, biologist, Yakima Indian Nation, Toppenish, WA 98948. Pers. commun., 1983.

this period. In most instances, the simulation suggests that production (based on rearing) in the Yakima Basin is limited by high flows during the irrigation season. Fish production based on spawning was calculated as the average of the WUA available during the appropriate spawning months.

We then calculated 1) summed WUA for rearing for a given species for the entire basin; 2) summed WUA for spawning the previous fall for the entire basin; 3) WUA totals converted to common units; and 4) production for a given water year, based on the life stage having the lowest equivalent value. The common unit used in the model was "equivalent redds." In the computer simulations, simulated production was primarily governed by rearing habitat availability.

For the WUA$_{spawn}$, we applied the conversion factor (from Equation (2)) to calculate equivalent redds; then we considered incubation flows to get net equivalent redds, and then we made the comparison with rearing equivalent redds. The shape of the incubation conversion curve was determined by comparing stage-discharge relationships from IFIM data with the spawning depth preference curves developed for spring chinook in the Yakima Basin. We calculated a ratio of minimum incubation Q to maximum spawning Q, converted that to "% redds viable" using the incubation conversion curve, and multiplied that number by the original WUA$_{spawn}$ equivalent redds to obtain net spawning equivalent redds.

In the first water year a returning year class was calculated in the first few water years in the model. In Water Year 5 we can calculate spawning and rearing habitat for spring chinook and determine which of these governs production, but if the production in Water Year 1 was extremely low due to a drought, full production for Water Year 5 would probably not be realized due to underseeding (unless continual hatchery supplements are anticipated). Thus we have developed a term called Recovery Equivalent Redds (RER) for each water year. This term is the number of equivalent redds in Water Year n-4 plus a constant recovery potential that recognizes that density dependent mortality in Water Year n will be somewhat decreased if production is below carrying capacity. The RER term was determined by assuming that production can expand from the lowest level predicted by our model to optimum production in three generations (12 years). This assumption is based on the premise that compensation will occur when fish densities are below carrying capacity (Beverton and Holt 1957).

We calculated the production for a particular year; when that year class returned, we added the recovery potential constant and if this RER was lower than spawning equivalent redds and rearing equivalent redds, then the calculated potential production for the year under consideration could be no higher than the RER value. The RER value rarely came into play in the model, the only occasions being the severe drought years in the historical record used as simulation flows. For example, the poor production during the 1941 drought not only affected predicted production in 1941 due to poor rearing flows and in 1942 due to low spawning flows, but it also decreased predicted production in subsequent years when those year classes returned--that is, 1945-46 and 1949-50. A good example is the low return of adults experienced in the Naches River in 1982 due to the drought of 1977 (Naches spawners are predominantly 5-year-olds) and the subsequent low number of smolts emigrating from this sub-drainage when habitat conditions were good.

Thus for each water year, production was determined by the lowest of: 1) net spawning equivalent redds, 2) rearing equivalent redds, and 3) recovery equivalent redds. Average annual production was then calculated by simply computing the average of the production for the 52 years analyzed.

This methodology can be used to estimate potential production based on microhabitat availability. In the Yakima Basin, factors other than microhabitat, such as inadequate screens and ladders and excessive harvest, can also act to depress fish production. Using this method, we estimated that the Yakima Basin can, on the average, support an escapement of roughly 30,000 spring chinook spawners provided that state-of-the-art fish screens and ladders are maintained, the Bureau of Reclamation operates the Yakima Project to meet fishery flow targets while fulfilling irrigation demands, and harvest of spring chinook salmon is properly managed.

I recommend that this methodology for estimating potential production be used with caution and with a full understanding of the assumptions involved. Efforts should be taken to minimize nonhabitat-related effects such as inadequate passage facilities and overharvest. Further investigations are needed in order to:

1. Better define microhabitat preferences for fry, fingerling, overwinter, and spawning life stages;
2. Validate the assumption that WUA is an indicator of relative as well as absolute fish abundance;
3. Develop multivariate preference functions that consider the interrelationships of microhabitat variables;
4. Continue long-term monitoring to develop survivorship curves and to describe stock recruitment relationships; and
5. Refine the Yakima IFIM to incorporate state-of-the-art techniques.

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QUESTIONS AND ANSWERS

Q: When you looked at the effects of flows in the Yakima River, what was the effect of flows on temperature effects?
A: Temperature is only a problem below Sunnyside, where the gradient becomes steep. In general, this is not a problem for spring chinook salmon.

Q: In rivers that have been channeled, such as the Trinity River, how can you apply PHABSIM with only one flow?
A: What I meant is that one applies three different flows independently to get a range of hydraulic conditions.

Q: Is 30,000 spring chinook salmon a fairly firm estimate? What about other species? Can you base the potential production on what one used to see in those systems?
A: This is what we came up with, so we used it. With the IFIM analysis, you use the available data or you will go broke fast. The best habitat has been cut off by the dams, so we know that the streams won't produce what they used to. We tried to look at historical records, but this is probably good only in a gross way.
Comment: I believe that the connection of weighted usable area (WUA) to numbers of fish is tenuous. There are many problems in connecting carrying capacity to production. There is lots of controversy, with all species. For example, in New Zealand, no correlation was found between WUA and retention of chinook salmon in channels. Does anyone know of a validation to relate WUA to the ability of an area to carry fish?
Comment: We just completed a study which indicated a good correlation of WUA with density of chinook salmon in Idaho, although there was no correlation for steelhead.
A: There are many different combinations; for example, sometimes cover is weighted heavily, other times velocity. One needs an answer that is practical.
Comment: In the late 1970s, ODF&W, NMFS, and the U.S. Bureau of Reclamation did some studies of WUA, and considered vegetation and canopy cover to make valid correlations.
Comment: In the Rogue River from 1974 to the mid-1980s, we did not use WUA but applied "indices of abundance" for spring chinook salmon parr. There was a 60-fold variance. In high-density years, there were smaller parr, but all spawning adults had been of similar size. The observations had been very inconsistent; I would expect that also for WUA applications. One needs to add factors other than density to get reconciliation.

SESSION III

Hatchery Management Strategies and Supplementation

Session Chair: C. Mahnken,
National Marine Fisheries Service,
Manchester, Washington

ADULT RECOVERIES FROM RELEASES OF SUBYEARLING AND YEARLING SPRING CHINOOK SALMON

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Adult spring chinook salmon (Oncorhynchus tshawytscha) returning to the Little White Salmon National Fish Hatchery (NFH) by about 1 June are subjected to a reduced photoperiod regime which causes accelerated maturation. These adults are spawned about 4 weeks earlier than untreated fish and by October of the following year the resulting progeny weigh nearly twice as much as juveniles from normally spawned adults. In contrast to normal juveniles, those from the accelerated spawning display behavioral and physiological signs of smolting as subyearlings in the first spring following hatching (Zaugg et al. 1986).

In a study designed to compare survival to adulthood, subyearlings tagged with coded-wire tags were released in May and June 1984 and 1985 while yearling fish were released those same years at their normal release date in April. Recoveries from yearlings were higher than from subyearlings for both years (Table 1), with releases in 1985 contributing a higher percent of adults than those in 1984.

Fish released as yearlings returned to the hatchery in a higher ratio of females to males than did fish released as subyearlings (Table 2). Also, only one of 119 returning males from the subyearling releases returned as a jack (2 years old), whereas 14 of 89 returning males (16%) from the yearling releases were jacks (3 years old).

Sixty-six percent of adults recovered from releases of yearling fish in 1984 and 1985 were 4-year-old fish, 30% were 5-year-olds, and the remaining 4% were 3-year-old jacks (Table 3). This compares with 80% of the adults from subyearling releases recovered as 4-year-olds and 20% as 3-year-olds. Regardless of age at release, the majority of adults matured at age 4 years.

An examination of the lengths of adults returning to the hatchery indicated that 4-year-olds from the subyearling releases were about the same size as 5-year-old adults returning from fish released as yearlings (Table 4). Average length of 4-year-old adults (77 cm) released as yearlings was slightly greater than 3-year-old adults returning from the subyearling releases (72 cm).

The release of subyearling spring chinook salmon has become an integral part of the production program at the Little White Salmon NFH. It has been cost effective and has resulted in an increase of returning adults for both the local fishery and as a source of additional spawners.

Table 1.--Adult recoveries from juvenile chinook salmon released from the Little White Salmon Hatchery in 1984 and 1985.

Group	Release Date	Release Weight (g)	Est. adult recoveries[a] Number	Est. adult recoveries[a] Percent
1984				
Yearlings	19 Apr	36.6	104	0.20
Subyearlings	7 May	7.0	11	0.02
Subyearlings	22 Jun	11.7	30	0.06
1985				
Yearlings	17 Apr	43.7	266	0.52
Subyearlings	6 May	7.1	101	0.21
Subyearlings	20 June	10.5	68	0.14

[a] Recovered in the fishery and returns to the hatchery; based on 50,000 released.

Table 2.--Numbers of tagged female and male adult salmon returning to the Little White Salmon Hatchery.

Total numbers from	Females	Males	Ratio female/male
Yearling releases	199	89	2.24
less jacks	199	75	2.65
Subyearling releases	158	119	1.33
less jacks	158	118	1.34

Table 3.--Age distribution of adult salmon taken in the fishery and returning to the hatchery from releases in 1984 and 1985.

Released group	Number of adults recovered and percent ( ) according to age 2 years	3 years	4 years	5 years
Yearlings	-	14 (4)	230 (66)	104 (30)
Subyearlings	1 (-)	60 (20)	-	

Table 4.--Mean fork lengths (cm) of adult salmon returning to the hatchery from releases in 1984 and 1985 (number of fish measured in parentheses).

Release groups	Age (years) 2	3	4	5
Yearling	-	56 (13)	77 (209)	89 (85)
Subyearling	46 (1)	72 (40)	90 (139)	-

References

Zaugg, W. S., J. E. Bodle, and J. E. Manning. 1986. Smolt transformation and seaward migration in 0-age progeny of adult spring chinook salmon (Oncorhynchus tshawytscha) matured early with photoperiod control. Can. J. Fish. Aquat. Sci. 43:885-888.

ZERO-AGE SMOLT STUDIES, MID-COLUMBIA RIVER 1987-89

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Introduction

This abstract summarizes the information obtained from the first 2 years of a study to produce 0-age smolts in the Carson Hatchery stock reared at Leavenworth National Fish Hatchery. Production of 0-age smolts is being investigated as a potential means to improve production of spring chinook in the mid-Columbia region. Disease, passage, and other undefined problems are currently limiting hatchery production through poor return rates in the range of 0.001 to 0.007 adults per smolt.

The studies are conducted under the mid-Columbia Coordinating Committee with the cooperation and support of the U.S. Fish and Wildlife Service and the Washington Department of Fisheries. Under the Coordinating Committee, the studies have been restricted to using only accelerated rearing as a means of producing 0-age smolts. Accelerated maturation in brood stock was not permitted because of concerns by some members that this procedure might result in adverse genetic changes.

The first objective of these studies is to determine if 0-age smolts can be produced. Second, we are attempting to determine if there is an advantage to producing 0-age smolts in this region with this stock. We have just completed the second year of this study. We have reared and assessed the smoltification of two year classes of 0-age spring chinook. However, we do not yet have any adult return data to complete our evaluation.

Methods

Our method of producing 0-age smolts was to take the first embryos available at the Leavenworth Hatchery and incubate these embryos and rear the young under the warmest water conditions we could provide. Eggs taken from the first and second spawnings in mid-August were fertilized with a single male for each female and incubated separately for each female until IHN test results were available. Embryos from IHN-positive fish were then incubated separately from those of IHN-negative parents. In 1987, all embryos were incubated at Leavenworth; however, in 1988, about 125,000 IHN-free embryos were transferred to Wells Hatchery for rearing in warmer water.

At Leavenworth, the incubation and early rearing water temperature was raised about 2-3°C above the well-water temperature used for normal production fish. A swimming pool heater heated the Leavenworth well water to provide temperatures of about 12°C. The group of eggs taken to Wells Hatchery in 1989 were incubated in warm well-water of about 12-14°C.

Prior to release, the Wells groups were returned to Leavenworth for a 2-week holding period. This was to ensure that all spring chinook test fish returned to the

Leavenworth Hatchery. In 1988, the Wells group was held in a modified fish ladder. High water and debris in Icicle Creek allowed some of these fish to escape after only 2 days holding.

All fish in this study were marked with a freeze brand and coded-wire tagged. Tagging and branding of the individual groups was conducted in March to give the fish adequate time to recover from any marking stress prior to release.

Physiological monitoring of each group was conducted to detect changes in plasma thyroxine (T_4) and gill ATPase levels. Beginning in early March, samples of 10 fish were collected each week from each group for this monitoring. Growth was measured by taking weight and length measurements from each of these samples.

Following release, the migration rates of each group were monitored at several downstream locations. Smolt sampling activities at Rock Island, Priest Rapids, and McNary Dams collected these groups during their migration through the Columbia River reservoirs.

Samples of about 1,100 fish from each group were retained at release for saltwater survival testing. These fish were transferred to Manchester, Washington, on Puget Sound where they were placed in net-pens at the National Marine Fisheries Service facility. The fish were placed in a freshwater lens held in place by a vinyl skirt around the top of the pens. An initial sample of 100 fish and all mortalities were collected for disease analysis.

Results

This study is in progress and has not produced final results. Results available include information on rearing and migration of juveniles. No adults have yet returned.

As anticipated, the growth of juvenile spring chinook at Leavenworth was increased considerably by raising the water temperature during their first winter. Fish hatched in late September and emerged in late October. The size (weight) of these fish remained about twice that of fish from the normal hatchery production as shown by the 1987 data (Fig. 1). The 1988 fish showed similar growth rates.

By the April release dates, the accelerated fish had reached sizes apparently capable of beginning migration. Accelerated fish reared at Leavenworth were about 8 g while fish reared in part at Wells in warmer water had reached about 16 g by late April. Similar growth rates were produced in 1988-89, when both embryos and fry were transferred to Wells for rearing.

Physiological monitoring showed that the accelerated fish were producing peaks in T_4 and ATPase levels that indicate smolting or readiness to smolt. This response was greatest in the Wells group. The peaks in T_4 were generally lower in accelerated fish than in yearling or normal production 0-age fish at Leavenworth.

Use of a longer photoperiod in a small group of Leavenworth accelerated fish in 1989 showed a greater T_4 peak comparable to normal production fish. The ATPase levels in all accelerated groups tended to be nearly the same as or slightly higher than yearling or normal production fish.

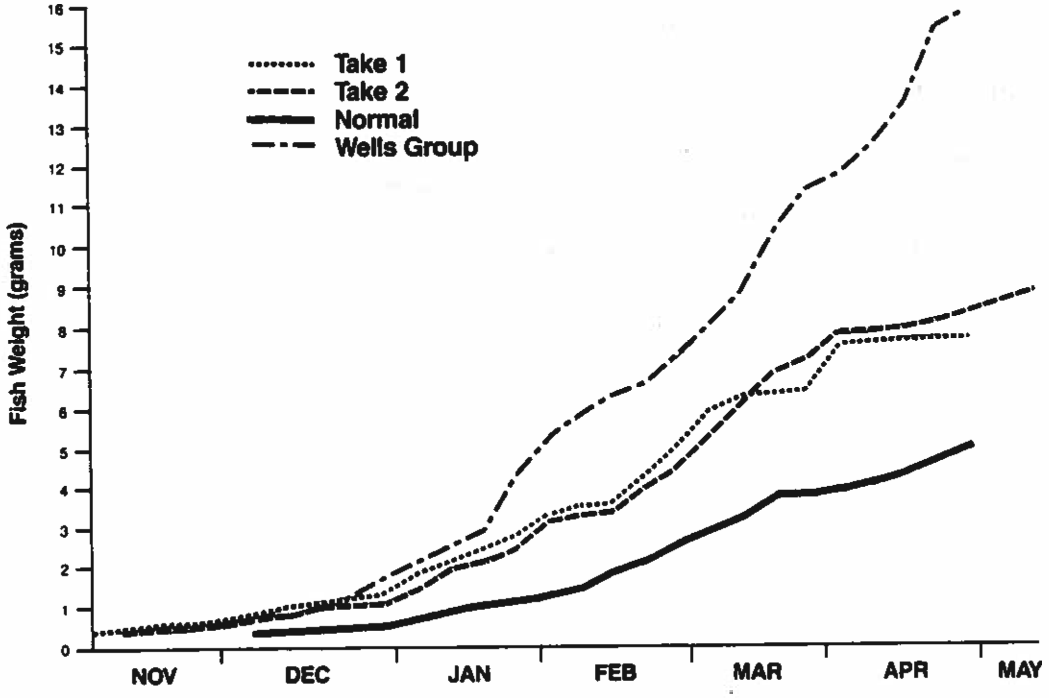

Figure 1.--Growth curves of the accelerated 0-age groups (Take 1, Take 2, and Wells) and the normal 0-age Leavenworth group that was spawned on the same day as Take 2.

Migration rates of accelerated groups were initially very rapid but decreased markedly downstream from the first recovery location. Accelerated fish appeared at Rock Island Dam in large numbers within 2-3 days of release. Accelerated fish tended to be collected in higher numbers than yearlings at Rock Island Dam. This differential recovery appears to be a unique characteristic of the dam rather than an indication of survival. However, at Priest Rapids and McNary Dams, yearlings were recovered at much higher rates than the accelerated fish.

Travel times to Rock Island Dam (Fig. 2) were longer, on the average, for accelerated groups than for yearlings, although initial portions of each accelerated group matched the rapid yearling migration to this first dam. At Priest Rapids and McNary Dams, the migration rates of accelerated groups were much lower than the yearling rates. At McNary Dam, few 0-age fish were recovered until early June, while nearly all yearlings passed the dam in May (Fig. 3).

Saltwater survival was initially high for both years. This indicates that the physiological condition of the accelerated groups allowed them to adapt to seawater. All fish had moved from the freshwater lens into the deeper seawater layer after several days. Mortality rates were high (46-80%) in accelerated groups during the first 120 days of saltwater rearing. Those deaths were due to vibriosis and BKD during 1987. In 1988, the fish were vaccinated against vibrio and had low mortality rates (0.3-3.6%) for the first 30 days. Later, mortality rates due to BKD were much higher.

Future adult recoveries will provide a complete evaluation of this study.

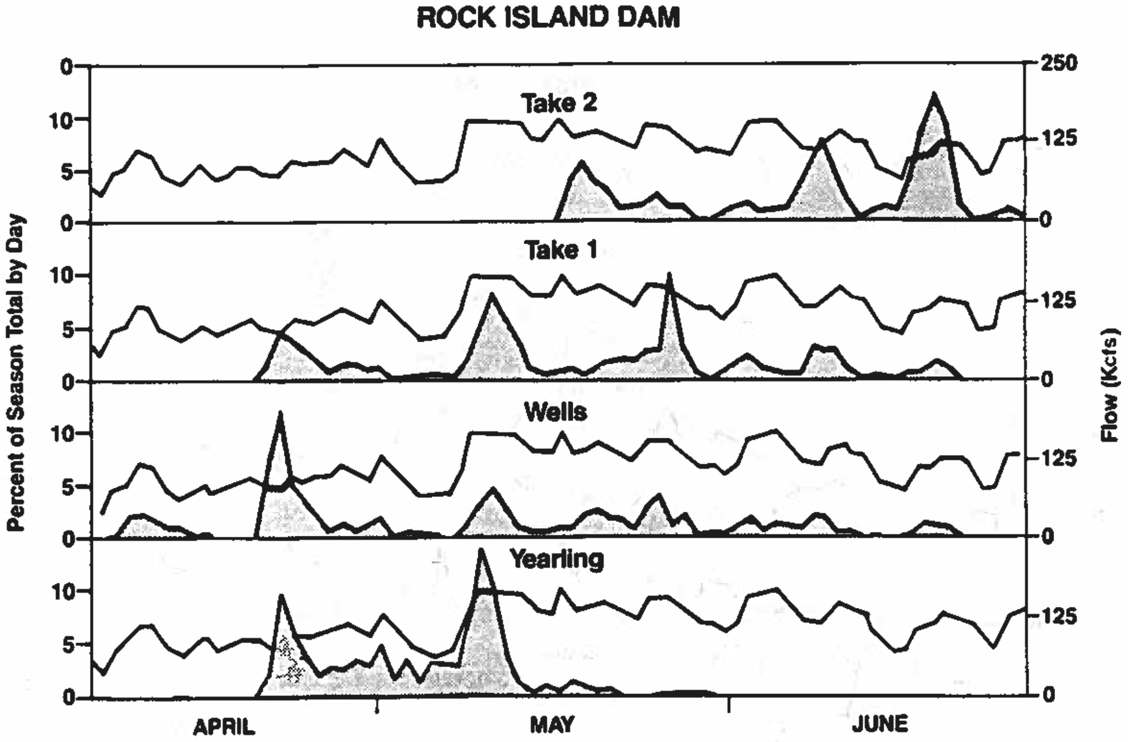

Figure 2.--Daily brand recoveries of Take 1, Take 2, Wells, and Leavenworth yearling groups at Rock Island Dam expressed as percentages of the total number of each brand recovered for the season (shaded area).

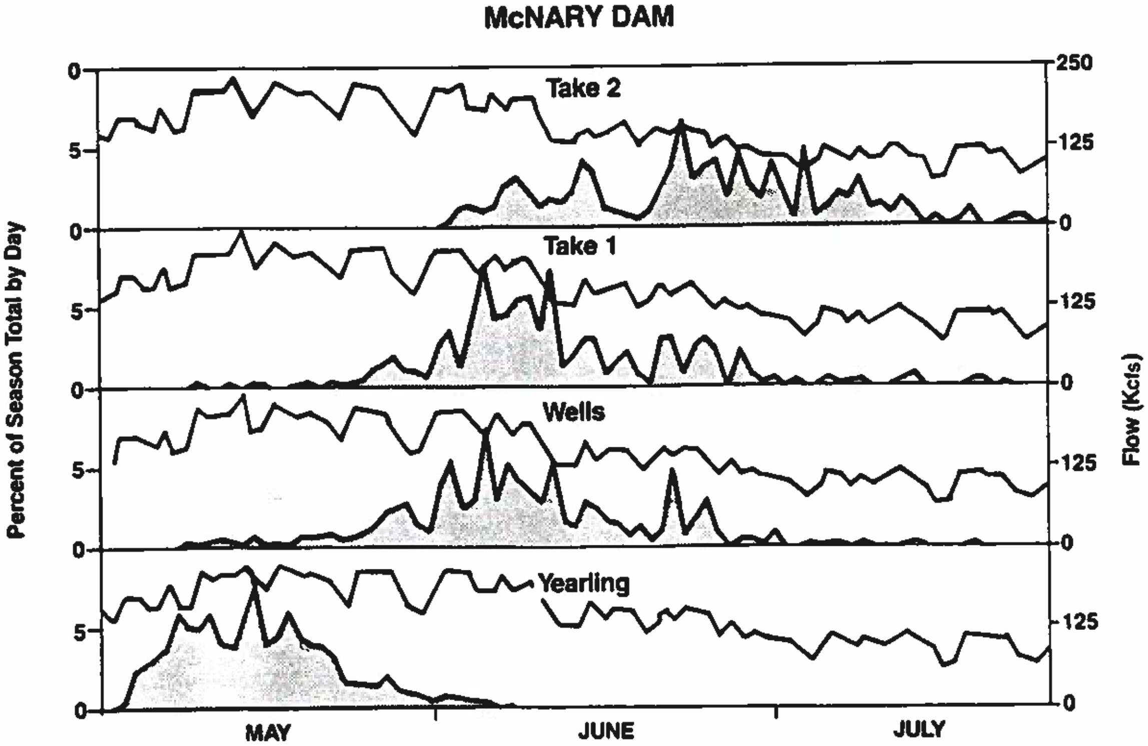

Figure 3.--Daily brand recoveries of Take 1, Take 2, Wells, and Leavenworth yearling groups at McNary Dam expressed as percentages of the total number of each brand recovered for the season (shaded area).

EVALUATION OF OUTMIGRATION PERFORMANCE AND SMOLT-TO-ADULT SURVIVAL OF SUBYEARLING SPRING CHINOOK SALMON SMOLTS

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The spring chinook salmon (Oncorhynchus tshawytscha) hatchery program in the Grande Ronde Basin is inadequate to provide adult returns capable of meeting broodstock, supplementation, and harvest objectives (Carmichael et al. 1986). There are not enough facilities in northeastern Oregon to expand yearling smolt production. Water sources suitable for siting new facilities are very limited because of severe winter conditions and summer flows and temperatures. To meet the long-term adult escapement goals, production of spring chinook smolts may be needed from well-water facilities such as Irrigon Hatchery. Well-water facilities generally have temperature regimes suitable for production of subyearling spring chinook smolts. There are obvious economic and hatchery production benefits associated with releases of subyearling smolts. For these reasons we began an evaluation of production and release of subyearling smolts. We chose Irrigon Hatchery as the incubation and rearing site because it theoretically has suitable water temperatures to produce a 23-g smolt for release in May of the first rearing year.

Our specific objectives were 1) to assess and compare outmigration performance of subyearling and yearling smolts and 2) to determine smolt-to-adult survival and benefits to hatcheries for subyearling smolts. Rapid River stock eggs were obtained from Idaho in 1986, 1987, and 1988. Eggs used for subyearling production were transported to Irrigon Hatchery for incubation and rearing. Eggs were incubated at a constant temperature of 11.2°C. Replicate groups of approximately 40,000 were marked Ad+CWT and replicates of 20,000 were cold branded. In all 3 years, fish were transported to Lookingglass Hatchery the first week of May and were held for approximately 2 weeks before release. Mean length, mean weight, and visual index of smolting were determined just prior to release. Yearling smolts were produced at Lookingglass Hatchery under the standard production program and were marked and branded as described for the subyearling smolts.

Branded fish were recovered and enumerated at Lower Granite Dam as part of the Smolt Monitoring Program. Migration success was determined as the percentage of branded fish released that were estimated to have passed Lower Granite Dam. Migration success, duration, and rate were determined for both subyearling and yearling smolts. Yearling smolts were released only in 1988 and 1989 so no comparisons for 1987 releases could be made. In both 1988 and 1989, the yearling smolts were released 43 days earlier than the subyearling smolts. We used comparisons between yearling and subyearling smolts only as an index of success because of the differences in release time and size.

We were unable to achieve the target release size of 23 g in 1987, 1988, or 1989. This was attributed to reduced growth in April that resulted from handling for marking and branding purposes (Fig. 1). Subyearling smolts were released in mid-May each year with a mean fork length range of 102-107 mm and a mean weight range of

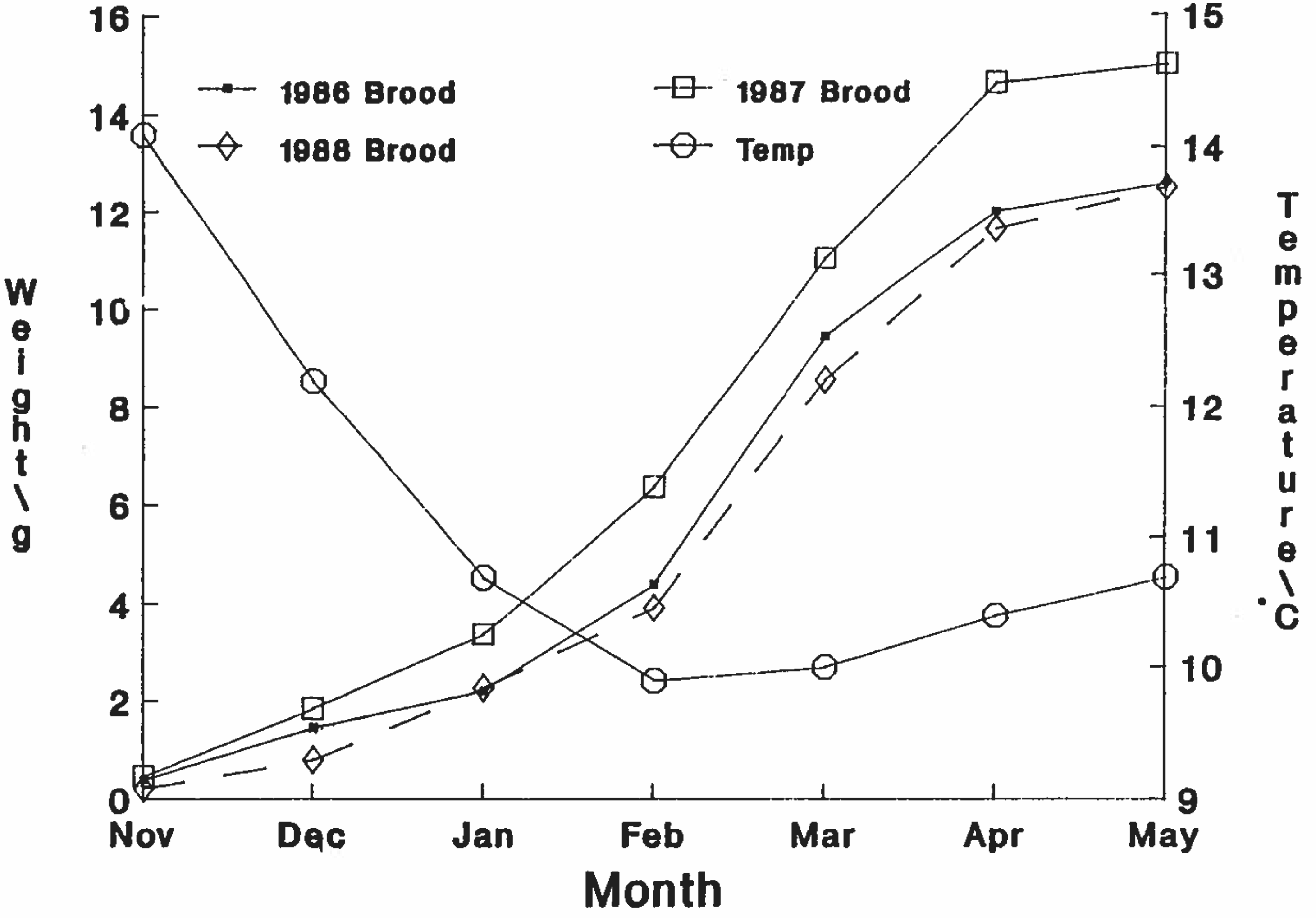


Figure 1.--Monthly growth and temperature profile for spring chinook subyearling smolts reared at Irrigon Hatchery, 1986-88 broods.

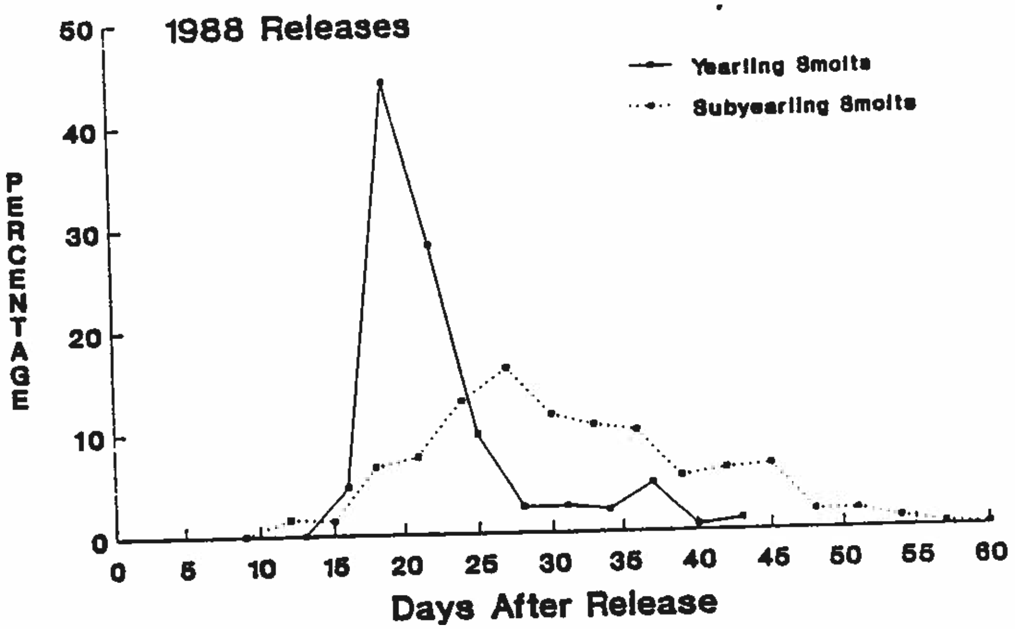
12.5-15.0 g (Table 1). Yearling smolts were released earlier at a larger size in both 1988 and 1989 (Table 1). Migration success of yearling smolts was slightly better in 1988; however, in 1989, the migration success of subyearling smolts was over two times better than the yearling smolts. We did observe differences in migration rate and duration between yearling and subyearling smolts. The length of time from release to migration completion was substantially longer for subyearling smolts and the migration rate of subyearling smolts was slower (Fig. 2).

Table 1.--Release information for Rapid River stock subyearling and yearling spring chinook smolts released from Lookingglass Hatchery. Standard deviation is presented in parentheses.

Age at release, brood year	Release date	Mean fork length (mm)	Mean weight (g)
Yearling			
1986	1 April 1988	125 (6.2)	23.0 (4.6)
1987	3 April 1989	123 (9.2)	22.4 (6.1)
Subyearling			
1986	20 May 1987	102 (6.0)	12.6 (5.4)
1987	13 May 1988	107 (6.2)	15.0 (3.0)
1988	15 May 1989	102 (6.1)	12.5 (2.3)

We observed significant shifts in the length frequency and mean length of subyearling smolts from the time of release to time of recapture at Lower Granite Dam (Fig. 3). This length shift was in part a result of growth; the length of many migrants recovered at Lower Granite Dam was greater than the length of the largest fish at release. Zaugg et al. (1986) reported significant mean-length shifts for 0-age spring chinook that were released from Little White Salmon Hatchery and recaptured in the Columbia River; however, the magnitude of change was much less than that which we observed.

The outmigration performance of subyearling smolts indicates good potential for success of this rearing-release strategy (Fig. 4). However, the true measure of success is survival to adulthood. Preliminary information regarding smolt-to-adult survival is not encouraging. One-ocean (age 2) and two-ocean (age 3) adults from 1986-brood releases should have returned in 1988 and 1989, respectively. There were no hatchery recoveries of any marked adults from subyearling smolt releases in either year. Lindsay et al. (1989) observed good outmigration success and poor smolt-to-adult survival for subyearling smolts released in the Deschutes River. We are unsure of what the adult age composition will be for subyearling smolt returns; however, if adults produced from 0-age smolts return at the normal total age, the majority of adults produced from the first releases in 1987 will return in 1990.



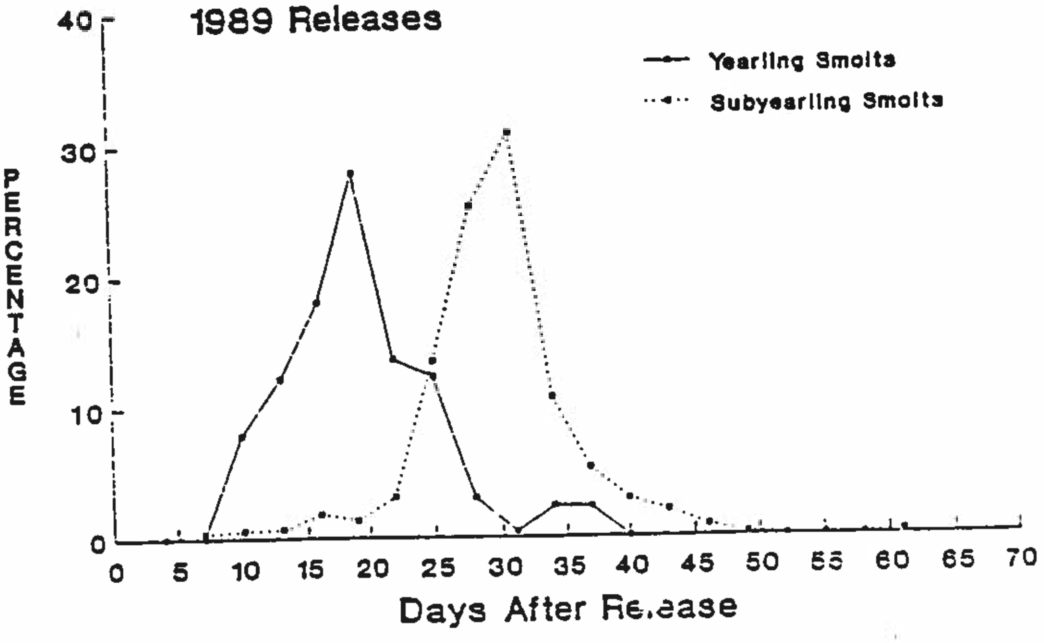
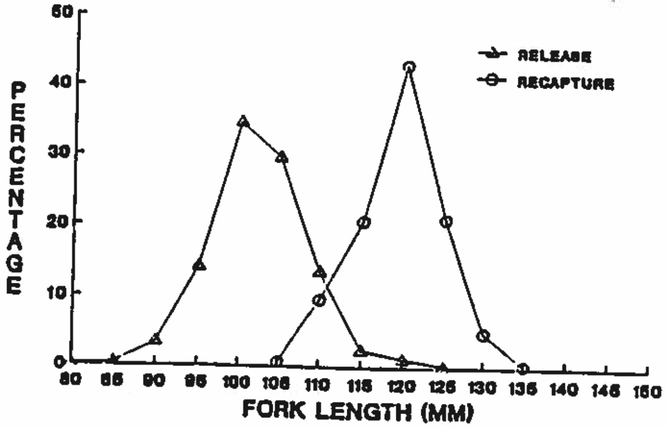
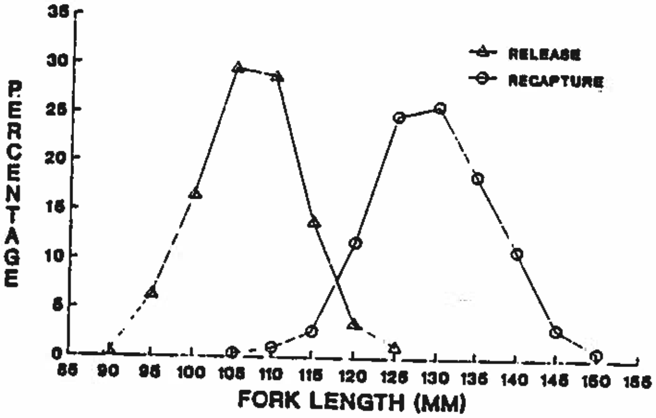


Figure 2.--Comparison of migration timing and duration past Lower Granite Dam of yearling and subyearling spring chinook smolts released from Lookingglass Hatchery in 1988 and 1989.

1986 BROOD YEAR



1987 BROOD YEAR



1988 BROOD YEAR

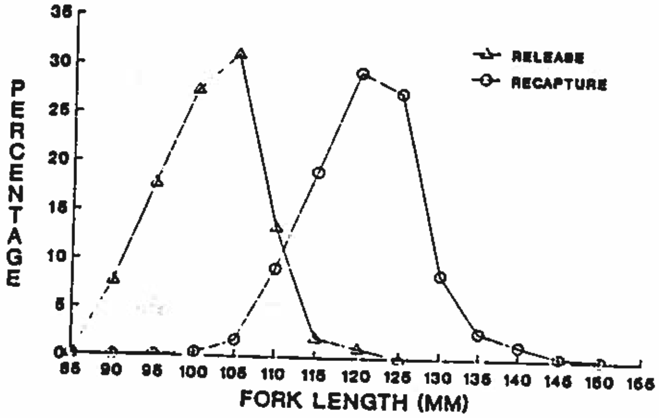


Figure 3.--Length frequency distribution (fork length) at release from Lookingglass Hatchery and at time of recapture at Lower Granite Dam for spring chinook subyearling smolts of the 1986, 1987 and 1988 broods.

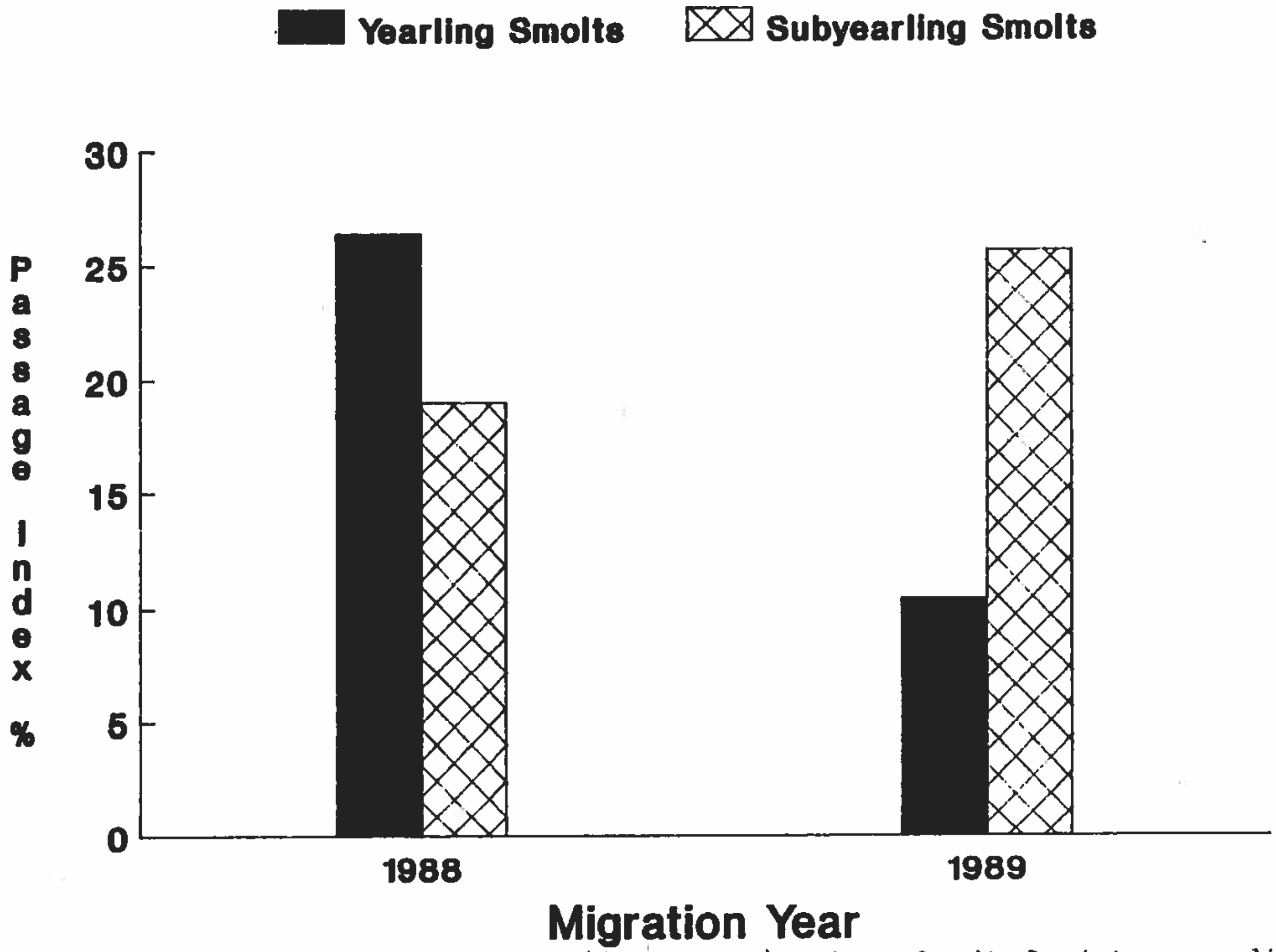


Figure 4.--Comparison of passage indices (% of release) at Lower Granite Dam between yearling and subyearling spring chinook smolts released from Lookingglass Hatchery in 1988 and 1989.

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QUESTIONS AND ANSWERS

Q: What were the weights after recapture at Lower Granite Dam, given the shift in the mean length?
A: The mean was 20 g.

Q: Given that there is spill at the dams in mid-April, it is likely that you missed this for the May release; what is the success of subyearlings in passing the dam?
A: There are some data for passage through the lower dams, but few at McNary Dam. Most subyearlings are probably barged from Lower Granite Dam. With the PIT tags it can be seen that some wild fish migrate late. The Grande Ronde wild fish are like the subyearlings, migrating in mid-May to late June.
Comment: The wild fish from the Tucannon River are the same as the subyearling May release.

Q: Did you record PIT tags at Lower Granite Dam? Did you get length/frequency data?
A: Fish were tagged from trap boxes in the Grande Ronde and at Lookingglass Hatchery. These PIT-tagged fish were passively monitored at Lower Granite Dam, so there were no length data. But from two sources they are reported as 90-110 mm and 102 mm.

Q: Regarding the 0-age fish from Little White Salmon River--do the adults return as falls or springs?
A: It is typical that they return as springs.
Comment: They also have a traditionally low harvest rate.

Q: What about fishing pressures?
A: The ocean catch is very little; also the in-river catch is small.

Q: Since there is concern about genetic maintenance, are particular characters selected?
A: We are not doing major selection for this group. If selection pressures are different from those in yearlings, we do not know what the effects would be. We do not believe that there would be genetic differences between the two.

Q: What about looking at subyearling and yearling smolt indices in Idaho?
A: This had been planned for the past year, but we could not get eggs from Idaho. We only had visual observations on smolting. Similar percentages appeared to be "smolty" between yearlings and subyearlings, which has also been noted in unsuccessful subyearlings and yearlings.

Q: What has been done regarding size and age relationships?
A: We have looked at gill Na^+-K^+ ATPase in yearlings and subyearlings. In subyearlings, although there are not extensive indications of smoltification, there are some indications, and that is the essential factor. Smoltification develops more at release.

Q: Regarding freeze-brand data, did differences in the quality of brands affect these data?
A: This is possible, but we did have retention of marked groups and quality control, particularly in the yearling and subyearlings, since they were branded at different times.

Comment: We don't know yet how to supplement with yearlings, let alone subyearlings.

Q: There is a lot of growth after release. Have you looked at outmigration timing between the time of release and time of recapture, particularly in regard to ecological competition with wild fish? This looks like it might happen also with the Leavenworth fish.
A: No, we don't know the effects of this; it would be difficult to assess. One could look at food and spatial overlaps--it could be important.

Q: Are you convinced that there is growth, or might only the bigger fish get to Lower Granite Dam?
A: We believe that it is mostly growth, since we see larger fish than at release; it is not just migration success.
Comment: We see no differences between mark quality and recovery. 0-age fish have most of their rearing in the mainstem. Regarding the summer and fall fish, there are not many of each at the same time. I would expect some competition with the resident non-salmonid fishes.

Q: Why did you use Carson stock instead of a mid-Columbia stock?
A: That was the only hatchery stock available.

A REVIEW OF REARING DENSITY EXPERIMENTS: CAN HATCHERY EFFECTIVENESS BE IMPROVED?

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Salmon hatcheries in the Columbia River Basin participate in a diversified program involving numerous government agencies, resource managers, citizen groups, and scientists to return today's valuable salmon runs to historic levels. In their efforts to maximize adult contributions from hatcheries, those involved with hatchery production have frequently assumed that maximum smolt liberations produce correspondingly large numbers of adults for fishery harvest. Hatchery production decisions, therefore, are often based on maximum fingerling carrying capacities. The effects of crowded rearing conditions on post-release survival of smolts is usually not given enough consideration.

Under the administration of separate governmental agencies, rearing density and post-release survival studies of chinook salmon (Oncorhynchus tshawytscha) have been conducted or are currently under way at five hatcheries on the west coast of Canada and the United States. Most of the evidence from these investigations suggests that high rearing densities are counter-productive in terms of hatchery contribution of adults. The subject of this paper is a review of the results from these studies.

Experiments have been conducted with spring chinook at Cowlitz Hatchery (Washington Department of Fisheries) (Hopley 1980). Spring chinook studies were also conducted by Fagerlund et al. (1987) at Capilano Hatchery (British Columbia Department of Fisheries and Oceans) and by Denton (1988) at Deer Mountain Hatchery (Alaska Department of Fish and Game). Tests are under way with coastal fall chinook at Elk River Hatchery (Oregon Department of Fish and Wildlife) (Downey et al. 1988) and with spring chinook (Banks 1989, unpubl. manuscr.) at Carson National Fish Hatchery (U.S. Fish and Wildlife Service).

Rearing conditions and ranges in pond loadings varied widely between studies (Table 1). Various sizes and modifications of rectangular circulating rearing ponds (Burrows and Chenoweth 1970) were used in tests at Cowlitz, Capilano, and Elk River. Swedish-type ponds were used at Deer Mountain Hatchery in Alaska and linear-flow, single-pass raceways were used at Carson National Fish Hatchery. Rearing unit volume varied from 22 to 566 m^3. Pond inflows ranged from approximately 700 to over 7,500 L/min. Fish size at release varied from approximately 6 to over 133 g.

Rearing density effects on survival and total estimated adult contribution for the completed studies at Cowlitz, Capilano, and Deer Mountain hatcheries are summarized in Figures 1-3. Results to date from the on-going studies at Elk River and Carson Hatcheries are shown in Figures 4 and 5.

Within each study, post-release survival rates decreased as rearing density increased. Although this response demonstrates the adverse effects of high rearing density on smolt quality, comparison of survival rates in rearing density studies can be

Table 1.--Summary of rearing conditions and ranges in pond loading parameters at five chinook salmon hatcheries where fingerling rearing density and post-release survival studies were conducted.

Hatchery	Cowlitz[1]	Capilano[2]	Deer Mountain[3]	Elk River[4]	Carson[5]
Race	Spring chinook	Spring chinook	Spring chinook	Fall chinook	Spring chinook
Brood year(s)	1975-76	1979-80	1977	1981-85	1982-84
Pond type	Rectangular circulating	Rectangular circulating	Swedish	Rectangular circulating	Raceway
Pond volume (m^3)	556	124	22	86	34
Pond inflow (Lpm)	7,570	2,385	719	1,703	757-2,271
Temperature (°C)	U[6]	6.1	U	U	6.1
Fish/pond (Thousands)	30-90	185-447	11-45	27-48	20-60
At release:					
Average weight (g)	90.8-133.5	5.7-7.7	17.7-17.8	U	22.8-27.0
Kg/m^3 rearing volume	6.4-17.6	11.2-22.4	6.4-32.0	9.6-25.6	9.6-44.8
Kg/Lpm inflow	0.4-1.4	0.5-1.2	0.2-1.0	0.5-1.3	0.2-2.0
Density index[7]	0.03-0.13	0.18-0.40	0.09-0.44	U	0.13-0.51
Flow index[7]	0.4-1.3	1.4-2.8	0.4-2.0	U	0.5-1.9

[1] Washington Department of Fisheries. Data from Hopley (1980 unpublished report).

[2] British Columbia Department of Fisheries and Oceans. Data from Fagerlund et al. (1987).

[3] Alaska Department of Fish and Game. Data from Denton (1988).

[4] Oregon Department of Fish and Wildlife. Data from Downey et al. (1988).

[5] U.S. Fish and Wildlife Service. (Banks 1989 unpublished data).

[6] Data unavailable.

[7] Density index (W/(L x V)) and flow index (W/(L x I)) as defined by Piper (1972) where W = known permissible weight of fish in pounds, L = average fish length in inches, V = rearing unit volume in cubic feet, and I = rearing unit water inflow in gallons per minute.

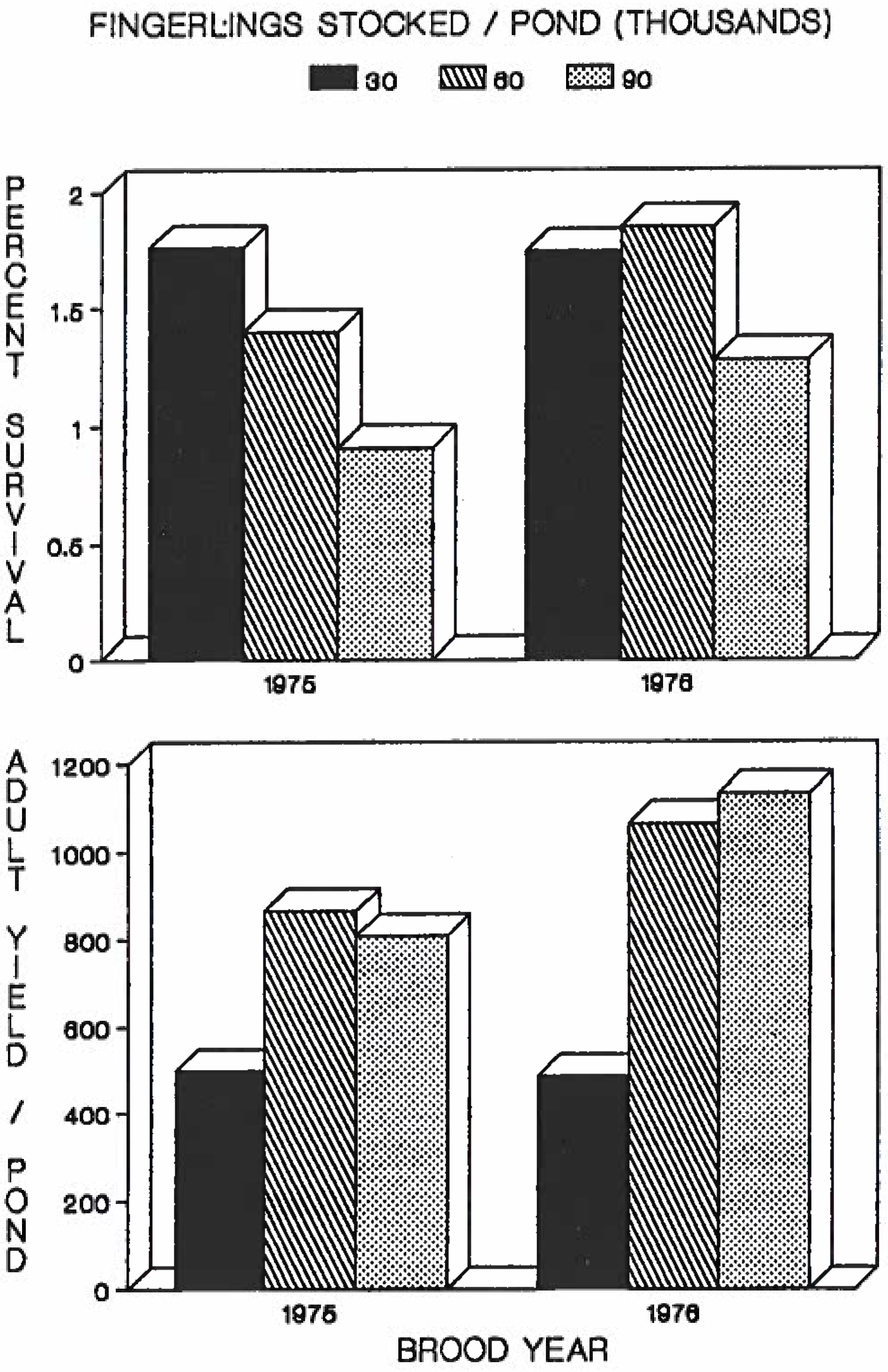

Figure 1.—Percent survival and adult yield per rearing pond in 1975- and 1976-brood spring chinook reared at three densities at Cowlitz Hatchery (Washington Department of Fisheries). Data from Hopley (1980 unpublished).

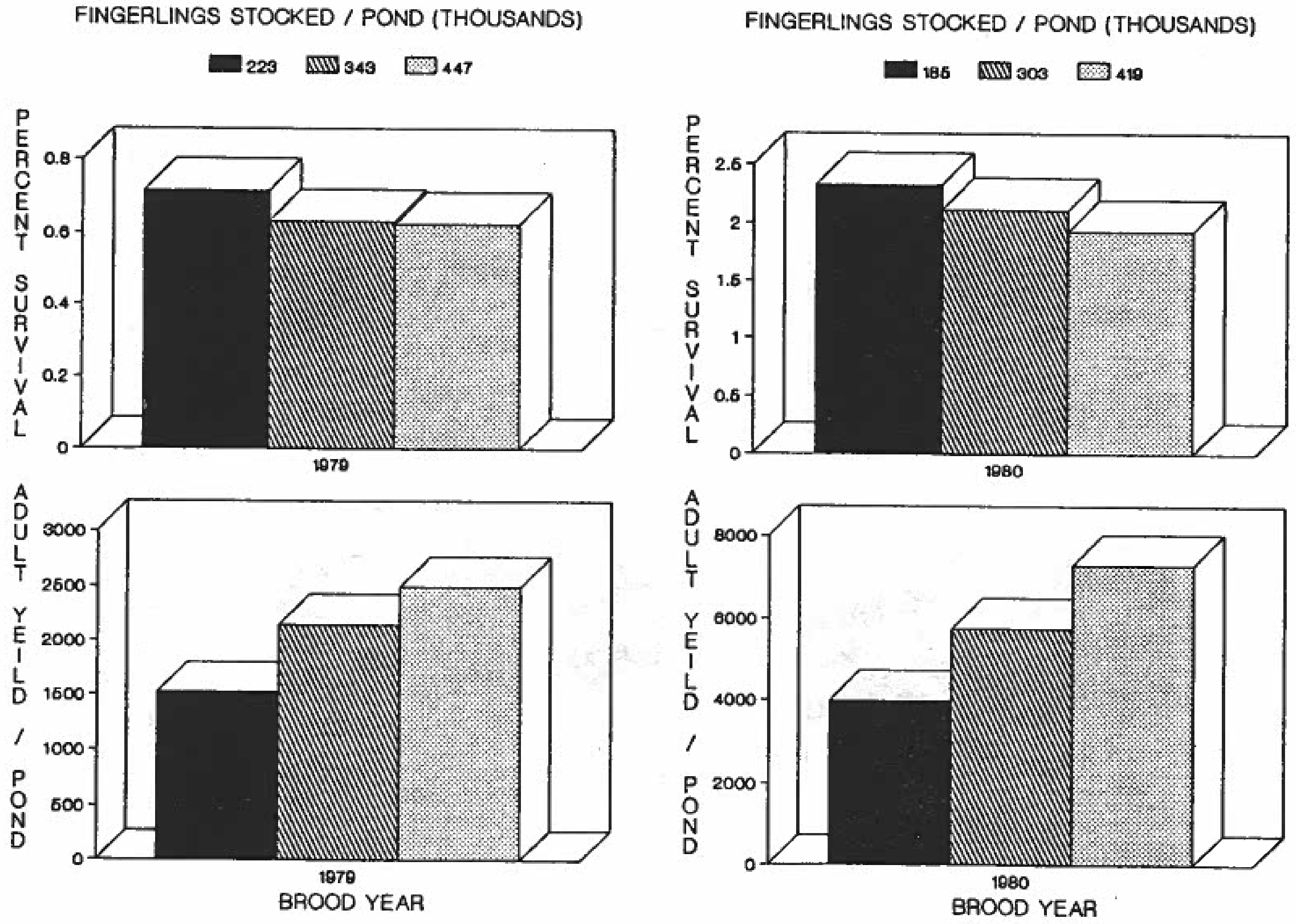

Figure 2.—Percent survival and adult yield per rearing pond in 1979- and 1980-brood spring chinook reared at three densities at Capilano Hatchery (British Columbia Department of Fisheries and Oceans). Data from Fagerlund et al. (1987).

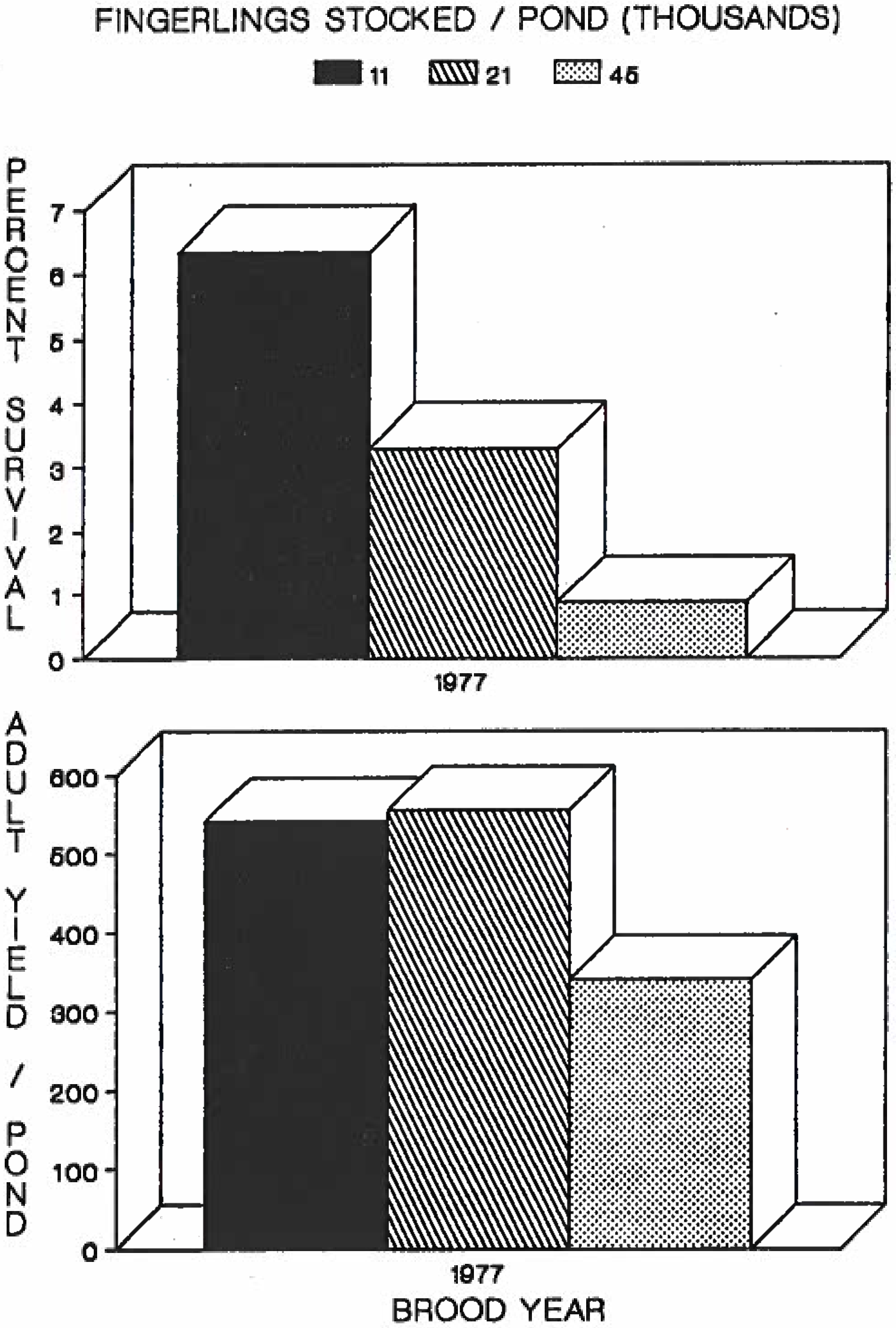

Figure 3.—Percent survival and adult yield per rearing pond in 1977-brood spring chinook reared at three densities at Deer Mountain Hatchery (Alaska Department of Fish and Game). Data from Denton (1988).

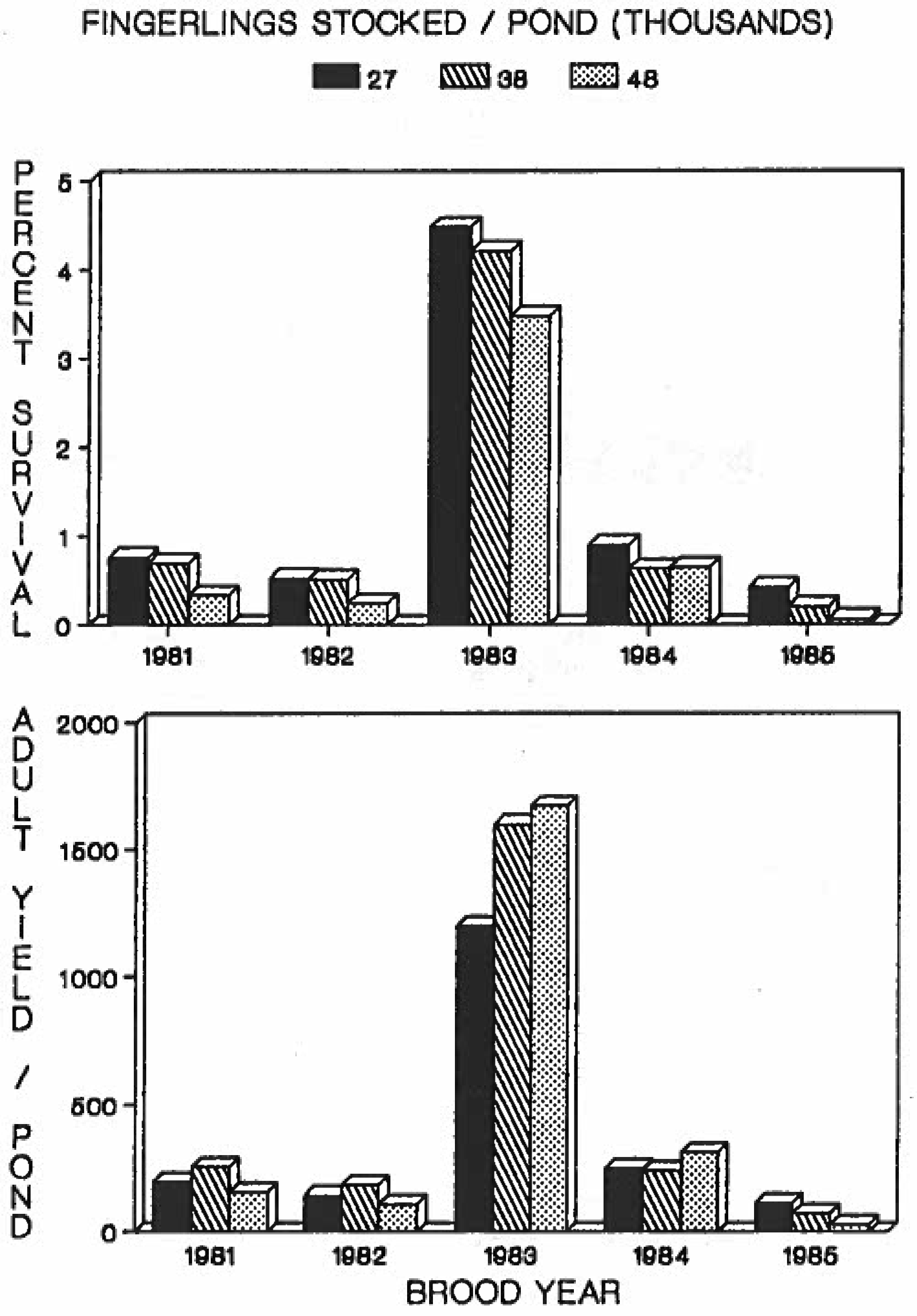

Figure 4.—Percent survival and adult yield per rearing pond in 1981-85-brood fall chinook reared at three densities at Elk River Hatchery (Oregon Department of Fish and Wildlife). Results are based on incomplete adult recoveries. Data from Downey et al. (1988).

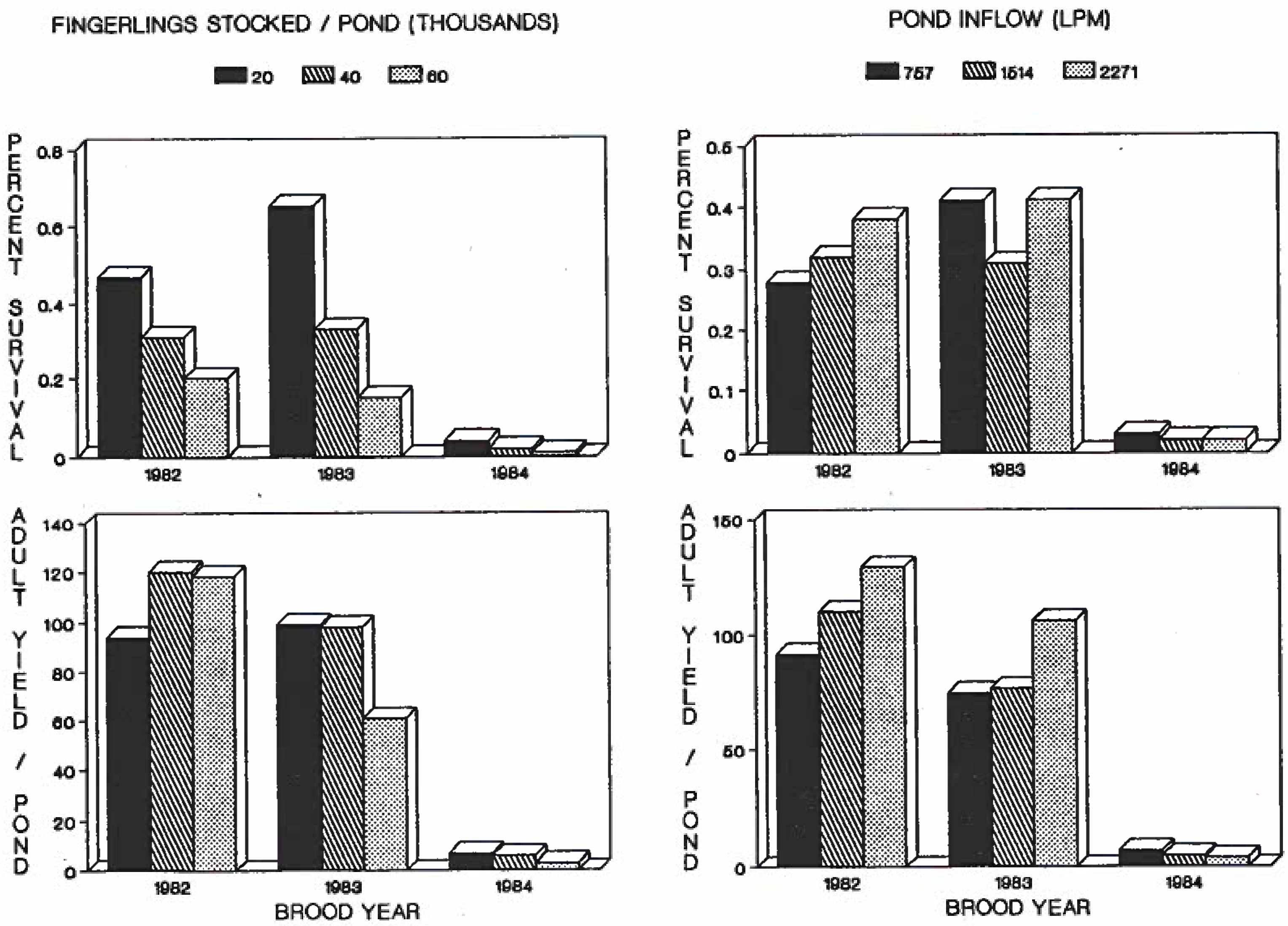

Figure 5.—Percent survival and adult yield per raceway in 1982–84-brood spring chinook reared at three densities and at three levels of water inflow per raceway at Carson Hatchery (U.S. Fish and Wildlife Service). Results are based on incomplete adult recoveries. Data from J. Banks (1989 unpublished).

misleading. Since different numbers of fish are reared within each test level, estimates of total adult yield (catch-release ratio x total fish released) are necessary before comparisons of production efficiency between rearing densities can be made.

At Cowlitz Hatchery, no increase in adult contribution was found when smolt production was increased from 60,000 to 88,000 fish per rearing pond with 1975- or 1976-brood fish (Fig. 1). Ponds with 28,000 smolts produced fewer adults than either of the two higher production levels.

Results from the spring chinook study at Capilano Hatchery are contrary to those observed at the other hatcheries. Increased rearing densities resulted in increased adult contribution levels in both 1979- and 1980-brood tests (Fig. 2). According to Fagerlund et al. (1987), the fish were reared for a period of 3 months prior to release at sizes ranging from 5.7 to 7.7 g. In contrast, fish at the other hatcheries were reared for time periods varying from 9.5 to 11 months and released at sizes of 16 g or larger. The difference in results at Capilano may be explained by the reduced period of rearing if adverse effects from crowded rearing environments accumulate over long periods.

Adult contributions of spring chinook at Deer Mountain Hatchery were nearly equal when spring chinook were reared at 8,500 or 16,800 fish per Swedish pond (Fig. 3). Total adult yield from each of these ponds exceeded that from the pond where 39,100 smolts were reared.

Through the 1987 return year, adult contributions of coastal fall chinook at Elk River have been higher in 3 of 5 years from rearing ponds with 38,000 fish than from ponds where 48,000 fish were reared (Fig. 4). Survival rates of 1983-brood fish were approximately four times higher than those of any other brood. Adult contribution levels from this brood also increased as rearing densities increased. This observation may suggest that, during high survival years, smolts of reduced quality from high rearing densities may be able to survive at higher rates and therefore out-produce smolts reared at reduced densities. To date, however, ponds with 38,000 smolts have produced more adults than ponds with 27,000 or 48,000 smolts (Downey et al. 1988).

Studies at Carson Hatchery were designed to test the effects of both rearing density and pond inflow on adult contribution. Although returns are incomplete, results indicate that adult contribution levels are related to both pond crowding and water inflow (Fig. 5). In 1982 brood-tests, contribution of adults from ponds with 20,000, 40,000 or 60,000 smolts were not statistically different (Banks 1989 unpubl. data). In 1983 brood-tests, ponds with 20,000 or 40,000 smolts produced significantly more adults than raceways with 60,000 smolts. Total adult recoveries from ponds with 2,271 L/min water inflow have exceeded those from ponds with 757 or 1,514 L/min inflow even though rearing temperatures were low (6.1°C) for most of the rearing period and dissolved oxygen levels in pond effluents were 7 mg/L or higher at smolt release. Reductions in contribution, therefore, were apparently due to factors other than low oxygen levels.

In conclusion, most of the evidence suggests that, for chinook salmon, high rearing densities do not result in increased levels of adult contribution. Conversely, there is also no evidence to suggest that strongly reduced rearing densities produce great increases in adult yield. In most cases the studies show that low or intermediate smolt production levels produce as many adults as high rearing densities. If these studies are indicative of smolt production and adult contribution limitations at other hatcheries, new criteria are needed for making production management decisions. Production levels in the past have been based primarily on maximum fingerling carrying capacities. Instead of accomplishing their intended goal, hatcheries operating at capacity may be merely contributing to their own fish cultural problems, such as disease outbreaks, and may be unnecessarily budgeting large sums of money on feed costs. Unfortunately, because of the unique rearing conditions at individual hatcheries (pond type, water quality, disease problems, species or race tolerance to crowding, etc.), optimum rearing levels are probably site-specific. If hatcheries are to operate at maximum efficiency, however, more studies of the hatchery crowding-adult yield relationship are needed.

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QUESTIONS AND ANSWERS

Q: Was oxygen supplementation used in any of the experiments?
A: No; the fish were in ponds with established flows. However, oxygen supplementation experiments are now under way. It will be interesting to see if increased oxygen will increase production. Maybe crowding has an adverse effect that overrides any oxygen advantages. It may turn out that we could use less water if oxygen is added to the same number of fish.
Comment: The Cowlitz Hatchery had 10-times the survival when 4 fish per pound were used instead of 20 fish per pound.
A: Most hatcheries have cold water and have a problem getting fish to that size. If there is fast growth, there are more precocious males. Getting larger fish is a good problem to work on.

Q: Did you look at growth rates or mean size in Carson fish?
A: There was no difference in mean size within brood years in the different treatments at release. This was surprising to see in so many raceways. The fish had the same feeding levels.

Q: If you lowered the flow but added more ponds, what would you see?
A: We didn't get into that because of variability with the different brood years. Flow is more significant at higher densities.

Q: What was the level of BKD?
A: In the Carson study, Brood-Year 1 had no mortalities from BKD, and only about 2-2.5% in Brood-Years 2-3, even though there was much higher BKD incidence. At present, we see different mortalities in different ponds. This is the first time we have noted interpond differences in mortality due to BKD. We would have to do studies with many brood years.

Q: In 100 years there is still no standard raceway, which makes it difficult to compare data--why are these still so different? Is it required because of species differences?
A: I don't know, but there may be a strong element of fashion and personal preference in this. It would be good to test various types of ponds. It is true that water supplies vary with siltation, etc., and perhaps different types work better than others in certain situations.

Q: Regarding your loading densities, High, Medium, and Low--is Medium the normal loading?
A: I understand that Medium was the normal loading for Cowlitz and Carson, and that at Carson this was 40,000 fish at 400 g/m.
Comment: This is the same as the loading at Elk River Hatchery.

Q: Was the diet the same for the whole year?
A: At Carson, the fish were started on OP4. Later, some BKD problems were suspected to be related to diet, so this was switched to OP3. The mortalities went down, so we stayed with OP3. I don't recall the diets in the other studies.

INBREEDING DEPRESSION, LOCAL ADAPTATION, AND OUTBREEDING DEPRESSION IN SALMON STOCKS: SOME IMPLICATIONS FOR HATCHERY MANAGEMENT

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Of concern both to hatchery managers and advocates of protecting wild salmon stocks are three genetic processes:

1) <u>Inbreeding</u>. Inbreeding leads to increased homozygosity, occasionally involving loss of alleles and increased expression of deleterious and lethal genes. Inbreeding also decreases genetic variability (i.e., genetic polymorphism) via drift in depressed populations, thereby diminishing resilience to environmental stress in wild populations.

2) <u>Local Adaptation</u>. One way to reverse losses in heterozygosity and genetic polymorphism is to introduce fresh genetic material from other sources (Ricker 1972). Unfortunately, this remedy has drawbacks. First, each wild stock and, to a lesser degree, each hatchery stock can be expected to have adapted genetically to local conditions. Therefore, introductions result in the mixing of local fish with others, which, in their new surroundings, are almost invariably inferior. Data supporting this assertion for salmon have been published recently by Reisenbichler (1988).

3) <u>Outbreeding</u>. Introducing new genetic material to a gene pool usually results in developmental disruption. Picture the genome of a given stock as a well-integrated configuration of interacting genes. Much as a computer program directs a computer to perform some task, these genes, working in concert, direct development, predisposing individuals of that stock to certain physiological and behavioral responses to their environment. By analogy, think of that stock's genome as a FORTRAN-IV program, the genome of an invading stock as a program in some other language. In the first, hybrid generation, offspring will possess both programs. Development of the hybrid might benefit from the double set of instructions, one better in directing the development of one set of instructions, one better in directing another set. On the other hand, parts of one (recessive alleles) may be masked by parts of the other (dominant alleles), and one set of instructions might interfere with the reading or execution of the other. Therefore, unless the two instruction sets are very similar (two versions of FORTRAN, for example), we might expect confused development and, consequently, lower fitness.

With recombination in the second generation, bits of one program will be mingled into sections of the other, and directions to the developing embryo are likely to be hopelessly jumbled, even with similar programs. As the two languages increasingly diverge, the problem can be expected to get worse.

Mixing fish stocks, by an analogous, genetic argument, is likely to result in diminished survival, growth, reproductive capacity, or all three in the F2 generation and beyond, even if the F1 shows hybrid vigor. And unless parental stocks are quite similar, even the F1 generation may display decreased fitness.

The purpose of this paper is to explore the net effects, over time, of these three genetic processes--inbreeding, local adaptation, and outbreeding--on the following:

1) Fitness of hatchery stock initiated with males from one source, females from another, and

2) Fitness of one population experiencing periodic immigration from another.

The Model

Consider a structural gene locus with two alleles, and suppose that the effects of these alleles are modified similarly by genes at two epistatic loci. Established genetics theory tells us that we can expect the alleles imparting greatest fitness to show dominance at all three loci. In addition, we can allow for varying degrees of overdominance at the structural gene locus. Now imagine an ecological gradient along which the relative fitnesses of the structural gene alleles change linearly. Such a model possesses only three (nonscaling) input parameters:

1) Relative breeding values of the two structural locus alleles at the gradient extremes,

2) Impact of the modifier alleles on structural gene breeding values, and

3) Degree of overdominance at the structural gene locus.

The model was designed to simulate changes in gene frequency and consequent changes in fitness. Computer runs using a full, factorial array of (biologically reasonable) extremes showed output to be extremely robust to variation in input parameter values. In addition, results indicate that output would be changed only minutely by the incorporation of additional modifiers into the model. Finally, the impact of fitness is essentially the same whether the gene complex modelled acts alone or as part of a polygenic system. Hence, the results obtained can be considered quantitatively as well as qualitatively applicable.

In support of the model, predictions of hybrid fitness as a function of genetic distance fit observed data (Reisenbichler, unpubl. manuscr.) almost perfectly.

Numeric output will be provided elsewhere in a more rigorous and detailed presentation. In brief, results are as follows:

Scenario I: Hatchery stock initiated from local males (or females) and introduced females (or males).

1) If genetic distance (see above) between parental stocks is small (below about 0.4), fitness in the first, hybrid generation can be expected to be similar to that of the local stock. There is a slight depression in fitness, but this is likely to be compensated, or even overcompensated, by the reintroduction of lost alleles.

2) Genetic distance tends to cluster around two values, near zero and near one. This means that as one moves farther and farther afield (in ecological/genetic type) to

find breeding stock, drop-off in F1 fitness follows very nearly a step function. Therefore, inasmuch as geographic distance correlates to ecological/genetic distance, nearby stocks generally may be mixed with no adverse effects. Mixing may even be advantageous. But beyond some critical distance, crossbreeding will result in an approximately 50% drop in fitness. Initiating such stocks would be decidedly unwise.

3) Hybrid vigor is invariably reversed in the F2 generation and beyond, even for very similar genetic stocks. For similar stocks, relative F2 fitness is about 95%; for diverse stocks, 50-60%. Gradual recovery follows due to local adaptation; 90% relative fitness is achieved, even for stocks with diverse parentage, by around generation 25. Practically, however, given the long life-histories of most anadromous salmonids, recovery is not a practical expectation.

Scenario II: Wild populations are invaded, or hatcheries are periodically refreshed with other stock.

Gene flow precludes effective adaptation. Thus a periodic influx progressively lowers fitness until about generation 5, at which point an equilibrium is reached. Here, unlike in Scenario I, strays (or donors) even from very similar stocks can produce deleterious effects. For example, if relative performance of the (pure) transplanted stocks is 80% (i.e., has a genetic distance of 20%), fitness of the recipient population drops 20% by generation 5. For very dissimilar stocks (relative performance = 20%), an equilibrium is reached at 30% of the fitness realized in the absence of mixing. In general, it is not advantageous to mix stocks on a periodic basis.

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QUESTIONS AND ANSWERS*

Q: How does this relate to supplementation strategy, where there is an annual infusion of a locally-adapted stock into the hatchery broodstock? Would you stay close to the optimum fitness?

A: If fish are brought in every year or so, you would still have effects of past breedings, where old genomes are being reshuffled in the progeny. Each individual stock may be alright, but the F2 fraction may not be as fit. One would expect deterioration.

Q: Even if the initial distance was not far apart?

A: It would have to be very close. It is clear that there is a point beyond which it would not be a good idea; it is still an open question.

Comment: The population of concern is the population to be supplemented. One would have to use a local stock in these programs.

Comment: Yes, one would have to keep infusing local wild stock into the hatchery gene pool.

Comment: One sees the F2 outbreeding depression in experiments with other animals as well as plants--e.g., sagebrush hybrids that are killed by aphids in a narrow zone between the parent sagebrush stocks.

A: In these cases, the model might not be appropriate for such close situations. Fitness is a function of the environmental gradients. This is defined by relative fitness of local stock compared to that of a foreign stock in that local environment. There are not a lot of data on this so far--one cannot say what is "near" and what is "large."

Q: You indicated a moderate increase in fitness for the F1--is that the level of improvement or would you expect more? Is it better to maintain pure parent stock and only produce F1 to harvest, and never get F2?

A: If you did catch all F1 and still have a way to get parents back; but how to do this? Also, the F1 would in some way not be allowed to breed. One wouldn't see a two- or threefold increase in fitness.

Comment: Unless the returns were to facilities right on salt water, one wouldn't get all F1 accounted for.

Comment: You could sterilize all F1--but one wouldn't expect a great increase in fitness, unless they were highly inbred strains to start with. But it would be difficult to maintain these.

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* In the absence of the author, this paper was presented and the questions answered by Dr. Robin Waples.

BIOLOGICAL MANIPULATION OF MIGRATORY BEHAVIOR: THE USE OF ADVANCED PHOTOPERIOD TO ACCELERATE SMOLTIFICATION IN YEARLING CHINOOK SALMON

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Hydroelectric development on the Columbia and Snake Rivers has created conditions which adversely impact juvenile salmonids (smolts) as they migrate seaward. The dams themselves exact their tolls directly by killing fish passing through turbines and spillways. Indirectly, the impoundments created by dams affect smolt survival by altering natural spring flow patterns resulting in delayed migrations and protracted exposure of smolts to predators. In drought years, smolts run the additional risk of mortality due to deteriorating environmental conditions, particularly increased water temperature.

To expedite the migration of smolts through the river system, particularly in low flow years, the Northwest Power Planning Council established a Water Budget Program. This program calls for strategic releases of water from storage reservoirs in an effort to flush smolts through the system. However, young salmon may not fully respond to such efforts if they are not physiologically prepared to migrate. There is evidence that coho salmon (Oncorhynchus kisutch) migrate at different rates depending on their level of physiological development within the transformation from parr to smolt. Juveniles in the more advanced stages of smolt development exhibited the highest migration rates.

In 1988, the National Marine Fisheries Service initiated a pilot study to determine the feasibility of manipulating physiological development and associated migratory behavior of juvenile spring chinook salmon (O. tshawytscha). Results from that study were encouraging. A treatment group, exposed to a photoperiod cycle advanced by 3 months, developed earlier physiologically and migrated slightly faster than a corresponding control group. These positive results led to an expanded research effort in 1989.

The second year of research, funded in part by Bonneville Power Administration, was conducted at Dworshak National Fish Hatchery. The basic study design included four treatment groups and a control group (approximately 2,300/group). The experimental groups were reared in hatchery raceways under controlled light and temperature conditions. The controls were reared under ambient outdoor light conditions. The treatments were as follows:

1) 18-week exposure to a 3-month advanced photoperiod cycle, and during the final 14 days, the water temperature was increased from ambient (4.5°C) to 11°C.

2) 14-week exposure to a 3-month advanced photoperiod cycle.

3) 18-week exposure to a 3-month advanced photoperiod cycle.

4) 18-week exposure to a 4-month advanced photoperiod cycle.

Physiological development was evaluated using gill Na^+-K^+ ATPase and thyroid hormones as indices. Members from each group were tagged with passive integrated transponders (PIT tags). PIT-tagged individuals provided detailed information regarding migratory behavior. A portion of the control group and the 18 week/4-month advanced treatment group were also freeze branded. The brand enabled us to visually identify each group at hydroelectric index sites and to sample fish for physiological data. Mark-recovery data were obtained at Lower Granite and Little Goose Dams on the Snake River and McNary Dam on the Columbia River.

At this time, physiological assays are still being processed; consequently, only mark-recovery data from PIT-tagged fish are available to characterize migratory behavior. Results indicate that fish from all four treatment groups migrated faster inriver than fish from the control group (Table 1, Fig. 1). Consistently, Treatment 1 yielded the fastest migration. Fish from this group were exposed to a 3-month advanced photoperiod cycle for the longest time (18 weeks) and subjected to a temperature increase for 14 days prior to release. The median travel time for that group was 7, 8, and 9 days earlier than the controls at Lower Granite, Little Goose, and McNary Dams, respectively (Table 1). Based on the median travel time, fish from the Treatment 4 group exhibited the least effect, yet still arrived 5, 4, and 5 days earlier than the control group at the same three dams, respectively (Table 1, Fig. 1).

The effect of photoperiod treatment, with or without an accompanying temperature increase, is also apparent in terms of the percent of marked fish recovered. Overall, fish from all the treatment groups were recovered in higher proportions than fish from the control group (Table 2, Fig. 2). Treatment 1 displayed the most pronounced response with 57.8% of the tagged fish recaptured. This was significantly higher ($p < 0.001$) than the 47.2% observed for control fish, and equates to a 22.5% increase in fish collected in the bypass system.

Increased recovery could be due to improved survival or increased guiding efficiency at the recovery sites. Shorter inriver migration times resulting in reduced exposure to predatory fish could account for some increased survival and hence increased recovery of treatment fish. Alternatively, treated fish may be guided into bypass systems in greater proportion than untreated controls--we have additional evidence which suggests that yearling chinook salmon which were more advanced in terms of smolt development are also more susceptible to guidance by submersible traveling screens. Improved fish guidance means that fewer fish pass through the turbines, thus avoiding mortality associated with those devices. Also, because more fish are collected in the bypass systems, more fish are available for barge or truck transport around hydroelectric dams. The extent to which either increased survival or increased fish guiding efficiency accounts for the observed high recovery proportions of treated fish is uncertain. Nevertheless, regardless of the mechanism, a benefit is realized. Higher fish survival during inriver migration means that more fish enter the ocean. All other things being equal, adult salmon contribution should increase.

The next phase of research will attempt to assess the benefits of these treatments in terms of adult contribution. Inriver evaluations similar to those described will be coupled with a coded-wire tagging effort to measure adult contribution to the various

Table 1.--Travel time and migration speed of PIT-tagged spring chinook salmon released at Dworshak National Fish Hatchery on 29 March 1989. Recovery sites were at Lower Granite, Little Goose, and McNary Dams.

Recovery site	Experimental group No.	Experimental group Condition*	Median travel time (days)	Mean migration speed from hatchery to recovery site (km/d)
Lower Granite	1	18 wk/3 mo + T	23.6	4.8
	2	14 wk/3 mo	24.2	4.6
	3	18 wk/3 mo	24.7	4.5
	4	18 wk/4 mo	25.8	4.2
	5	Control	30.9	3.7
Little Goose	1	18 wk/3 mo + T	26.6	6.2
	2	14 wk/3 mo	29.2	5.9
	3	18 wk/3 mo	29.9	5.7
	4	18 wk/4 mo	30.2	5.7
	5	Control	34.4	4.9
McNary	1	18 wk/3 mo + T	33.4	9.7
	2	14 wk/3 mo	36.8	9.0
	3	18 wk/3 mo	36.8	8.8
	4	18 wk/4 mo	37.0	8.6
	5	Control	41.9	7.8

* Fourteen- or 18-week exposure to 3- or 4-month advanced photoperiod cycle, with and without increased temperature (T).

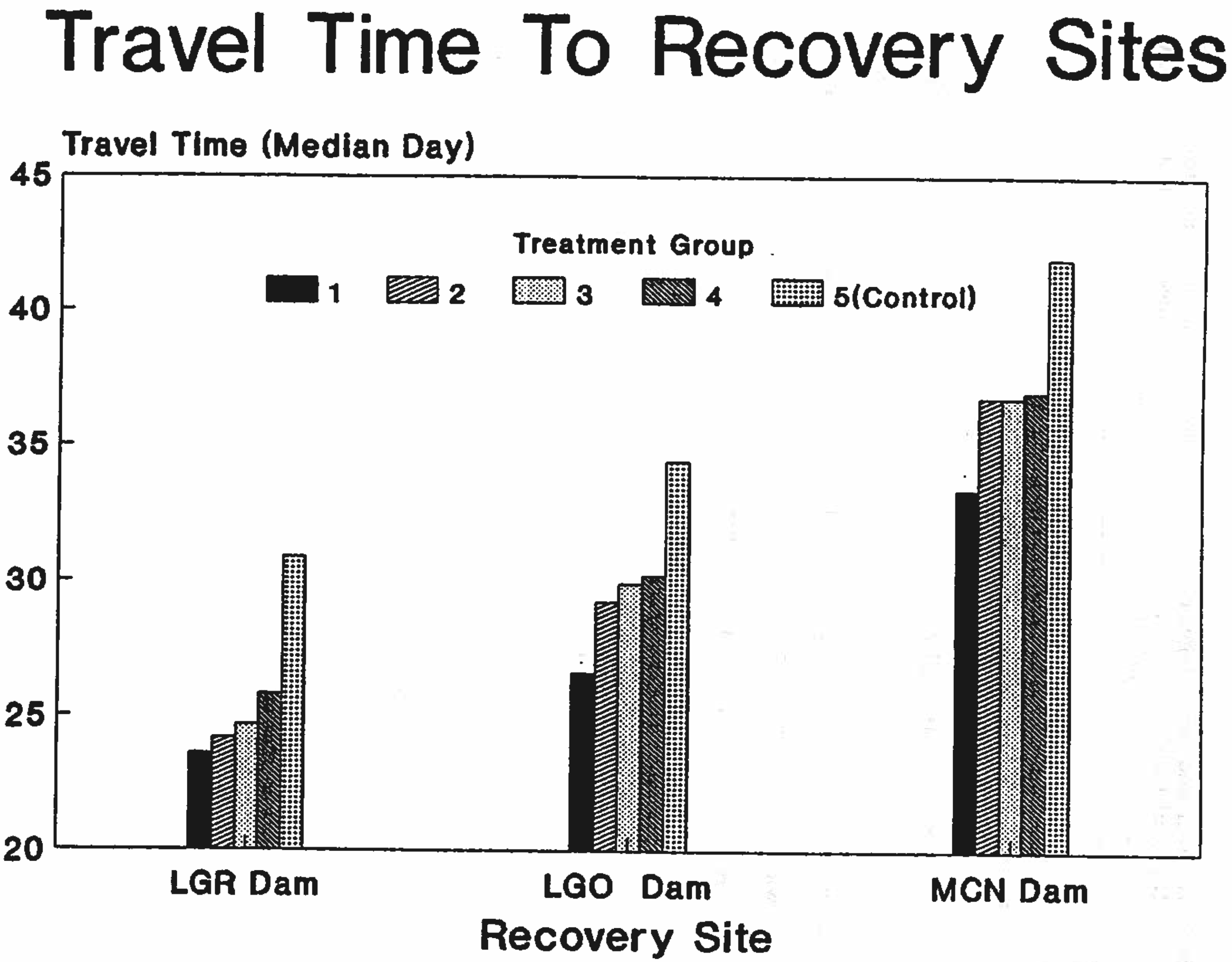

Figure 1.--Median travel time of experimental groups from release at Dworshak National Fish Hatchery to recovery at Lower Granite (LGR), Little Goose (LGO), and McNary (MCN) Dams. Data are based on recovery of PIT-tagged fish.

Table 2.--Number and percentages of PIT-tagged spring chinook salmon from Dworshak National Fish Hatchery which were recovered at Lower Granite (LGR), Little Goose (LGO), and McNary (MCN) Dams, 1989.

Experimental group		Recovery site							
		LGR		LGO		MCN		Total	
No.	Condition	No.	%	No.	%	No.	%	No.	%
1	18 wk/3 mo + T	746	33.7	404	18.2	129	5.8	1,279	57.8
2	14 wk/3 mo	647	27.6	442	18.9	151	6.5	1,240	53.0
3	18 wk/3 mo	621	26.7	369	15.9	149	6.4	1,139	49.1
4	18 wk/4 mo	637	28.1	352	15.5	131	5.8	1,120	49.4
5	Control	666	28.0	327	13.8	128	5.4	1,121	47.2

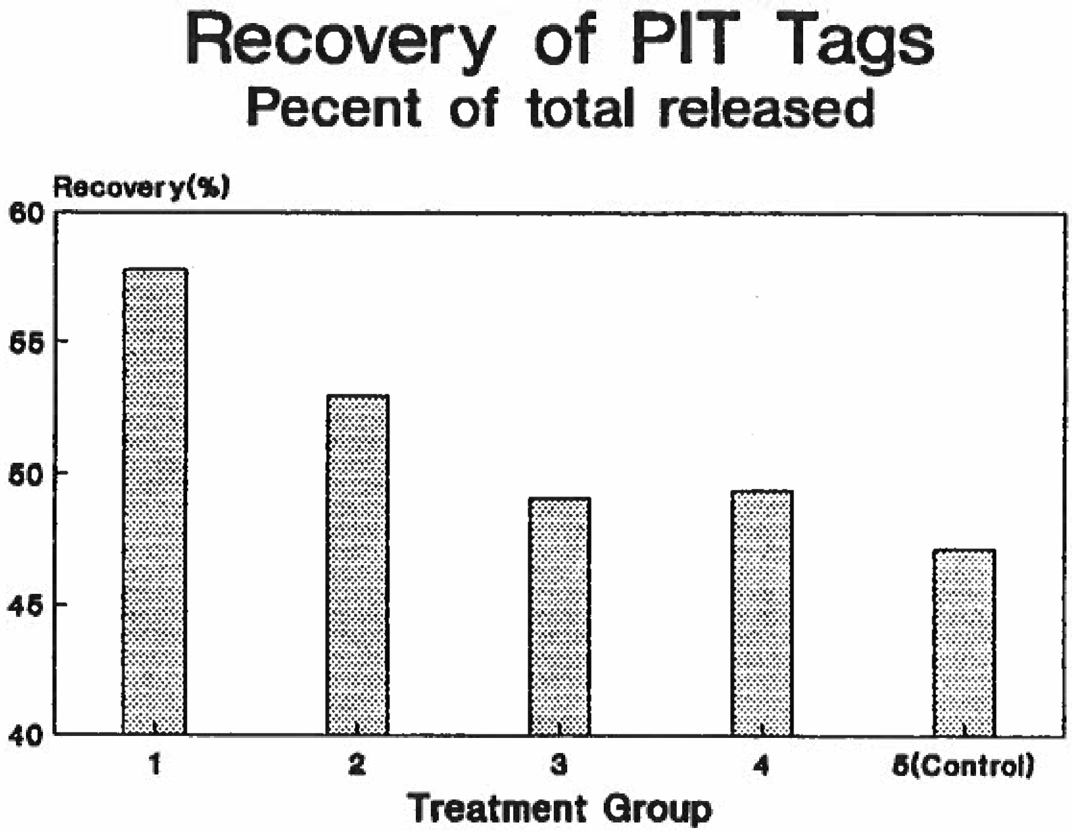

Figure 2.--Recovery of PIT-tagged fish from experimental groups released at Dworshak National Fish Hatchery. Data presented are for all tagged fish recovered at all three recovery sites.

fisheries and hatcheries. To date, all of the research has been conducted at a single hatchery. Future investigations will include additional hatchery sites in the Snake-Columbia Basin.

QUESTIONS AND ANSWERS

Q: Was your temperature boost constant or were the fish acclimated and then maintained at the higher temperature?
A: Acclimated over 24 hours and then maintained.

Q: If we don't match peaks of release, aren't we exacerbating a bad situation if we only have so much water on the low flow years--by trying to shift timing to earlier releases?
A: Possibly. Maybe one could delay releases to maximize responses for survival. In the upper drainages, transport programs attempt to separate species and stocks and treat them differently. One could do this in a variety of ways. We will be looking at this year's data to see if various treatment groups reacted differently to flows.

Q: Have you matched daily flows with treated fish and controls?
A: We have the data, but they are not yet analyzed.

Q: Are there size effects?
A: We are still looking into this; we have only preliminary data.

Q: Would a sharp peak with faster migration be desirable within the transportation program? It appears that this is already crowded.
A: Possibly this could be worked out with the Fish Transportation Oversight Team.

Q: Would the photoperiod acceleration have any effect on saltwater transition?
A: We don't know. It should be a benefit, but we await adult return data which could show this. We can do a lot toward changing these fish and adapting them to a more efficient passage or transportation system. Each complements the other, and we need a holistic approach.

Q: In the percentage recoveries, the photoperiod treatments alone showed no differences from the controls, only when temperature was a part of the treatment. How about all temperature and no photoperiod treatment?
A: I agree that it looks like this, but one photoperiod alone did show a significant difference. We also had a temperature-only group, which I did not show, but it did not even do as well as the controls.

SESSION IV

Habitat Enhancement

Session Chair: S. H. Smith
Bonneville Power Administration

EXPECTATIONS FOR SPRING CHINOOK SALMON POPULATION RESPONSES TO HABITAT ENHANCEMENT PROJECTS IN NORTHEASTERN OREGON

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Extensive effort and large sums of money are being expended throughout the Columbia Basin to enhance spring chinook salmon (Oncorhynchus tshawytscha) habitat. Some misconceptions exist regarding the near-term natural production benefits that will result from habitat enhancement projects in subbasins of the Snake River.

The Grande Ronde Subbasin serves as a good example to examine the theoretical potential for increasing spring chinook salmon production with habitat enhancement. Historically this basin supported large runs of spring chinook salmon (Van Cleve and Ting 1960; Smith 1975). Although accurate estimates of spawning escapement are not available, escapement has been indexed annually since the 1940s by enumeration of redds. Peak escapement occurred in 1957 when an average of 21.1 redds/km were observed (Thompson and Haas 1960; Oregon Department of Fish and Wildlife 1964-86). Spawner escapement remained fairly stable from 1964 to 1973 (range 6.5-10.8 redds/km), well below the peak in 1957. Escapement declined sharply in 1974 and has remained severely depressed (Fig. 1). There have not been substantial reductions in spring chinook habitat quantity or quality since the mid-1950s, when production levels were high; therefore, the reduction in population numbers cannot be attributed to degradation in rearing and spawning habitat. Population decline has occurred primarily due to reduced smolt outmigrant survival caused by major flow and passage alterations in the Columbia and Snake Rivers.

The eight dams that exist between the Grande Ronde River and the ocean impose a major density-independent mortality that has caused a substantial reduction in recruits per spawner at all spawner abundances. When we examine Ricker-type hypothetical stock-recruitment curves (Ricker 1975), we would expect that, as the density-independent mortality rates increased with the construction of each dam, the stock-recruitment curve would shift downward (A toward C in Fig. 2) with the equilibrium population size decreasing correspondingly (Junge 1970). This type of population response was observed for John Day River spring chinook salmon. Lindsay et al. (1986) reported significant declines in recruit-per-spawner ratios as dams below the John Day River were completed. The recruit-per-spawner ratio at equal spawner abundance levels was significantly less for the 1970-79 broods than for the pre-1970 broods. These changes in the population dynamics were attributed to decreased smolt survival that resulted from completion of John Day Dam and expansion of The Dalles Dam powerhouse. Over the past 15 years, the spawner escapement in the Grande Ronde Basin has been so low that the spawning and rearing habitat has been underutilized. Because of low densities, the egg-to-smolt survival rates have been approaching the theoretical maximum for this basin, with little density-dependent survival effects.

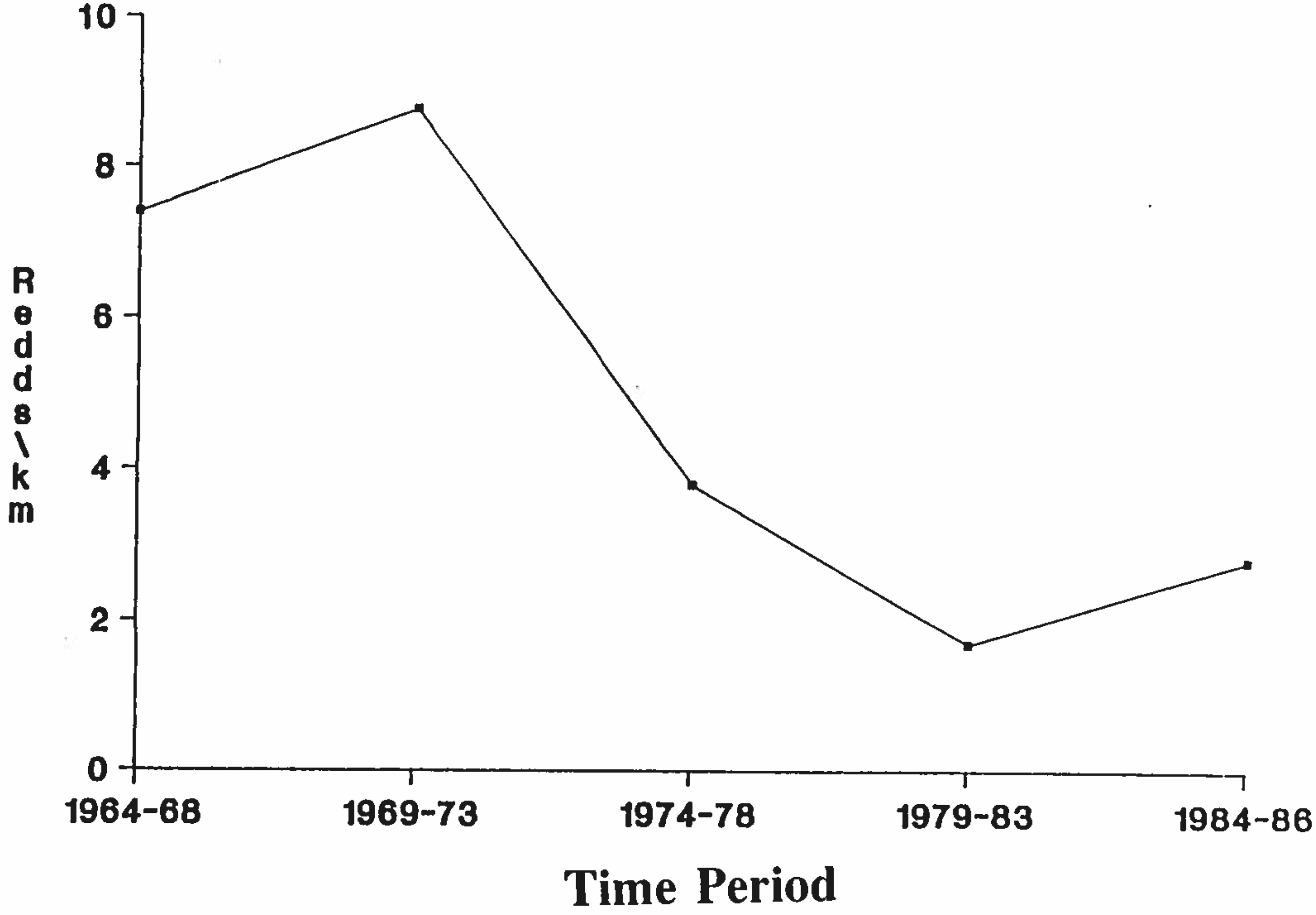

Figure 1.--Spring chinook salmon redd counts in the Grande Ronde River Basin for the years 1964-86. Data points are 5-year averages.

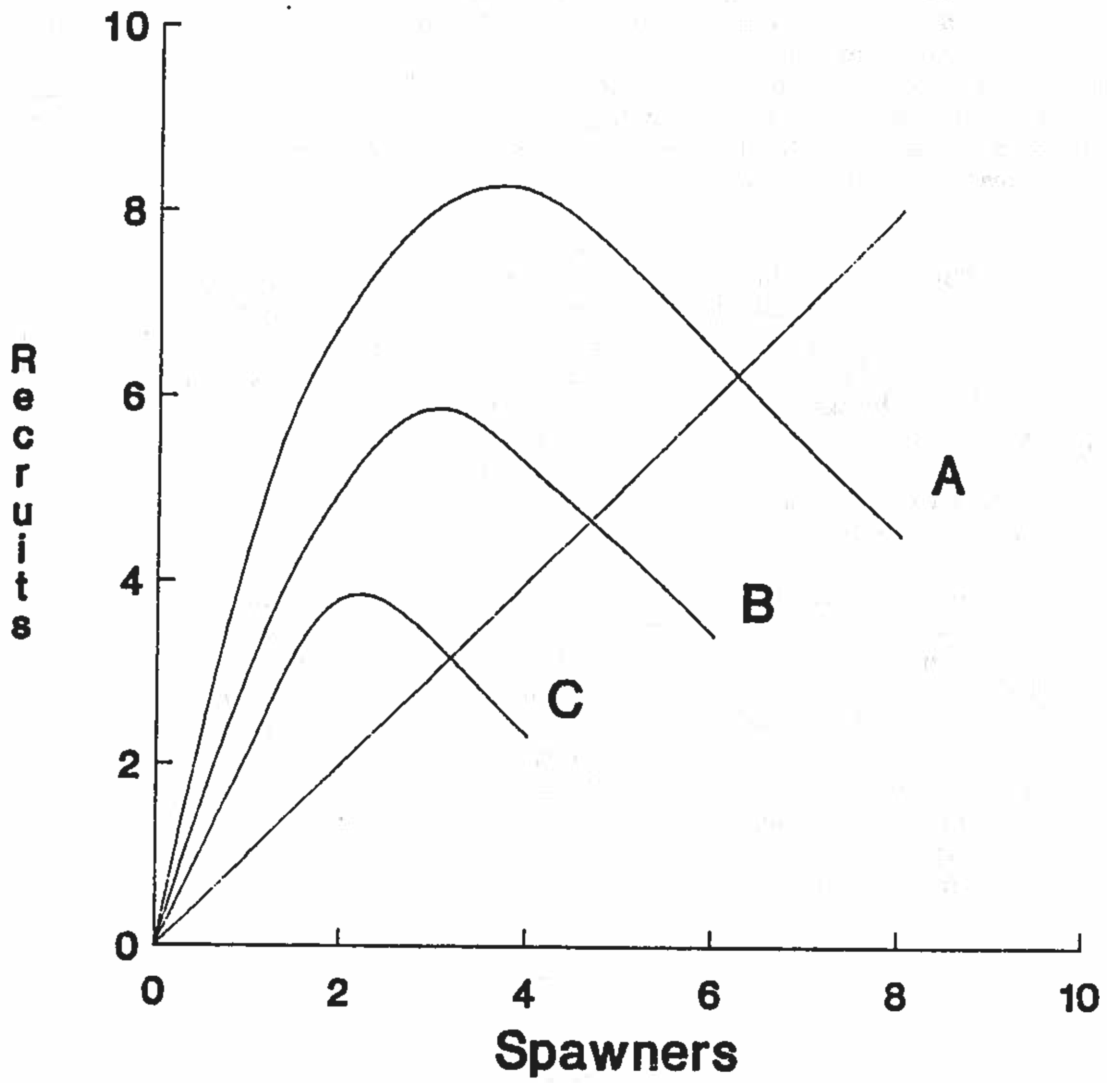

Figure 2.--Hypothetical Ricker-type stock recruitment curves.

There is some evidence that the freshwater habitat in the Grande Ronde Basin is not currently limiting production. A large part of the spring chinook habitat is in wilderness areas in the Minam and Wenaha Rivers (Carmichael et al. 1986). The habitat in these drainages is relatively pristine and the quality is far superior to habitat quality in other drainages throughout the basin, which has been degraded for many years by a variety of land use activities. If the freshwater habitat was limiting production, we would expect the streams in the wilderness areas to support higher chinook production levels than equal-size streams with degraded habitat. Higher spawner densities were observed in wilderness habitat from 1964 to 1973; however, since 1974, redd densities in the wilderness habitat have been consistently equal to redd densities in the degraded streams (Fig. 3).

The habitat enhancement work that is ongoing can be categorized into two general areas, stream channel morphology alteration and riparian habitat recovery. I am unaware of evidence that indicates significant habitat improvement benefits from physical alterations of channel morphology; however, improved riparian habitat does result in improved habitat quality and increased carrying capacity (Platts 1981; Bottom et al. 1985). Even though habitat quality will be improved in the Grande Ronde Basin through riparian habitat protection and enhancement programs, spring chinook natural production will not increase significantly as a result until natural spawning escapement increases substantially. Other species of anadromous and resident fishes may benefit from habitat enhancement.

It would be negligent and shortsighted to discontinue habitat protection and enhancement work because near-term benefits will not be realized. It is critical to protect and enhance habitat for the long-term benefits. Riparian habitat recovery will take many years for severely degraded streams. Any reductions in habitat quality could result in reduced freshwater survival and cause populations on the edge of extinction to become extinct. Work will continue in the Snake and Columbia Rivers to improve smolt survival, and with improved smolt survival the recruit per spawner ratios of these depressed populations will rebound. We must remain optimistic that the productivity of upriver spring chinook salmon populations will be restored and the habitat will be fully seeded in the future.

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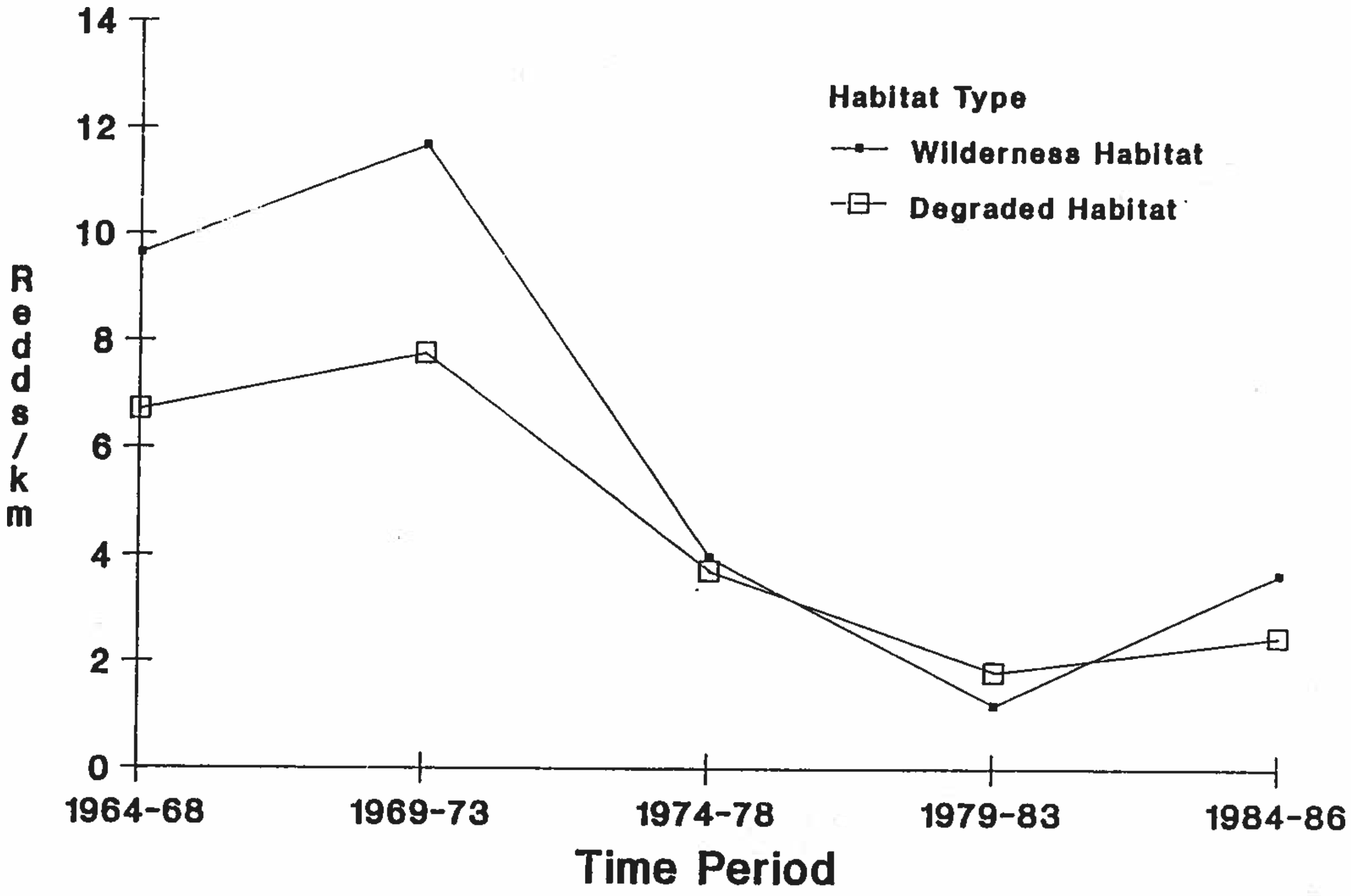

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QUESTIONS AND ANSWERS

Q: When you say that current levels are 10% seeding, is that based on a few places having most or is there some throughout the system?
A: This is based on snorkel monitoring of 200 transects statewide. These index transects were not random, but established to monitor progress on BPA programs. Because they were not random, perhaps the seeding level is not a true average. Maybe the figure is too high, because the investigated habitats were better than average.

Q: Are the fish clumped where they do well?
A: This is probably the case--that is why we don't see more response to improved habitat. The fish have not distributed fully outside of those areas. Parr seem to be clustered in certain prime areas.

Q: Regarding the density-dependent values on survival--one doesn't need full seeding to get a potential of 11 million smolts. Increased survival would lead to that. What level of seeding is actually desirable?
A: About 40 to 50%

Q: Is percent seeding vs. survival based on actual data, or on other subbasins?
A: It is based on monitoring of parr density--any data we have plus data from any other similar subbasin. The shape of the curve might differ if it was based only on Idaho, but these are data used in the subbasin planning for the Salmon and Clearwater Subbasins.

EVALUATION OF RIPARIAN HABITAT REHABILITATION

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Prior to significant white settlement (1850), the Snake River Basin supported annual salmon runs of about 1.75 million returning adult fish. Now, only about 100,000 enter this basin each year. For the past 45 years, stream (riparian[1]) repair projects have been going on within this basin to enhance salmonid fishes.[2] If riparian condition is not a limiting factor and everything was going right over the last 45 years in riparian rehabilitation the results would have shown by now--but they have not. We know that riparian habitats are badly degraded. Platts (1986) gave reasons why riparian habitats were in worse condition in 1986 than at any other time since Europeans entered the western United States. The drought conditions over the Snake River Basin during 1987 and 1988 further exacerbated the situation. Even though riparian habitats are in poor condition overall, water flow management continues to override in importance in the riparian ecoystem.

Riparian Repair on Water Flow Management

One of the major focuses of attention in the upper Snake River Basin has been on channel and bank repair, while the primary factor affecting declines in chinook salmon populations can be attributed to practices affecting water flow regimes.

The fate of chinook salmon in the Snake River Basin today lies not in how many logs or boulders can be dropped into the channel, but depends upon those flow regimes and flow conditions needed to take juveniles to the ocean. Secondarily, their fate is intertwined within land stewardship in the upper drainage rearing areas. I have argued for many years that good land stewardship will produce more, and at less cost, than the benefits from placing gabions, logs, and boulders in streams.

Chinook salmon survived quite well under a wide range of natural perturbations in pristine rivers and streams of the Snake River Basin. Undoubtedly the best fishery management scenario, then, is to maintain these habitats in an unaltered condition. This means, whenever possible, to concentrate on buffering or eliminating those watershed impacts that accelerated the decline in salmon populations and the condition of their habitat. These impacts or major limiting factors relate mainly to flow regimes.

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[1] Riparian is defined in this report as most federal and state agencies use the term. Riparian includes the channel, water column, streambanks, and all surrounding vegetation influenced by an almost continual water source.

[2] Riparian repair or riparian rehabilitation are defined in this report as any effort to increase the fish-producing potential of an already degraded habitat. Riparian enhancement is defined as any effort to increase the fish producing potential above what the habitat was capable of producing in any of its naturally occupied states.

There are many flow regime management concepts worthy of review. Those that could improve the status of chinook salmon are

- Purchase or control of uncontracted storage waters;
- Use of water for instream flows from upstream water banks;
- More intensified water conservation and management;
- Water right transfers for fisheries benefits;
- Modification of presently used flood control operations;
- Addition of new water storage facilities for instream flows;
- Changes in instream use designations to favor fisheries.

Funding Priorities

The available money should be spent where it will do the most good and provide a favorable cost-benefit approach (Platts and Rinne 1985). The days of unlimited funding with little supervision of where and on what this money is going to be spent are about over. In the September 1989 meeting of the Idaho Water Resource Board, a representative of a large supplier of hydro-power testified that the Bonneville Power Administration had recently surpassed the $1 billion mark for fisheries mitigation. The purpose of his statement was to question if this expenditure by the rate payers was justifiable and if a product of equal value was ever delivered. Such questions will become more pointed as power surpluses disappear.

With Gramm-Rudman-Hollings Act spending restrictions soon to make drastic changes in revenue end-points, there will be real questioning whether the expenditures of any monies, whether they be federal, state, or private, are justifiable. When tough decisions have to be made--such as, do we cut catastrophic health insurance, reduce programs such as medicare and the aid to the homeless, reduce drug prevention efforts?--so this same money can be spent on an anadromous fisheries program, then mitigation funding decisions become much more critical.

In addition to direct monies being spent on rehabilitation of chinook salmon runs, decisions that have indirect effects are being made on water issues that have wide influence on regional, state, and local economies, and, of course, on major fisheries. For example, the Idaho Water Resource Board has established minimum instream flows at Swan Falls Dam, which effectively limit the amount of upstream agriculture development that can occur in the Snake River Basin. Hydroelectric dams have been curtailed in the Clearwater, Salmon, and Middle Snake Rivers, primarily because of fishery values. There is now even more need to modify additional water resource management strategies in the Snake River Basin to further accommodate anadromous fish requirements. The fishery continues to make more and more demands, and rightfully so, but where is the end point of demand?

My point is that it is extremely important at this time to spend monies very wisely. Misuse of funds on one type of rehabilitation effort now will depress future efforts for more successful rehabilitation.

Stream Repair in Perspective

Habitat enhancement has both positive and negative results. The positive results are

- As methods continually improve there will be more opportunities to maintain a chinook salmon fishery and still utilize the other land and water resources.

- It is often a cheap and quick method by which to attain annual targets and goals.

- Project work can help develop good public relations and provide interesting projects for outside organizations, and, in so doing, creates advocates for good salmon management.

- Salmon numbers can be increased within local areas.

The negative results are

- It can avoid good land stewardship.

- Money is diverted from more worthy projects.

- The watershed approach to fisheries management is ignored.

- It builds carpenters and not biologists by providing easily applied "cookbook" approaches that often do not work.

- The quick fix can be only temporary.

- It leads to site-specific analysis of fisheries habitats only.

Historical and Present Perspective

Riparian repair methods have not changed much, but treatment priorities have changed during my tenure. When I first came on board in the late 1950s, one of the main stream repair methods used was the removal of large organic debris from channels; this method was used through the late 1970s. At that time it was called channel cleaning or channel maintenance and took most of the available fisheries monies. The first channel cleaning project I encountered and spoke out against got me ushered off the District. Some of this thinking is still with us and exemplifies our lack of understanding in dealing with a limited subset of habitat variables and not being able to deal with true limiting factors.

Because we have many streams in the Snake River Basin presently in an artificially stressed state and barely adequate for salmon survival, and other streams that do not naturally provide suitable habitat for salmon, we have streams that lend themselves to some type of riparian rehabilitation. There is a definite need for this stream rehabilitation analysis, however, to be done within a hydro-geologic, contact historic, and futuristic approach, while making sure it is planned under a priority system.

Streams can react violently or slowly to a stress and then naturally rehabilitate themselves quickly or slowly. Those streams with fast recovery times do not usually need monies spent trying to repair them. Those streams with long recovery time or that can never recover need careful consideration.

Long-term records of ecosystem responses to natural or artificial control are rare. Therefore, we have great difficulty visualizing the past conditions or states of a stream. Frequently, people look at a stream in a badly degraded state and firmly believe that it has always looked this way. Historic influence and changes usually go back farther than present minds can comprehend, and easily beyond documentation.

Dealing with the Limitations

Artificial riparian repair never should be used to circumvent the real causes of stream degradation. Pouring time and money into a degraded stream that is going to be continuously disturbed is futile. A decade ago, Binns (1980) recommended that prior to installation of structures, fishing pressure should be evaluated to determine if the project is justified and if shelter is the only factor limiting the population.

Artificial stream repair should not be substituted for vigorous, responsible stewardship of the surrounding watershed. The cop-out for using stream repair in place of good land stewardship has made the overall program much weaker. The many case histories lying around out there back this statement. Also, stream repair must be done in a watershed and even in a basin perspective.

The stream and its watershed function as a unit. If the watershed is not conducive to enhancement, stream repair structures will soon cease to be productive. Few stream repair projects are compatible or fit within the needs of the valley-forming processes. The state of the art for this type of analysis has not kept up with project demand. The real test of a stream repair or enhancement project is not only if it will be cost effective but also whether or not the project survives over time in compatibility with valley-forming processes. The stream must not be divorced from its valley in the analysis.

The point in this long abstract is that it is time for the profession to ask some serious questions and develop well thought out and justifiable answers. Is riparian repair producing a favorable cost-benefit ratio? Would this money be better spent on gaining better stewardship or on the more controlling limiting factors? Is our spending of monies today being done wisely enough that it will not jeopardize future funding sources? Are we integrating spring chinook management into the needs of the complete economic system? These questions should be answered.

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QUESTIONS AND ANSWERS

Q: What is Rule 3.6?
A: It is the water bank rule that limits access of water for fish. The Water Resources Board has legislative authority to make water-use rules; if the water is used for nonconsumptive purposes, whoever sells it must comply with Rule 3.6. The Water Budget is going to go to pieces. Galloway will make it worse. Rule 3.6 takes options away from us.

Q: Can you define proper stewardship for small multi-use streams?
A: To abide by the laws and regulations for the best benefit of the public for all uses. We don't need another law for good stewardship--it is all there.

Q: What can you say about livestock fencing on privately-owned land?
A: This is a good idea for stream repair. But rather than fencing, it would be better to go into long-term <u>other</u> uses for the watershed.

Q: If there are laws on the books, they are obviously not enforced. Where has the breakdown been?
A: I believe that it is in good monitoring--to stay on top of problems, to follow Environmental Impact Statements, to coordinate, to do away with fighting within and between agencies. Stewardship is the one way we have without spending money to get more chinook salmon. Just point to the directions we need to take. There are many opportunities here.

Q: Is there any value in the Upper Bear Valley rehabilitation project?
A: It was not beneficial and it was very costly. There are two things happening in this large project, which is taking $1 million per mile. It has taken over all processes; we will never have another wet meadow. It may destroy other reservoirs. They hauled in large numbers of junipers from Owyhee. The stream is now changing its habitat type. The project is almost futile; it will magnify future problems. Cottonwood would disintegrate faster!

Q: Does this tell us that in the real world we don't have responsibility or authority as fish biologists over land stewardship? These projects occur no matter what we say about Environmental Impact Statements, etc. Where do we go from here?
A: I agree. But the burden has to shift from fish biologists to land managers. It is a long process. Poor judgment in stream repair would take away accomplishments that have been made.

Q: Is there potential for spring chinook salmon habitat improvements, downstream from John Day Dam, for example?
A: Maybe less and less spawner/recruitment effect. There are no great opportunities here. The Grande Ronde is at its theoretical potential; the habitat there has been stable since the 1950s--habitat is not limiting production. Downstream from John Day Dam?--in protection, yes, but we have to know what the limiting factors are.