SPECIAL REPORT TO THE U. S. ARMY CORPS OF ENGINEERS ON TWO REPORTS CONCERNING PROPOSED COMPENSATION FOR FOR LOSSES OF FISH CAUSED BY ICE HARBOR, LOWER MONUMENTAL, LITTLE GOOSE, AND LOWER GRANITE LOCKS AND DAM PROJECTS, WASHINGTON AND IDAHO

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PREFACE

This report is an analysis of the two reports, A Special Report on the Lower Snake River Dams, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite, Washington and Idaho, U. S. Department of Commerce, National Marine Fisheries Service, U. S. Department of Interior, Fish and Wildlife Service Bureau of Sport Fisheries and Wildlife, September 1972[1] and Special Lower Snake River Report for Compensation for Fish and Wildlife Losses Caused by Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Locks and Dam Projects, Washington and Idaho, U. S. Corps of Engineers, Walla Walla, 1973[2].

Subsequent to the agreement to evaluate the above two reports, a third report was made available by the U. S. Corps of Engineers. This report is untitled and can be assumed to be an in-house analysis of the two reports mentioned above. Although not reviewed *per se*, it was used as a resource document.[3]

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1 Hereafter referred to as the Agencies' Report

2 Hereafter referred to as the Corps' Report

3 Hereafter referred to as the Corps' Supplemental Report

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* * *

INTRODUCTION

Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Lock and Dam projects were authorized by Public Law 14, 79th Congress, and were approved March 2, 1945. They were designed to provide slackwater navigation, irrigation, and hydroelectric power generation with the Lower Granite project to provide additional flood protection for the Lewiston-Clark area. Ice Harbor, Lower Monumental, and Little Goose lock and dam projects were completed in 1962, 1969, and 1970 respectively, and the upstream Lower Granite project is scheduled for completion in 1975 (Fig. 1).

The projects are similar in design and operation, and the designs include power plants, navigation locks, recreation areas, and fish passage facilities. The filling of the impoundments involves some railroad relocation and in the Lewiston-Clarkston area, levees with pumping plants will be necessary.

Pool elevations of the projects will vary according to seasonal runoff and with usage, and fluctuations up to several feet daily can be expected. Tailwater fluctuations for power peaking operations may range up to 5 ft in the case of the Ice Harbor project (Table 1), but may range up to 35 ft under flood flows, depending on timing and volume of reservoir releases.

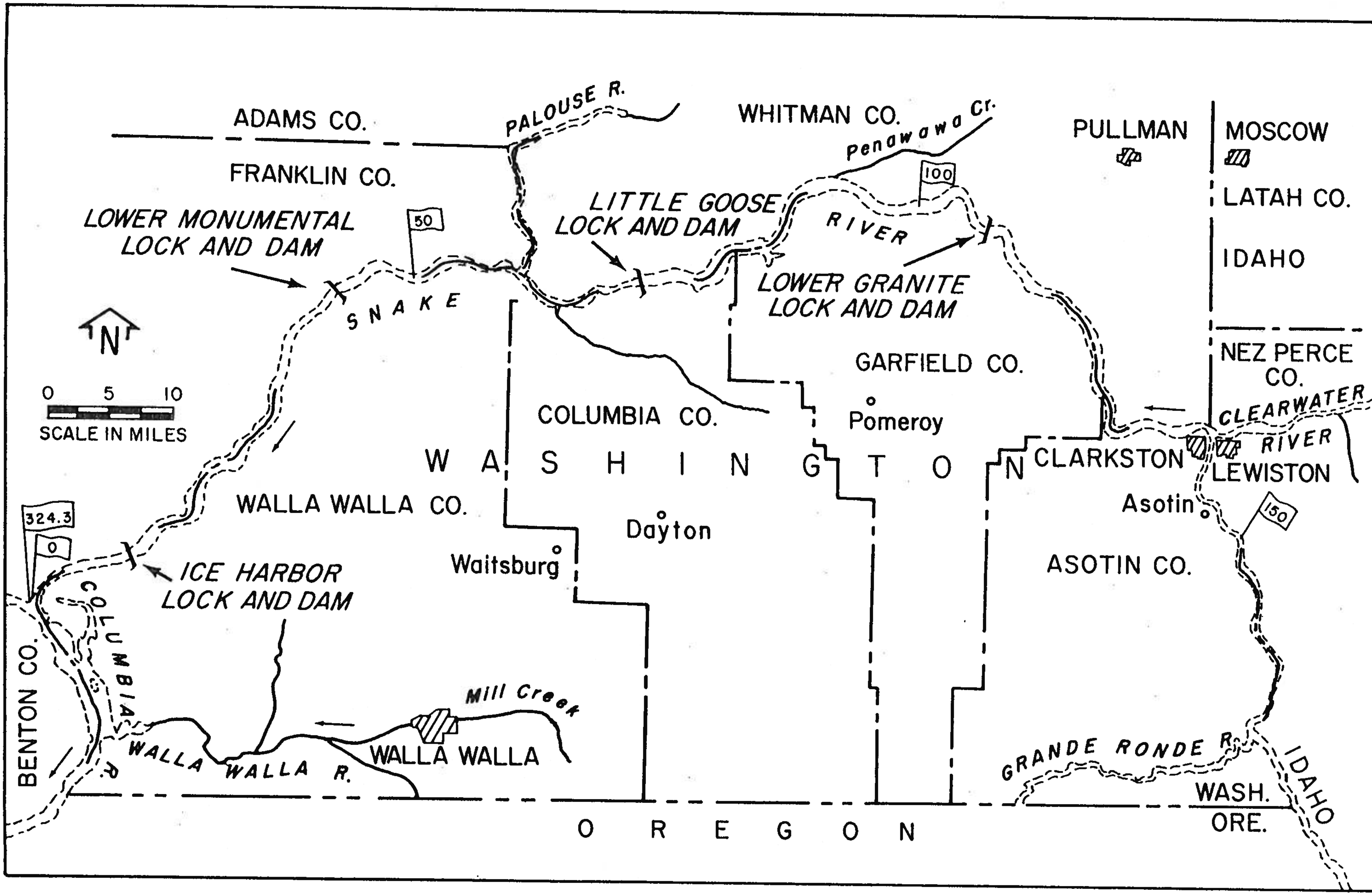

FIG. 1. Lower Snake River projects (from the Corps' Report)

Table 1. Pertinent engineering and operation data, Lower Snake River projects (from the Agencies' Report, p. 6)

Project	Elevation (feet) msl	Capacity (acre-feet)	Surface area (acres)	Stream inundated (river miles)
Ice Harbor				
Normal pool	440	417,000	9,200	35.0
Tailwater	337-342*			
Lower Monumental				
Normal pool	540	377,000	6,590	29.0
Tailwater	374-441*			
Little Goose				
Normal pool	638	565,000	10,025	37.2
Tailwater	357-541*			
Lower Granite				
Normal pool	738	485,000	8,900	39.0
Tailwater	633-639*			
Totals		1,844,000	34,715	140.2

* Tailwater range for non-flood period

PROJECT IMPACTS ON ANADROMOUS AND RESIDENT FISHES AND THE STATUS OF REQUESTS FOR COMPENSATION

The Snake River system is one of the more productive rivers in the United States, and historically has contributed substantially to the anadromous and resident populations of the Columbia River complex. The contribution of chinook salmon, *Oncorhynchus tshawytscha*, to the commercial and sport fisheries of the Columbia River is major, while the steelhead trout, *Salmo gairdneri*, contributes significantly to the support of an extensive sport fishery throughout the lower Columbia and Snake Rivers. The fall run of chinook salmon contributes to both the river and ocean commercial and sport fisheries, while the spring and summer run chinook salmon are harvested principally in the river; their contribution to the ocean fishery is presently unknown.

Principal resident game fish other than the salmonids are the small-mouth and large-mouth bass, white sturgeon, and channel catfish. Of lesser importance to the resident fishery are rainbow trout, Dolly Varden, brown bullhead, mountain whitefish, white crappie, and bluegill. Non-game fish include carp, squawfish, suckers, chiselmouth, and shiners.

The Agencies' Report claims that, prior to project construction, about 5,000 fall chinook spawned in the Snake River below the mouth of the Clearwater River, although accurate counts of the actual numbers of fish spawning in this stretch of river have not been made because of the turbidity of the free-running river. Some information is available from early estimates of spawning ground requirements.

Prior to construction of the project, the lower Snake River supported the largest summer-run steelhead fishery in the state of Washington. The project has changed many of the rapids and pool areas to large, deep impoundments and previous methods of fishing for these large trout are no longer effective, except in the tailrace areas immediately below the dams. An estimate has been made that about 130,000 angler-days annually could have been expended on steelhead fishing over the next 100 years if the project had not been built.

Similarly, the Washington State Department of Game estimated that approximately 250,000 days annually would be spent fishing for the resident fish within the area affected by the projects.

The major effects that the construction of the four dams would have would be the conversion of a free-flowing stream to a reservoir-type habitat, the inundation of the mainstem spawning, and the addition of four obstacles with accompanying hazards to the upstream and downstream migrants. The change from a stream to reservoir condition also alters the character of the sport fishery for the anadromous and resident fish in the project area.

Prior U. S. Fish and Wildlife Service reports on Ice Harbor, Lower Monumental, and Little Goose projects recommended measures to minimize fishery losses on an individual project basis, and according to the Agencies:

> "Such measures were largely limited to upstream fish passage facilities at the dams, spawning channel development, and artificial propagation of anadromous species. Fish passage

facilities have been the only features provided. According to the Corps of Engineers, these facilities were constructed at a cost of $38,844,000. Research is being conducted to develop measures to provide improved conditions for juvenile fish migration at the Lower Snake River dams. The initial measures for minimizing losses to anadromous and resident fisheries were based on insufficient information and were not adequate to maintain these fisheries. Therefore, to maintain the runs of anadromous fish in the Snake River system, and to offset losses to the sport fishery for anadromous and resident species, measures recommended in the early reports must be augmented and accomplished according to the agencies."

The compensation requested by the Agencies is based upon three principal types of impact: (1) losses of downstream migrants at the four projects; (2) a loss of a resident river fishery of high caliber; and (3) the inundation of spawning grounds for fall chinook salmon. Acknowledgment is made of the fact that the collection of the downstream migrants by the use of traveling screens and subsequent transportation by trucks, has definite possibilities of relieving the problems; however, the engineering and biological problems have not been completely solved, and the results are still variable according to species. Thus, the compensation requested assumes a constant loss at each dam.

The requests and justifications for compensation for losses do not include losses due to nitrogen supersaturation, but assume that the problem will be resolved in a reasonably short period of time. Progress in correcting this problem has been very encouraging.

OUTLINE OF THE AGENCIES' METHOD OF DETERMINING AND JUSTIFYING THE REQUESTED COMPENSATION

The Agencies' method of determining the compensation for losses caused by the four Lower Snake River dams consists of the following steps:

1. The Agencies developed a philosophy of compensation for the management of the potential of watersheds (or major sections of the river) rather than by mitigation for losses on a project-to-project basis. For the Lower Snake River, this approach requires an estimate of the potential production of spring chinook, summer chinook, and steelhead trout for the entire watershed.

2. The methods used in determing the potential of the watershed were:

   a. determination of the maximum run size for each species that passed over McNary Dam between 1954 and 1967, and

   b. determination of the maximum percentage of McNary fish that passed over Ice Harbor Dam between 1962 and 1967, and

   c. computation of the number of each species to be maintained as Snake River stocks by multiplying the maximum number passing over McNary and the maximum percentage counted over Ice Harbor (a and b, above).

3. In order to justify the use of maximum McNary counts, they (the Agencies) compared the total runs returning to the Columbia River since Bonneville (1938) with the calculated optimum sustainable runs.

4. The optimum sustainable runs were calculated by:

   a. using optimum escapements determined in the 1950's, and

   b. multiplying the optimum escapements by the return/spawner for the pre-McNary period. During this process, they also developed the return/spawner in the post-McNary years (1957 to 1967) and pointed out the drastic drop in production. They maintained, by inference, that since the calculated optimal runs for the entire river were similar to the maximum runs for the entire river, the use of maximum runs for the Snake were justifiable as optimal.

5. The losses to the fishery (i.e., to the fishermen) were determined by comparing the calculated optimum sustainable yield with the yield that could be expected to be sustained under existing conditions. These figures were used to point out the loss to the fishermen in recent years and under existing conditions, and <u>were not used directly</u> in the calculations for compensation.

6. Compensation for losses of downstream migrant salmon and steelhead trout attributed to the four Lower Snake River dams was estimated by:

   a. assuming a loss of 15% of the downstream migrants of each species at each dam, for a cumulative total effect of 48% for the four dams; and

   b. multiplying the expected run for each species at Ice Harbor by 0.48; then

c. determining the size of hatchery required to replace the losses (derived in 6-b).

7. Using the estimated costs of capital outlay and the maintenance and operation costs of the hatcheries and the benefits accrued from the fish produced, the cost-benefit ratio of the compensation was developed.

8. Compensation for the loss of the fishery for resident fishes other than salmon was computed on the basis of a reduced availability of the more desired species and the contention that reservoir fishing is not equivalent in quality to river fishing.

Prior to project construction, high quality stream fishing existed for bass, sturgeon, and channel catfish. With the impoundments, this fishery has been adversely affected directly by inundation and indirectly by fluctuations of the reservoirs which have reduced the spawning and rearing success of bass and some of the other species. The Agencies estimated that the average annual man-day use of this area during project life would have been 250,000 angler-days, but with the project, the use would become restricted to the species more adaptable to warmer waters. This use is forecast at 205,000 angler-days, for a loss of 45,000 angler-days annually.

The Agencies request for compensation is in the form of a supplemental stocking of catchable-size rainbow trout in tributary streams in areas such as Asotin Creek, Grande Ronde, Tucannon, Touchet, and the Walla Walla Rivers. This would require the construction of facilities capable of producing 85,000 lbs of rainbow trout annually. In addition, the Agencies also consider the factor of the quality of the river fishery in comparison to reservoir fishing, and they use the ratio (which apparently has been established) that 2 days of river fishing is equivalent to 3 days of reservoir fishing, as far as benefits to the state are concerned. This would raise the quantity of trout necessary for compensation to 93,000 lbs.

9. Compensation for the losses to the fishery of steelhead trout within project influence was in the form of replacement in kind and numbers, as well as the acquisition of access to streams supporting good steelhead fishing.

The steelhead trout support an extensive sport fishery throughout the entire Columbia River system and an incidental commercial fishery on the Columbia River. As with the spring and summer chinook, the escapement over Bonneville Dam has remained relatively constant but, as with the salmon, the commercial fishery has been drastically reduced (Fig. 2). According to the Agencies, the sport fishery for steelhead trout has increased during recent times and they projected the 52,000 angler-days annually occurring in the lower Snake River project area before

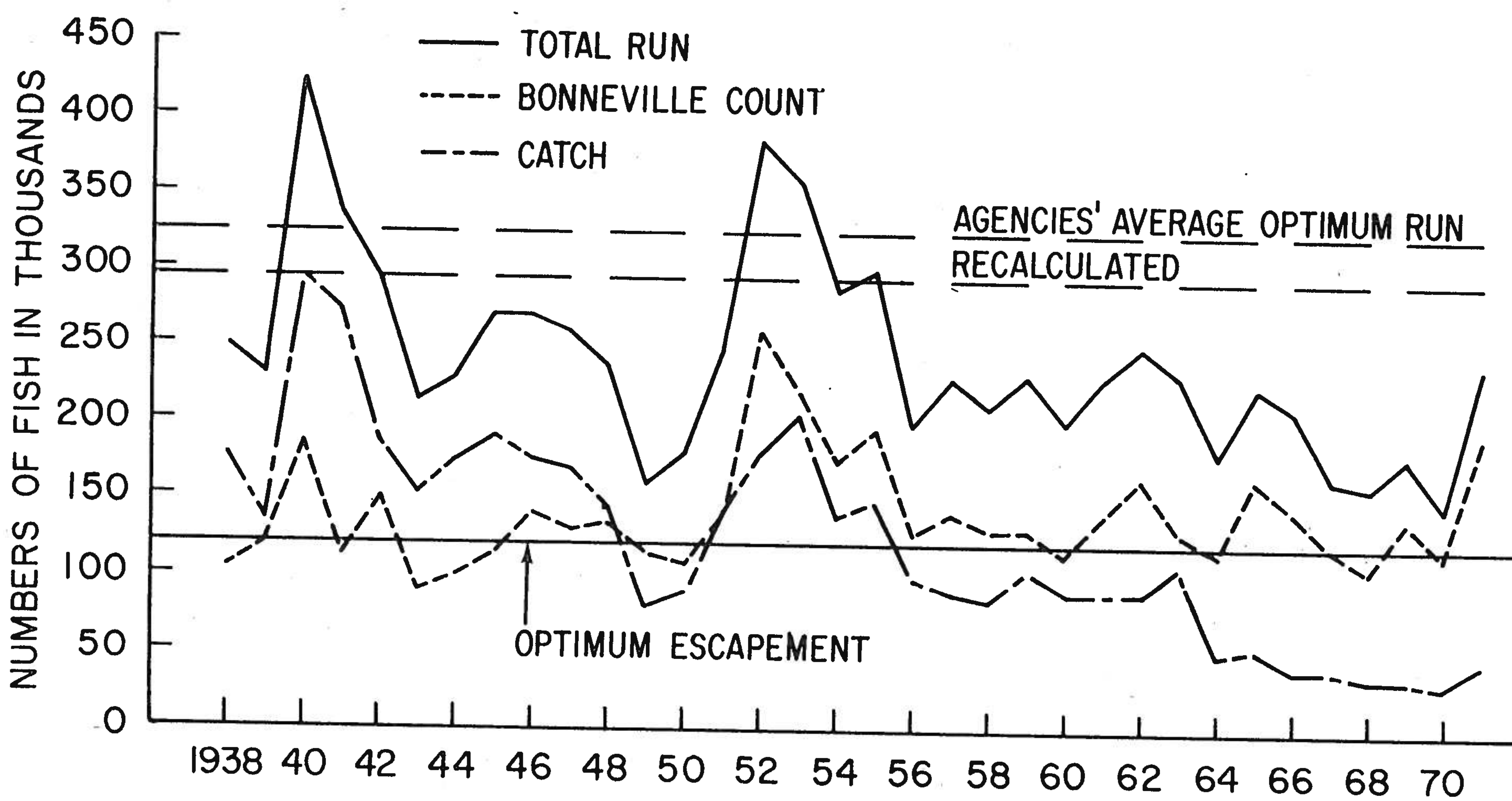

FIG. 2. Status of steelhead trout runs, 1936 - 1971, showing the Agencies' and the recalculated (the author's) values for the optimum sustainable run (modified from the Agencies' Report).

construction to grow to an estimated 130,000 angler-days annually during the 100-year project life--if the projects were not built.

In a procedure similar to that developed for the salmon, the Agencies determined the size of the run to be maintained in the Snake River to be 114,800 steelhead trout (Table 2). Then, to compensate for the estimated loss of 48% to a run of this size due to project causes, it was recommended that hatchery facilities be provided accordingly.

In addition, a sport fishery for steelhead trout has also developed to substantial proportions within the project area. Prior to project development, this fishery was an open river fishery and subsequently, the reservoir conditions have caused the fishermen to become decreasingly effective. With the completion of Lower Granite, approximately 140 miles of stream which was once available to the fishery will essentially be eliminated. The Agencies estimated that this loss is equivalent to the 130,000 angler-days mentioned above.

The Agencies state that there is no known way to compensate for this loss within the project area, so they recommend that either access to tributary streams of high quality be provided on a permanent basis, or that public fishing areas be established by direct acquisition of approximately 150 miles of land averaging

Table 2. Estimated distribution of salmon and steelhead trout runs to Snake River system in percentage and number (revised from the Corps' Report, Table 2)

River Segment	Fall chinook Maximum Count McNary Dam 97,500 (1958) Distribution Percentage	No. of Fish	Spring-Summer chinook Maximum Count McNary Dam 222,100 (1957) Distribution Percentage	No. of Fish	Steelhead Maximum Count McNary Dam 172,600 (1962-63) Distribution Percentage	No. of Fish
Snake River:						
Lwr. Monumental-China Gardens (mainstem spawning)	26.5	8,526			4.0	4,600
Tucannon River			2.0	2,400	3.0	3,400
Clearwater River	0.5	161	0.5	600	37.5	43,200
Asotin Creek					1.5	1,700
Grande Ronde River			10.0	12,200	14.0	15,900
Snake River: China Gardens-High Mountain Sheep	5.5	1,770				
Salmon River			79.5	97,200	30.5	35,200
Imnaha River	0.5	161	5.5	6,700	3.5	4,000
Snake River:						
High Mountain Sheep-Appaloosa	1.5	483				
Appaloosa-Pleasant Valley	5.5	1,770				
Pleasant Valley-Hells Canyon	33.0	10,617				
Hells Canyon Dam Fish Facilities	27.0	8,687				
Small tributaries			2.0	2,500	5.0	5,700
Imnaha River-Hells Canyon Dam	——	——	0.5	600	1.0	1,100
	100.0	32,175 1/	100.0	122,200 2/	100.0	114,800 3/

1/ McNary Dam maximum count 97,500 x 33% = 32,175 (rounded to nearest 100) (68% is the highest percentage of McNary counts over Ice Harbor 1962-67; however, this count has room for doubt so 33%, next highest percentage, was used).

2/ McNary Dam maximum count 222,100 x 55% = 122,200 (rounded to nearest 100) (55% is the highest percentage of McNary counts over Ice Harbor 1962-67).

3/ McNary Dam maximum count 172,600 x 66.5% = 114,800 (rounded to nearest 100) (66.5% is the highest percentage of McNary counts over Ice Harber/fish year 1962-67 adjusted to include estimates of fish migrations during months when no counts were made).

100 ft in width adjacent to certain selected streams. Although they recommend in the report that the lands be acquired through a willing seller concept, their basic objective is to insure, on a permanent basis, access to streams of high quality fishing.

DISCUSSION

1. Analysis of the Concept of Compensation for the Management of the Potential of the Snake River Watershed

The fact that the four Lower Snake River dams were authorized for construction and completion within a relatively short period of time and are scheduled to operate as a system, virtually compels the natural resources of the area to be managed as a unit. Needed are: (a) definition of the boundaries of the watersheds under question, and (b) agreement upon the potential of the watersheds for production of the various species of fishes.

As so often is the case, there are insufficient data to give precise estimates as to the numbers of fish that were produced by the area prior to project development, and the Agencies argue with considerable validity that the size of the existing stocks (which can be considered as depressed) should not be used as a baseline to develop the parameters for compensation. The fact that the current runs are maintained at a near-constant level by increasing restrictions upon the fishery (Figs. 2, 4, and 5) reflect the depressed and, according to the Agencies, unacceptable condition of the runs.

2. The Methods Used in Determining the Potential of the Watershed

The determination of the run size for each species by using the counts over McNary Dam and then multiplying them by the percentage that pass over Ice Harbor is mathematically simple, and sound. The two questions one may have about the procedure are the selection of the counts over McNary and the percentage of these that can be expected to continue over Ice Harbor (see 3, following).

3. The Justification for the Use of the Maximum McNary Counts and the Percentages Used of McNary Fish Passing Over Ice Harbor

The Agencies used the McNary counts from 1954 through 1972 to determine the maximum number of salmon and steelhead trout passing over McNary Dam (Table 3). They then determined the percentage of chinook salmon and steelhead trout counted at McNary Dam that passed over Ice Harbor in the 11-year period from 1962 through 1972 (Table 4). For their calculations of numbers destined for the Snake, the only percentages considered were those for the 6-year period from 1962 through 1967. The percentages used were either the second-highest percentage, or else some compromise between the first and second.

In recent years, the percentage of McNary fish passing over Ice Harbor has shown a tendency to increase; therefore, for all but the fall chinook, the percentages used were reasonably close to the average for the 11-year period. For the fall chinook, the second-highest percentage was used, and this decision was made subsequent to the

Table 3. Number of chinook salmon and steelhead trout counted at McNary Dam, 1954-1972 - from the Corps' Supplemental Report (w/additions)

Year	Spring and Summer chinook salmon	Fall chinook salmon	Steelhead trout
1954	113,079	13,476	75,059
1955	92,489	16,426	85,575
1956	103,052	11,290	42,554
1957	222,149	70,607	105,728
1958	128,564	97,528	87,890
1959	115,760	55,730	110,475
1960	129,430	47,337	96,895
1961	113,796	41,200	103,743
1962	108,640	44,116	163,181
1963	97,096	57,363	113,646
1964	109,341	58,593	100,742
1965	74,581	76,326	118,960
1966	108,022	75,119	145,130
1967	122,666	73,087	77,700
1968	127,731	72,757	112,522
1969	134,032	79,375	76,681
1970	107,338	61,554	69,759
1971	101,730	69,718	109,630
1972	119,514	49,307	93,820
Totals -	2,229,010	1,070,909	1,889,690
Averages -	117,316	56,364	99,457

Table 4. Number and percentage of chinook salmon and steelhead trout counted at McNary Dam passing Ice Harbor Dam (revised from Corps' Supplemental Report)

Year	Spring & Summer Chinook			Fall Chinook			Steelhead		
	McNary number	Ice Harbor number	%	McNary number	Ice Harbor number	%	McNary number	Ice Harbor number	%
1962	108,640	64,252	59.1	44,116	30,049	68.1	163,181	115,796	71.0
1963	97,096	47,653	49.1	57,363	13,537	23.6	113,646	74,539	65.6
1964	109,341	49,273	45.1	58,593	11,097	18.0	100,742	58,860	58.4
1965	74,581	26,879	36.0	76,326	12,345	16.2	118,960	62,873	52.9
1966	148,022	60,864	41.1	75,119	15,018	20.0	145,130	65,798	45.3
1967	122,666	65,908	53.7	73,087	19,022	26.0	77,700	44,205	56.9
Average 1962-67	110,057	52,472	47.4	64,101	16,844	28.8	119,893	70,345	58.4
1968	127,731	74,304	58.2	72,757	24,377	33.5	112,522	82,383	73.2
1969	134,032	83,001	61.9	79,375	17,507	22.1	76,681	63,889	83.3
1970	107,338	67,313	62.7	61,554	10,385	16.9	69,759	53,870	77.2
1971	101,730	59,244	58.2	69,718	11,004	15.8	109,630	67,029	61.1
1972	119,514	73,196	61.2	49,307	10,430	24.4	93,820	63,593	67.7
Average 1968-72	118,069	71,412	60.4	66,542	14,741	22.5	92,482	66,153	72.5
Average 1962-72	113,726	61,081	53.7	65,210	15,888	24.4	107,434	68,440	63.7

release of both the Agencies' and the Corps' Reports. Instead of using the maximum percentage of 68.1, the second-highest (33.5) was used. The estimated numbers and distribution of fall chinook in the Snake River system, along with the spring and summer chinook and steelhead trout distribution, are shown in Table 2, which is a revision of the Corps' Report Table 2.

The percentages used of McNary fish passing over Ice Harbor appear to be justified.

4. Analysis of the Use of the Maximum Counts Over McNary Dam

The Agencies used two approaches for justifying the use of the maximum runs over McNary:

(a) by comparing the calculated optimum sustained run in the entire Columbia River system with the maximum runs experienced in the river system and, by inference, stating that since these were reasonably similar, the maximum over McNary is also similar to the optimum, and

(b) by showing that the maximum counts in recent years, with a minimal fishery, are of the same general sizes as those of previous years when a substantial fishery was supported, they contend that the escapement should not be any less.

Although both of these concepts have considerable basis in fact, the latter approach is simpler, and much easier to justify.

The pre- and post-McNary brood years were examined to detect any changes in sizes of runs or any changes in productivity (return/spawner). The measure of productivity for the two periods was compared. The Dalles brood years from 1942 to 1952 were considered pre-McNary and The Dalles brood years 1957 to 1967 were defined as post-McNary. The return/spawner was determined for the two periods by taking the average run size for the 11-year period in each case and dividing by the average escapement for the respective periods (Table 5). The return/spawner for the spring chinook dropped from 3.57 to 2.07, the summer chinooks from 2.77 to 1.15, and the summer steelhead from 2.72 to 1.54.

At this point, the Agencies state (page 5, Appendix A, Agencies' Report) that "the ocean catches for runs considered here are generally minor and are therefore not included. Ocean catches of Columbia River steelhead and sockeye are insignificant, and scale studies of ocean-caught chinook indicate that the vast majority of these are fall chinook." This infers that the drop in production is directly related to changes in environment. The reduction in the return/spawner in recent years is rather dramatic, and the Agencies point out that in the post-McNary period, the value for summer chinook dropped to 1.15, recognizing that when the value drops below 1.0, the run is not reproducing itself. They also

Table 5. Basic Columbia River salmon and steelhead data for estimation of the production rates (return/spawner) for the 11 brood years preceding the completion of McNary Dam and the 11 brood years after the completion of The Dalles Dam.

Period	Parameter	Salmon			
		Spring chinook	Summer chinook	Sockeye	Summer steelhead
Pre-McNary-The Dalles brood years (1942-1952)	Average escapement (1942-1952)	52,400	37,900	49,100	95,600
	Average run size (Salmon: 1946-1956) (Steelhead: 1947-1957)	187,300	105,100	195,900	259,600
	Return/spawner	3.57	2.77	3.99	2.72
Post-McNary-The Dalles 1/ brood years	Average escapement (1957-1967)	83,200	82,500	72,500	130,000
	Average run size (Salmon: 1961-1971) (Steelhead: 1962-1972)	172,500	94,500	100,400	200,800
	Return/spawner	2.07	1.15	1.38	1.54

1/ Production in these years was also influenced in varying degrees by other dams: Brownlee (1953)
Priest Rapids (1960)
Oxbow (1961)
Rocky Reach (1961
Ice Harbor (1962)
Wanapum (1963)
Wells (1967)
Hells Canyon (1967)
John Day (1968)
Lower Monumental (1969)
Little Goose (1970).

Source: Fish and Wildlife Agencies Supplemental Report Appendix B point out that, currently, no direct fishery is permitted on the summer chinooks although, historically, it was the single most important run in the Columbia.

A basic principle of fisheries management is to regulate the runs by determining both maximum and optimum escapements. The maximum escapement obtained on a sustaining basis may not necessarily be optimum for management. On the other hand, the optimum escapement which produces the optimum sustaining yield does not necessarily give the greatest return/spawner.

According to the Agencies' Report, by the late 1950's a sufficient amount of data was available from the fisheries and the counts at Bonneville Dam to determine "on an excellent basis" the optimum escapement levels for the various runs. These are given as 80,000 each for spring and summer chinook, and 120,000 for summer steelhead (line 2, Table 6). The Agencies' Report then develops the optimum sustainable run (line 1, Table 6) by multiplying the optimum escapements by the return/spawner for the pre-McNary period. The Agencies maintain that these are the run sizes that could have been harvested on an "optimum sustainable yield", if the optimum escapement levels had been followed and if the series of dams starting with McNary had not been constructed. Optimum production is obtained by harvesting at the level that sustains the greatest difference between the run produced and the escapement required. These levels were not maintained for several reasons, including overfishing in the river, changes in environment,

Table 6. Computation of average yearly loss to Columbia River fisheries based on difference between optimum yield[1/] and current yield

Period	Parameter	Salmon: Spring chinook	Salmon: Summer chinook	Salmon: Sockeye	Summer Steelhead
Pre-McNary-The Dalles	Average optimum run	285,600	221,600	319,200	326,400
	Otpimum escapement	80,000	80,000	80,000	120,000
	Optimum sustainable yield (difference)	205,600	141,600	239,200	206,400
Current	Average run	172,500	94,500	100,400	200,800
	Average escapement > 1968-1972	115,400	74,800	68,700	129,800
	Average sustainable yield (difference)	57,100	19,700	31,700	71,000
Average yearly loss to fisheries (difference between yields)		148,500	121,900	207,500	135,400

1/ Optimum yield is average yearly harvest that could have been taken by fisheries if McNary and subsequent dams had not been constructed.

Source: Fish and Wildlife Agencies Supplemental Report (Appendix B) losses of downstream migration through inadequate screening of sources of water for irrigation, and unknown factors such as the ocean fisheries.

In typical spawner recruit curves, often called Ricker-type spawner recruit curves, the return/spawner is greater at the lower levels of escapement, and the optimum sustainable yield is determined by drawing a line asymptotic and parallel to the 45 degree line of equal replacement (Fig. 3). The return/spawner at this point of maximum sustained yield is always less than at any point on the curve below the optimum escapement. Thus, it is not technically correct (on the basis of the information presented) to multiply the optimum escapement (80,000 spring chinook, 80,000 summer chinook, and 120,000 summer steelhead) by the return/spawner of the pre-McNary era, which was developed for spring chinook on the basis of an average escapement of 52,400, for summer chinook at an average escapement of 37,900, and for summer steelhead at 95,600. Thus, the values of 3.57, 2.77, and 2.72 for returns/spawner, respectively, are too high for the calculation of the optimum runs.

It is not possible to estimate with reasonable accuracy the return/spawner at escapements of 80,000 with the data available--as a family of curves (Fig. 3) may pass through the two points that are known; i.e., the return/spawner for the pre-McNary era and the points at which the line may be parallel at escapements of 80,000 for fall and spring chinook, and 120,000 for steelhead. For example,

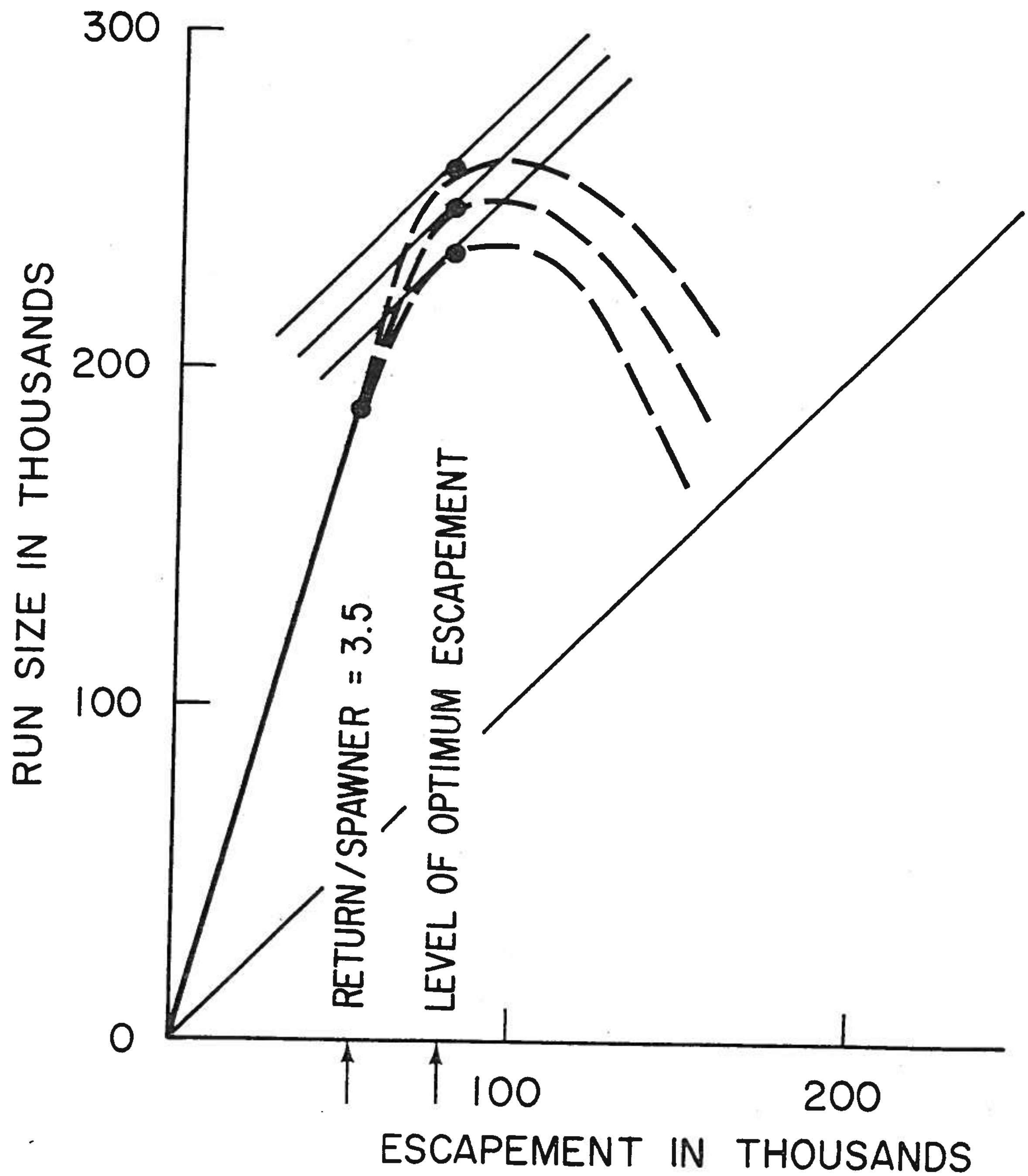

FIG. 3. Ricker-type spawner/recruit curve for spring chinook salmon showing some probable levels of optimum sustained yield given the return/spawner at an escapement of 53,000 and an optimum sustained yield of 80,000.

for the spring chinook, the optimum size of the run probably falls on the curve somewhere between 235,000 and 260,000 adults produced by an escapement of 80,000, so the return/spawner is probably between 2.93 and 3.25. Using the figure of 3.0, the optimum escapements and losses to the fishery for spring chinook salmon are shown in Table 7. Reconstructing the spawner-recruit curves for summer chinook and summer steelhead, the returns/spawner of 2.56 and 2.42 were derived, along with the recalculated losses to the fisheries (Table 7). Also, by using the average escapements for the years 1968 to 1972 (post-John Day) as shown in Table 6, the return/spawner of the late post-McNary period changed from the Agencies' estimate of 2.07 for spring chinook to 1.49, and from 1.15 to 1.26 for summer chinook, while the return/spawner for summer steelhead remained constant at 1.54. It is unlikely that these most recent changes in productivity in these later years (1968 to 1972) are real, unless spring chinook became particularly vulnerable by the developments in the river during that period while the conditions improved for summer chinook and remained constant for summer steelhead. This is unlikely. These values may fall within natural variation, but are more likely to reflect the status of the knowledge of the sizes of the runs, the sizes of the catch, and unknown losses between dams.

The procedure of comparing the optimum sustainable run with the maximum runs--which are quoted as 281,000 (in 1955) for spring chinook, 207,000 (in 1957) for summer chinook, and 383,000 (in 1952) for summer steelhead--is difficult to support. However, since the results are

Table 7. Recalculated computation of average yearly loss to Columbia River fisheries based on difference between optimum yield[1/] and current yield

Period	Parameter	Salmon			
		Spring chinook	Summer chinook	Sockeye	Summer Steelhead
Pre-McNary-The Dalles Brood years (1942-1952)	Average optimum run	240,-00	204,800	255,000	290,000
	Optimum escapement	80,000	80,000	80,000	120,000
	Optimum sustainable yield (difference)	160,000	124,000	185,000	170,000
	Return/spawner	3.0	2.56	3.19	2.42
Current	Average run	172,500	94,500	100,400	200,800
	Average escapement	115,400	74,800	68,700	129,800
	Average sustainable yield (difference)	57,100	19,700	31,700	71,000
	Return/spawner	1.49	1.26	1.46	1.54
Average yearly loss to fisheries		102,900	104,300	153,300	99,000
Agencies' calculated yearly loss		148,500	121,900	207,500	135,400
Difference		45,600	17,600	54,200	36,400
Percentage		31%	14%		27%

1/ Optimum yield is average yearly harvest that could have been taken by fisheries if McNary and subsequent dams had not been constructed.

not directly applicable to the sizes of hatcheries requested for compensation, the significance is felt primarily upon the development of the losses to the fisheries. Furthermore, the returns/spawner are so low (assuredly $<$ 3.5) that there is no significance in attempting to refine for compensatory purposes.

When both the Agencies' and the recalculated (the author's) optimum sustainable runs are compared with the maximum runs of recent history (Figs. 2, 4, and 5), some questionable results are evident for the salmon; however, the expected returns for steelhead are more reasonable. For the salmon, particularly the summer chinook, the calculated return/spawner appears still to be too high. As the optimum sustained escapement calculated by the Agencies cannot be considered too high (i.e., overescapement), the productivity of the runs (return/spawner) may be even lower than anticipated for the 1950's.

Perhaps the most likely conclusion one can draw from the entire analysis is: there are so many variables affecting productivity (i.e,, overfishing in the river, unknown influences of ocean fishing, changes in environment, losses due to hazards presented at dams--including passage through turbines and mortalities due to excess nitrogen--and differential survival of wildfish when hatchery fish are introduced into the stocks) that the theory of Maximum Sustained Yield (MSY) is not applicable. It may even be that "natural" variations are so great that an e capement which is held constant will produce variations that defy the application of the theory.

The obvious drop in productivity should be of great concern.

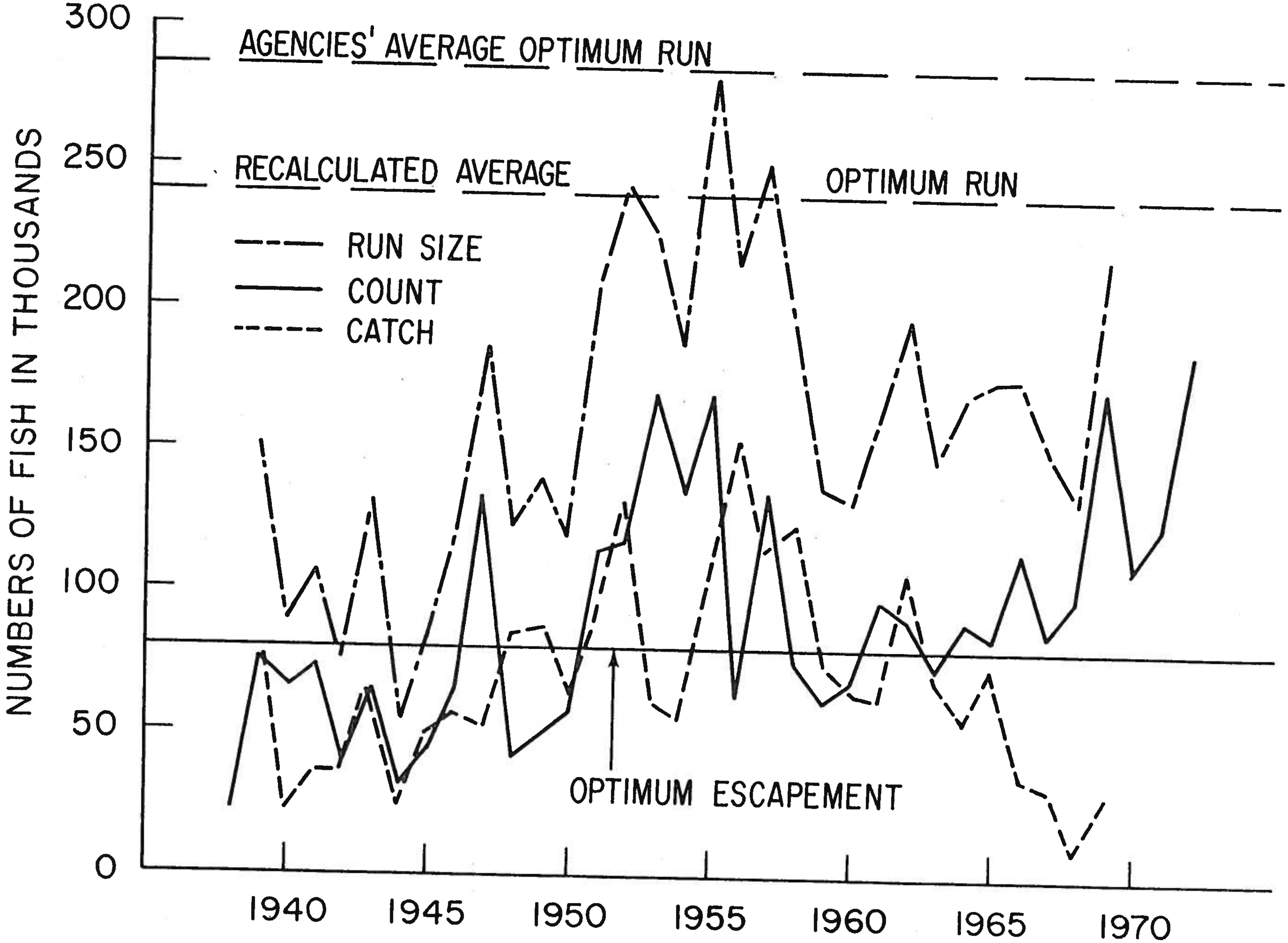

FIG. 4. Status of spring chinook salmon runs, January 1 to May 31, 1939 to 1972

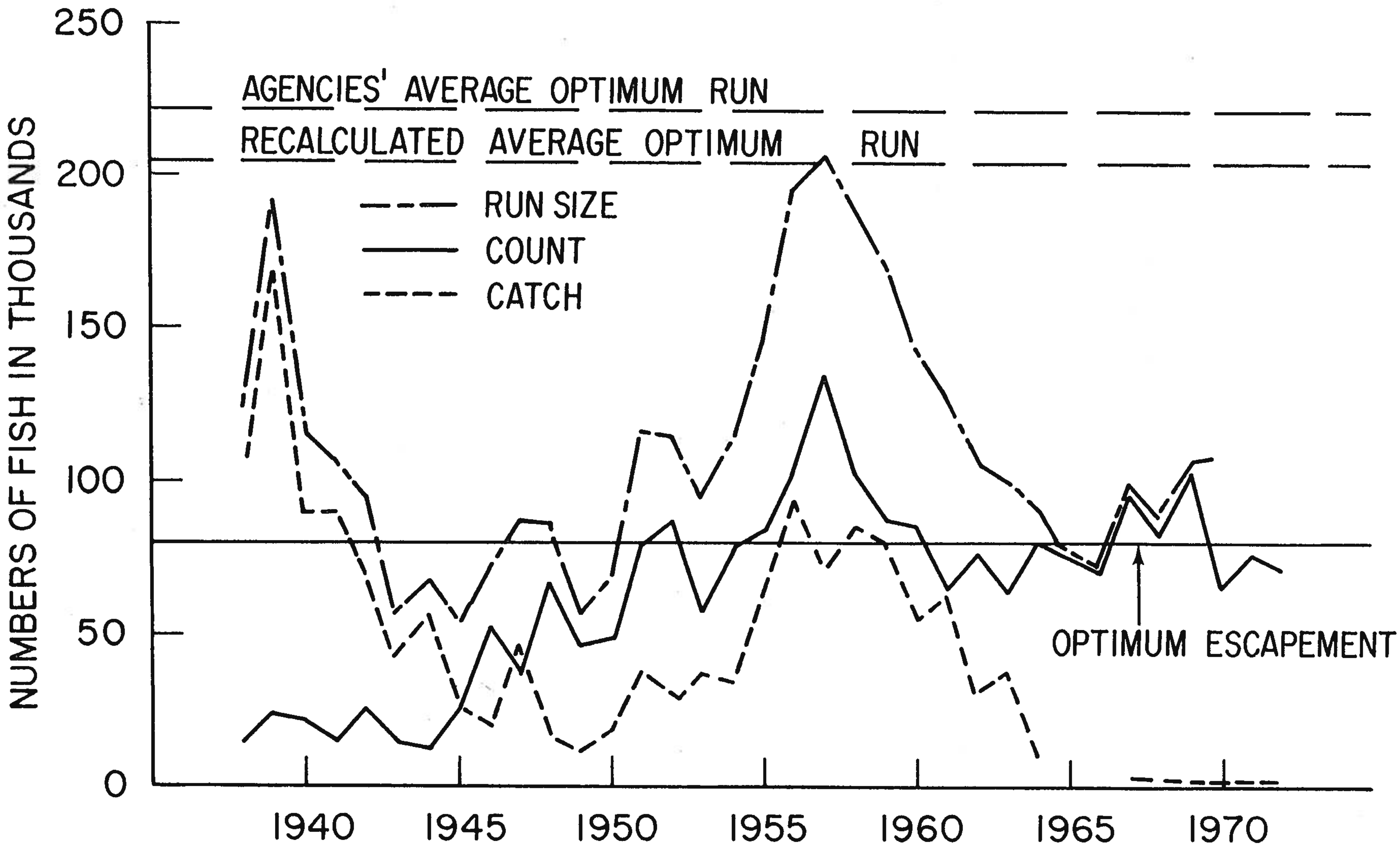

FIG. 5. Status of summer chinook salmon runs, June 1 to July 31, 1938 to 1972

5. Analysis of the Calculated Losses to the Fishery

As mentioned previously, the losses to the fishery were determined by comparing the calculated optimum sustained yield of the pre-McNary period with expected yield for the post-McNary period. As discussed in 4 (above), the calculated optimum sustained yield may be too high because of the use of the return/spawner which may be doubtful. With the recalculated return/spawner, the losses to the fishery were determined to be 31% lower (than the Agencies' figure) for spring chinook, 14% for summer chinook, and 27% for steelhead. Nevertheless, the losses are still substantial--over 300,000 fish annually.

6. Analysis of the Compensation for Losses to Downstream Migrants

There appears to be agreement among all parties that the estimate of a 15% mortality of the downstream migrants at each dam is reasonable, and possibly conservative. Thus, the expected mortality of 48% of the run as a result of the passage of downstream migrants over the four Snake River dams has been generally accepted. Acknowledgment is also made of the considerable effort expended by the Corps of Engineers and other agencies in the development of screening facilities at the projects so that the downstream migrants can be diverted, captured, and transported below the lowest project to some safer point of release. Although this appears to have considerable potential, the entire process including diversion, capture, and transportation has not been perfected to the point where it compensates for the anticipated 48% loss.

Thus, the 48% loss, sustained by a population which already is suffering a decrease in productivity, will cause an additional burden that the runs--particularly, summer chinook--apparently cannot bear.

Therefore, the request for maintenance of the runs at some level near those requested by the Agencies appears to be reasonable and well-founded.

At our present state of knowledge, stream improvement, capture and transportation of downstream migrants, the possible creation of new water resources (rivers) and other suggested means of compensation do not appear to have the merit and standing of fish hatcheries.

Therefore, if the principle of accepting the maximum runs--which appears to be reasonable--is accepted and the 48% mortality can be anticipated, the size of the hatcheries required to replace the loss can be estimated. The agencies anticipate losses equivalent to 20,700 adult fall chinook salmon, 58,700 spring- and summer-run chinook salmon, and 55,100 steelhead (Table 8).

Table 8. Estimated losses, and artificial propagation costs associated with anadromous and resident fish maintenance, following Lower Snake River project construction (Agencies' Report, partially revised table 4)

Species	Max run	Loss (adults)	Number (adults)	Hatchery Capital costs	Hatchery Annual OM&R costs	Collect., eyeing, trans. Capital costs	Collect., eyeing, trans. Annual OM&R costs
Fall chinook	32,700	20,700 1/	5,294	2,623,000	$146,803	$562,488	$30,080
Spring & summer chinook	122,200	58,700 2/	3,800	$8,960,000	$502,000	$432,000	$50,000
Steelhead trout	114,800	55,100 2/	7,200	$18,140,000	$834,000	$819,000	$95,000
Rainbow trout			(85,000) 3/	1,275,000 4/	96,000		
Total costs				$30,998,000	1,578,803	$1,813,488	$175,080

Total capital costs: $37,011,488 5/

Total OM&R costs: $ 1,753,883

1/ Based on total replacement for 5,000 adults in inundated spawning area plus cumulative smolt loss of 48% at four dams.

2/ Based on 15% smolt loss for each of the four dams (48% cumulative loss)

3/ Number of pounds needed for liberation at three to the pound

4/ costs include collecting, eyeing, holding, and transportation, as well as hatchery requirements,

5/ based on $4,200,000 land acquisition and development costs for fishing access added to capital costs.

7. Analysis of the Benefit-Cost Ratios for Hatcheries

The benefit-cost ratios for the hatcheries are difficult to develop with reasonable accurace because of the unknowns concerning costs, values, and the questionable uses of catch-to-escapement ratios of 4:1 for chinook and 2:1 for steelhead. These are probably too high, and are borne out by the fact that the productivity (return/spawner) has been reduced to values considerably less than catches of 4:1 would allow. The best estimates for the benefit-cost ratios are given in Tables 9 through 13. A different method of computing the benefit-cost ratio was tried for chinook and steelhead, and the results were very similar (Table 14 for chinook).

Table 9: (Revised) Commercial landings and sport fishing use, with and without compensation [1/] in Columbia River System and Pacific Ocean (anadromous species) and in Lower Snake River project area (resident species).

Areas and species	Commercial Fisheries									Sport Fisheries 4/		
	with compensation			without compensation			difference					
		Landings			Landings			Landings				
	Escapement	Pounds	Value	Escapement	Pounds	Value	Escapement	Pounds	Value	w/comp Ang days	w/o comp Ang days	diff Ang days
Columbia R. System, Ocean												
Fall chinook 2/	32,700	1,668,000	917,000	14,400	734,000	404,000	18,300	? 934,000	? 513,000	? 163,500	? 72,000	? 91,500
Spring and summer chinook 2/	122,200	6,232,000	4,362,400	63,500	3,238,000	2,266,600	58,700	2,994,000	2,094,800	611,000	318,000	293,000
Steelhead 3/	114,800	692,000	208,000	59,700	360,000	108,000	55,100	332,000	100,000	763,000	397,000	366,000
Totals	269,700	7,900,000	5,487,400	137,600	4,332,000	2,778,600	132,100	?	3,159,550 ?	1,537,500 ?	787,000 ?	750,500 ?
L. Snake Project Area												
Resident										250,000	205,000	45,000

1/ Insofar as possible, "with compensation" is intended to reflect the pre-project condition.

2/ Calculations based on catch to escapement ratio of 4:1 (commercial catch 3:1 and sport catch 1:1) average weight per fish of 17 lbs; and commercial value of $0.55 per pound for fall chinook, $0.70 per pound for spring and summer chinook.

3/ Calculations based on catch to escapement ratio of 2:1 (commercial catch 0.67:1 and sport catch 1.33:1); average weight per fish of 9 lbs; and commercial value of $0.30 per pound.

4/ Angler-days for anadromous fish are based on catch to escapement ratios (footnotes 2 and 3) and an estimated 5 days of effort per fish (the value of an angler-day for anadromous fish is $6.00).
Angler-days for resident fish are based on creel studies of Washington Department of Game and the ratio of 3 reservoir angler-days to 2 stream angler-days.

From BSFW Report (Appendix A) as revised by correspondence.

Table 10. An economic analysis for fall chinook prepared on a 100-year project life as a basis for benefit-cost comparison.

Item	100-year life
Cost	
Initial construction	$2,750,000
Capital investment	152,000
Annual O & M	250,000
Total amortized annual cost	402,000
Benefit	
Commercial fishery value	
934,000 lbs at $0.55/lb	513,000
Sport fishery value	
91,500 angler-days at $6.00/day	549,000
Total annual benefits	$1,062,000
Benefit-cost ratio	2.64:1

Table 11. Economic analysis for spring and summer chinook salmon prepared on a 100-year project life as a basis for benefit-cost comparison

Item	100-year life
Cost	
Initial construction	$11,250,000
Capital investment	621,700
Annual O & M	900,000
Total amortized annual cost	1,521,700
Benefit	
Commercial fishery value	
2,994,000 lbs at $0.70/lb	2,095,800
Sport fishery value	
293,000 angler-days at $6.00/day	1,758,000
Total annual benefits	$3,853,800
Benefit-cost ratio	2.5:1

Table 12. An economic analysis for steelhead trout prepared on a 100-year project life as a basis for benefit-cost comparison

Item	100-year life
Cost	
Initial construction	$15,000,000
Capital investment	828,900
Annual O & M	1,000,000
Total amortized annual cost	1,828,900
Benefit	
Commercial fishery value	
332,000 lbs at $0.30/lb	99,600
Sport fishery value	
366,000 angler-days at $6.00/day	2,196,000
Total annual benefits	$2,295,000
Benefit-cost ratio	1.3:1

Table 13. An economic analysis of the Lower Snake River sport fishery prepared on a 100-year project life as a basis for benefit-cost comparison.

Item	100-year life
Cost	
Initial land cost	$2,000,000
Capital investment	110,500
Annual O & M	30,000
Total amortized annual cost	140,500
Benefit	
Sport fishery value	
130,000 angler-days at $6.00/day	780,000
Total annual benefits	780,000
Benefit-cost ratio	5.6:1

Table 14. Spring and summer chinook benefit-cost ratio

Year	Cost	Discounted cost[1]	Benefit	Discounted benefit[2]
0	11,871,000	11,871,000	0	0
1	900,000[3]	857,143	0	0
2	900,000[3]	816,327	3,853,800[4]	3,495,510
3	900,000[3]	777,873	3,853,800[4]	3,330,856
4	900,000[3]	740,741	3,853,800[4]	3,171,851
5	900,000[3]	704,225	3,853,800[4]	3,015,493
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
98	900,000	7,563	3,853,800	32,384
99	900,000	7,200	3,853,800	30,830
100	900,000	6,870	3,853,800	29,418
Totals		$28,527,536		67,802,371
Benefit-cost = 2.377				

The method of calculating the benefit-cost ratio is from Benefit-Cost Aspects of Salmon Habitat Improvement in the Alaska Region, U.S.D.A. Forest Service, Alaska Region, February 1969.

[1] $Cost/(1 + i)^n$ where i is the discount rate of .05 on long-term government bonds and n is the number of years

[2] $Benefit/(1 + i)^n$

[3] Based on total capital costs for spring and summer chinook

Cost

Initial construction		- $11,250,000
Capital investment		621,000
	Total -	11,871,000
Annual OM&R costs		900,000

[4] Benefit

Commercial fishery		2,095,800
Sport fishery		1,758,000
	Total -	3,853,800

8. Analysis of Compensation for Losses to Resident Fishes

The analysis of the losses of fishing in a free-running river compared to reservoir-type fishing is extremely difficult to make, because of the biases in evaluation of substituting one kind of fishery for another. In this case, the only form of compensation that is acceptable to the agencies is off-site mitigation in the form of planting of the more desirable species--such as rainbow trout--in either tributaries of the Snake, on other off-site locations, or even possibly the creation of new rivers by the Corps. This type of mitigation needs to be negotiated.

On-site enhancement is limited by the fluctuations of the reservoir, the problems of dealing with the railroads with their demands for assuring the integrity of the dikes and berms upon which the railroads are located, and the unwillingness of the agencies to accept the substitution of species.

9. The Compensation for Losses of Steelhead Fishing

The agencies appear firm in their request for access to rivers of high quality steelhead fishing by requesting assurance of access of approximately 150 miles of river to substitute for the area inundated. This can be accomplished by either direct purchase or some other form of negotiation that is legally binding for continued access during the life of the project.

A recommendation cannot be made at this time for the type of assurance of access, but outright purchase of all these properties should be a last resort...unless wildlife mitigation becomes a persuasive factor.

CONCLUSIONS

1. The concept of managing the entire watershed rather than by a project-to-project basis is a sound one, particularly when one agency, such as the Corps of Engineers, is responsible for the development of the resources of a major portion of the watershed. Such is the case for the Snake River.

2. The runs of spring chinook, summer chinook, and steelhead trout have degraded, from many causes, in recent years. Further degradation can be expected by the construction and operation of the four Lower Snake River dams.

3. The Agencies' method of computing losses to the fish runs of the Lower Snake River (i.e., the use of the cumulative loss of 48% of the downstream migrants) appears to be sound.

4. The use of the maximum size runs over McNary times the percentage of McNary fish that pass over Ice Harbor is justifiable.

5. The Agencies' use of calculated optimum sustainable runs for computing losses to the fishery may result in an overestimate, but not grossly so.

6. The numbers of fish to be replaced can be estimated at approximately 18,500 for fall chinook, 59,000 for spring and summer chinook (total), and 55,000 for steelhead trout.

7. The summer chinook are obviously in jeopardy, and a substantial effort to maintain this run is justifiable on the basis that enhancement can occur by proper hatchery management, by effective screening, and by habitat control.

8. Off-site mitigation for the loss of the resident fishery needs to be negotiated. This could include planting of trout in waters in the Lower Snake Area and also completely off-site.

9. Access for steelhead fishing in tributary streams needs to be assured.

10. The benefit-cost ratios are very difficult to evaluate as the catch-to-escapement ratios used for salmon (4:1) exceed the productivity of wildfish...and differential harvesting is not defined.

11. Management (including the harvest) after hatcheries are constructed will be exceedingly difficult, as the return/spawner for wildfish is currently about 3.0, while the anticipated return/spawner for hatchery fish is calculated to be as high as 14.0. Further degradation of wild stocks can occur when the hatchery fish comprise 48% of the Snake River run.

RECOMMENDATIONS

1. Because of the decline in the stock of summer-run chinook and the apparent drop in productivity approaching bare maintenance, support by the use of hatcheries is urgent. Compensation for the losses of spring chinook is also requested, so it is recommended that the spring chinook and summer chinook hatcheries be authorized and constructed simultaneously and, as soon as possible.

   It is further recommended that the hatchery sites be chosen carefully and great credence be given to the desirability of having a number of small hatcheries rather than one or two large facilities. These are almost essential in Idaho because of the distribution of the fish east and west of the Idaho Primitive Area. The transportation of fishes across state lines cannot be avoided entirely, but the problems of disease control, inspection, and authority can be minimized by construction of one or two hatcheries in the Grande Ronde River area in Oregon and additional sites and hatcheries should be considered for the state of Washington.

2. It is recommended that the integrity of the stocks be maintained as much as possible. In the attempt to maintain the integrity of the stocks, siting should be done carefully to consider environmental as well as genetic influences. It is suggested that an attempt be made to adapt the hatcheries to the environment rather than by creating new environments by temperature and water control. That is, once-through systems should be considered prior to recirculating

systems, both for biological and economic reasons.

3. It is recommended that a fall chinook hatchery also be constructed close to, preferably within, the Snake River area. Once again, this is an attempt to maintain the integrity of the local stocks which do migrate into Idaho at the present time.

4. As the planting of catchable trout is already practiced in the area, by the Washington State Department of Game, it is recommended that additional off-site planting be considered. Although no catchables are planted at the present time in the Clearwater River in Idaho, it is felt that this can soon become a viable fishery because of the cooling influence of Dworshak Dam.

5. It is recommended that off-site mitigation, possibly including artificial rivers and lakes, be considered, but this does not have a sense of urgency.

6. It is recommended that permanent access to rivers of high quality steelhead fishing be acquired. The access need not be in the form of outright purchase if permanency is assured. The management of the wildlife resources may be a deciding factor in determining the type of access provided.

7. It is recommended that the Corps consider negotiation with the Agencies for the maintenance of an optimum number of fish for the

entire Snake River Area, and if this number is maintained by improved screening, transportation, habitat control, etc., the Corps' obligations for maintenance and operation of the hatcheries be reduced at the Corps' option.

8. Special consideration should be given to the management of stocks which are 52% wild...with a return/spawner of 3 ...and 48% hatchery stocks with returns/spawner up to 14.

9. The implementation of the above recommendations continues to emphasize the burden upon the Agencies for wise fisheries management, so it is essential that the Corps and the Agencies integrate their programs ever more closely and that mutual assessment be continuous.

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