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REINTRODUCTION OF ANADROMOUS FISH RUNS TO THE TILTON AND UPPER COWLITZ RIVERS

by

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Final Report

for
Washington State
Department of Fisheries
and
Department of Game
Olympia, Washington

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Director

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

APPENDIX TABLE

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ABSTRACT

The technical evidence and fisheries management experience in the upper Cowlitz River basin associated with hydropower development are examined. Thirteen potential options are developed and evaluated ranging in approximate cost from $108 million to about $200,000. If action is to be taken the least cost option to establish a run of early coho in the Tilton River and Winston Creek is recommended. This option must achieve adequate smolt passage survival through Mayfield reservoir to succeed and is a key condition of all options.

Specific fisheries and environmental management techniques are identified which can be applied to the system to reintroduce coho salmon to the Tilton River and Winston Creek tributaries of Mayfield Reservoir. Exclusive plants of early coho salmon upstream will facilitate identification at the hatchery, develop genetic purity in time and facilitate the imprinting of the early stock to the upstream habitat. Priority management of Mayfield reservoir should be placed on development of anadromous coho salmon if adequate smolt survival through the reservoir can be achieved. Secondary priority should be placed on a sport fishery for resident fishes.

Contamination of the water supplies to the Cowlitz Salmon and Trout hatcheries with incurable fish disease (IHN virus) will occur if infected fish are planted upstream. Coho salmon pose the lowest threat of transmitting this disease and are therefore the only species which can presently be considered. An upwell induction system in Mayfield Reservoir to increase the downstream movement of coho smolts is presented which can also be used to reduce the temperature of the Cowlitz River during the summer for disease control at both hatcheries.

The remainder of the watershed above Mossyrock Dam is best managed for

resident coho salmon, and rainbow and cutthroat trout. A significant sport fishery has been developed in Riffe Lake for these species and others. If a smolt collection facility is to be included in the proposed Cowlitz Falls Dam and certain fish diseases (i.e. IHN virus) controlled in the future, the upper watershed may once again be considered for rearing spring chinook salmon.

REINTRODUCTION OF ANADROMOUS FISH RUNS TO THE TILTON AND UPPER COWLITZ RIVERS

INTRODUCTION

The 49th legislature of the State of Washington in the 1985 regular session amended RCW 75.08.020; added a new section to chapter 77.04 RCW; and made an appropriation. This amendment called for the directors of the State Fisheries Department and the State Game Department in cooperation with the director of the School of Fisheries, University of Washington to develop proposals to reinstate the salmon and steelhead trout runs in the Tilton and Upper Cowlitz rivers. The objectives of this report are to: 1) review the history of the salmon and steelhead runs to the Tilton and upper Cowlitz rivers including the changes in the environment as a result of hydropower development; 2) review the communicable diseases affecting the salmon and steelhead populations in the Cowlitz River including the success of prophylactic measures used at the hatcheries; and 3) identify and develop the possible options which may be used to reintroduce salmon and steelhead runs to the Tilton and upper Cowlitz rivers.

DESCRIPTION OF HYDRO-PROJECTS AND STUDY AREA

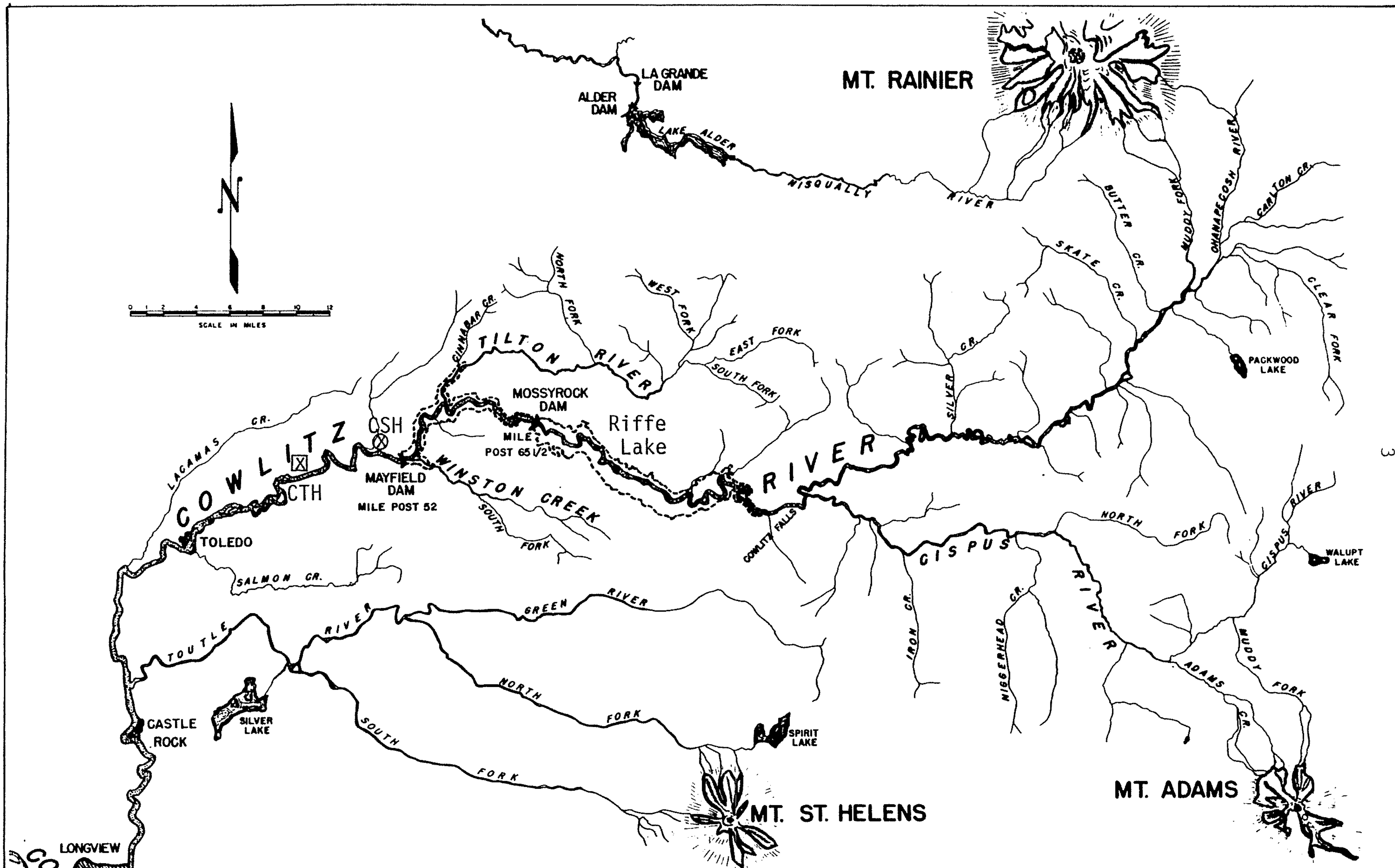
Mayfield Reservoir

This review will focus on the Cowlitz River basin above Mayfield Dam (Fig. 1). Mayfield Dam, a 185 foot high concrete arch (Figure 2), was constructed by Tacoma City Light at Rm 52 and began operation in April 1962. It created a reservoir 13.5 miles in length with a water level elevation which can range from a maximum normal elevation of 425 feet to a minimum of 415 feet. Mayfield reservoir has a total storage capacity of 133,764 acre feet and is operated as a run-of-the-river facility with an average retention time of 19 days (Table 1). The penstock intakes withdraw water from the upper 36 feet of the reservoir.

Fish Facilities

Beginning in July 1961, upstream migrants were passed over Mayfield Dam by a five component fish passage facility consisting of: 1) the powerhouse collection channel, 2) a fish barrier dam, 3) a ladder and water supply, 4) a trap, hopper and tramway, 5) a truck to haul the fish hopper, and 6) an unloading ramp in Mayfield reservoir (Thompson and Rothfus 1969). These upstream passage facilities were utilized through 1968 when Mossyrock Dam began operation and the Cowlitz Salmon Hatchery was completed. Passage of adults upstream was blocked at the salmon hatchery 1.5 miles below Mayfield Dam by a barrier dam in 1969 and the fish were induced to migrate up a ladder to a holding pool and a separation facility operated at the hatchery. Since that time all adult salmon and steelhead passed above Mayfield Dam have been hauled via trucks and no natural upstream passage remains.

The water supplying the Mayfield turbines enters the intake structure from the top 36 feet of the reservoir at full pool. The downstream migrant fish facilities that guide fish from the turbine supply water to a safe



☒ CTH = Cowlitz Trout Hatchery

⊗ CSH = Cowlitz Salmon Hatchery

TACOMA CITY LIGHT

DRAINAGE MAP OF COWLITZ RIVER

JULY 5, 1950

Dwg. No. MS-116
Drawer No 68

FIG. I

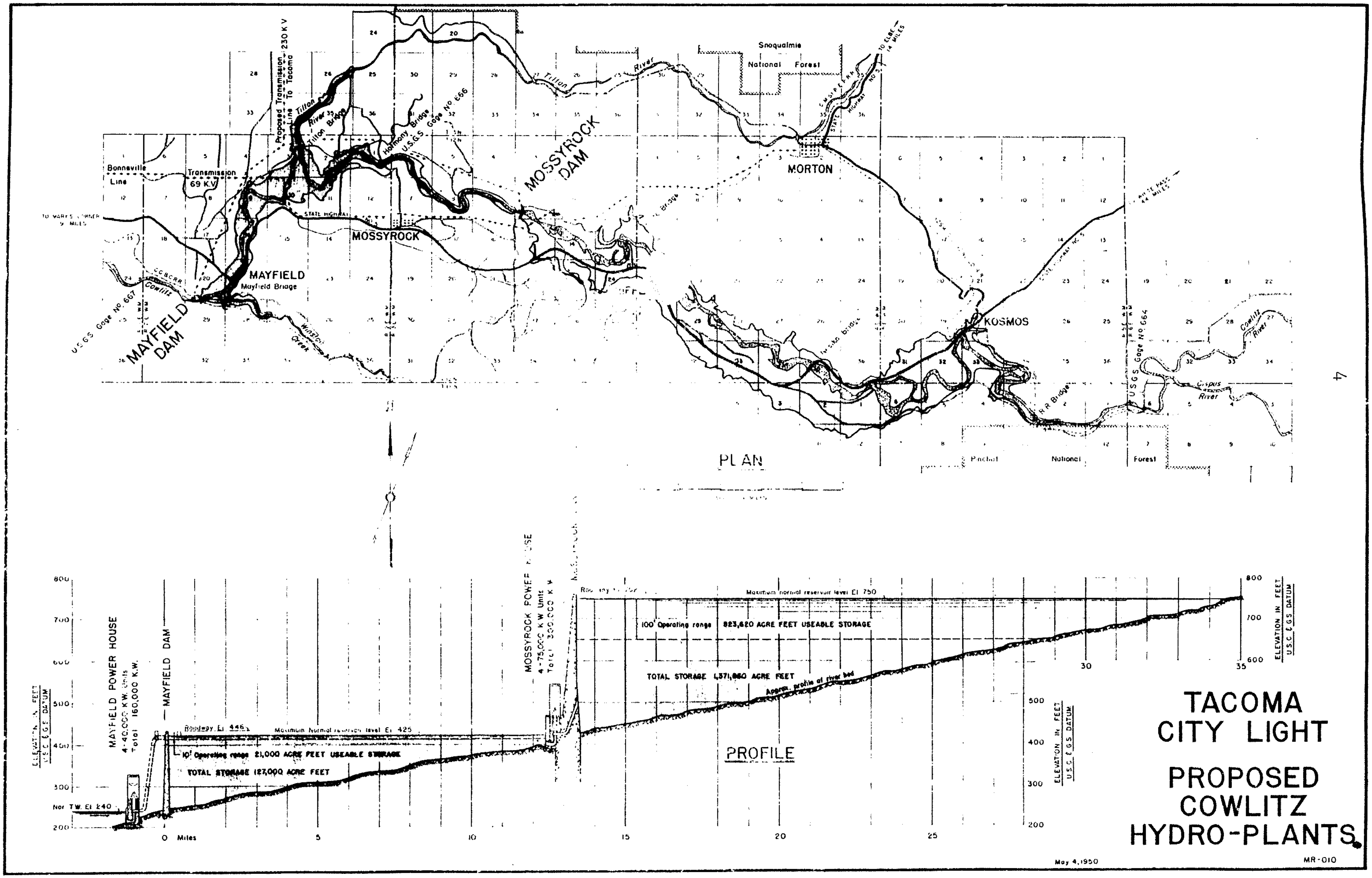

TACOMA
CITY LIGHT
PROPOSED
COWLITZ
HYDRO-PLANTS
PLAN
PROFILE
MAYFIELD DAM
MOSSYROCK DAM
MAYFIELD
Mayfield Bridge
MOSSYROCK
MORTON
KOSMOS
Snoqualmie National Forest
Pinchot National Forest
Tilton River
Cowlitz River
Cispus River
Winston Creek
Harmony Bridge
Tilton Bridge
R R Bridge
U.S.G.S. Gage No 666
U.S.G.S. Gage No 667
U.S.G.S. Gage No 664
Proposed Transmission Line To Tacoma 230 K V
Transmission 69 K.V.
Bonneville Line
STATE HIGHWAY
MAYFIELD POWER HOUSE
4-40,000 K.W. Units
Total 160,000 K.W.
MOSSYROCK POWER HOUSE
4-75,000 K.W. Units
Total 300,000 K.W.
Roadway El 446
Maximum normal reservoir level El 425
10' Operating range 21,000 ACRE FEET USEABLE STORAGE
TOTAL STORAGE 127,000 ACRE FEET
Maximum normal reservoir level El 750
100' Operating range 823,620 ACRE FEET USEABLE STORAGE
TOTAL STORAGE 1,371,860 ACRE FEET
Approx. profile of river bed
Nor. T.W. El 240
ELEVATION IN FEET U.S.C. & G.S. DATUM
0 Miles
5
10
15
20
25
30
35
May 4, 1950
MR-010

FIG. 2.

Table 1. Comparison of the characteristics of the upper Cowlitz River reservoirs (source: R.W. Beck, 1981).

Parameter	Mayfield	Mossyrock	Cowlitz Falls (proposed)
Average annual flow, cfs	6,345	5,057	5,057
Storage, ac ft	133,764	1,686,000	20,000
Area, acres	2,200	11,335	1,872
Average retention time, days	19	168	2
Dry summer retention time, days	--	315	5.8
Reservoir length, miles	13.5	22	14
Reservoir width, miles	0.75	2	0.35
Normal drawdown, ft	10	60	6
Intake level, ft below surface	36	210	30-90
Froude Number	0.313	0.012	2.9
Inflow to volume ratio	34.3	2.2	183

passage below the dam consist of four components including: 1) a vertical louver system, 2) a bypass slot and pipe, 3) a secondary separator and its appurtenances, and 4) a transfer pipe and flume to transport fish to the tailrace below the powerhouse (Thompson and Rothfus 1969). These facilities remain operable to the present time.

Mossyrock Reservoir

The construction of the 325 foot high concrete arch Mossyrock Dam (Figure 2) by Tacoma City Light at Rm65.5 was completed and began operation in April 1968. It created a reservoir 22 miles in length with a water level elevation which may be fluctuated annually between a maximum elevation of 778 feet to a minimum of 650 feet. Mossyrock reservoir (Riffe lake) is operated as an annual storage reservoir for flood control and hydropower. Flood control requires the lake to be a minimum of 35 feet below full pool by November 30 each year. The reservoir has a storage capacity of 1,686,000 acre feet. The inlets to the penstocks are located at elevation 512 feet, a depth of 266 feet below the maximum surface elevation. Due to the height of the dam, length of the reservoir, depth of the penstock intakes and location of Mossyrock Dam above Mayfield Dam, fish facilities were not incorporated into the dam. The delay of downstream migrant salmonids through Mayfield reservoir was found to be about 2-3 months for fall chinooks (Allen 1965) and evidenced by year around catches of juvenile coho (Phinney and DeCew 1974). The additional delay through the larger Riffe Lake was expected to preclude effective utilization of fish facilities at Mossyrock Dam.

Thermal Characteristics of Reservoirs

The thermal behavior of Mayfield and Mossyrock reservoirs strongly influences the production and management of fishes in the upper basin. The thermal structure of Mayfield reservoir was investigated by Westley and Goodwin (1967) prior to the completion of Mossyrock Dam upstream. They found Mayfield reservoir during that time period to be weakly stratified with the upper five miles behaving as a relatively well mixed river and the remainder as a moderately to weakly stratified lake. The volume and temperature of the inflowing river water and the surface location of the penstock withdrawal system were the two main factors influencing thermal structure.

Prior to the operation of Mossyrock Dam the Cowlitz River flowing into Mayfield reservoir achieved diurnal maximum temperatures of 20°C during late summer when hot sunny weather occurred simultaneously with low river flow. Following the construction of Mossyrock Dam the temperature of the water released into Mayfield was reduced during the summer period due to the withdrawal of cold water from Riffe Lake.

Recently Tipping and Kral (1985) measured the vertical temperature and dissolved oxygen profiles in Mayfield reservoir and found a poorly developed thermocline indicating water heat build-up only in the upper 3 meters. They observed that the penstocks appear to be siphoning off much of the warm surface water. The tailrace water temperature was commonly found at about 3 meters depth in Mayfield Lake. Dissolved oxygen profiles showed a decline of about 2-3 mg/l at 20 meters depth. The hypolimnion showed signs of stagnation from the first of July through mid-October. Westley and Goodwin (1967) also reported reduced dissolved oxygen values in the hypolimnion during August and September prior to fall overturn. The stagnation of the hypolimnion results from the combined effects of surface withdrawal of the active storage and retention of the 106,000 acre feet of dead storage in the reservoir.

The thermal structure and behavior of Riffe Lake is quite different due to strong thermal stratification. Two very important indicators of reservoir behavior are the Froude number and the annual inflow to volume ratio (Table 1), R. W. Beck 1981). A small Froude number exhibited by Riffe Lake (0.012) indicates strong stratification and a stable lake type behavior. The isotherms in the lake will tend to be horizontal and uniform over the entire lake. A small inflow to volume ratio also indicates strong stratification. Vertical temperature and oxygen profile data for Riffe Lake verify this structure (Tacoma City Light, unpubl. data). The thermal structure of Riffe Lake responds primarily to meteorological variables rather than tributary inflow temperature. Due to the great reservoir depth, strong stratification and deep penstock withdrawal of cold hypolimnial water Riffe Lake has a pronounced summer cooling effect on the Cowlitz River flowing into Mayfield reservoir.

River Temperature Below Mayfield Dam

USGS water temperature data for the Cowlitz River 1.4 miles below Mayfield Dam was plotted for the period 1954-61 (Higgins and Hill 1973) before dam operation on the river and for the period 1974-82 (USGS Water Supply Data 1975, 76, 77, 78, 79, 80, 81, 82) following operation of both reservoirs. The maximum, minimum and mean for each period are plotted in Figure 3. It is apparent the pre-dam temperatures in the Cowlitz River exhibited larger extremes each month than the post-dam temperature regime. The pre-dam mean temperature ranged from 4.1°C in January to 16.1°C in August compared to a post dam mean annual temperature change from 5.3°C in February to 11.1°C in August. The reservoirs have had the effect of increasing the mean water temperature in the months of November through February by as much as 2.7°C and reducing mean temperatures during the months of June through September by as much as 5.0°C. The Cowlitz Salmon Hatchery and the Trout Hatchery (8.5 miles below Mayfield Dam) are sited downstream from this water quality station.

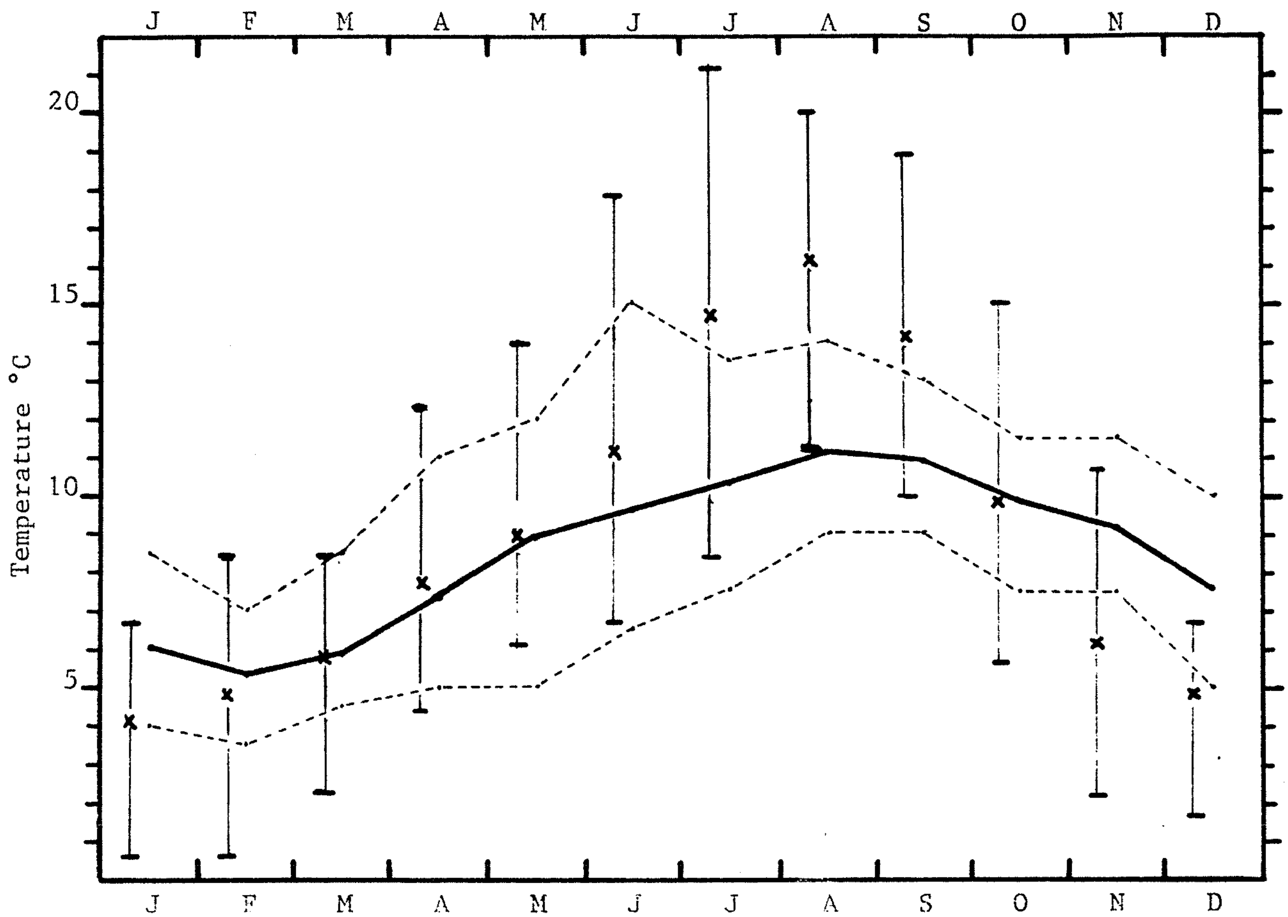


Fig. 3. Monthly maximum, minimum, and mean Cowlitz River water temperatures below Mayfield Dam for the pre-dam 1954-61 period (Higgins and Hill 1973) and the post-dam 1974-82 period (U.S.G.S. Water Supply Data 1975 to 1982). The vertical bars and x represent the maximum, minimum, and mean pre-dam period, while the dotted and solid curves represent the maximum, minimum, and mean post-dam period.

Both hatcheries pump water from the Cowlitz River for the production of salmon and steelhead. The thermal quality of the water supplied to these hatcheries is of critical importance in the success of these operations.

Cowlitz Falls Hydro Project

An application for license to construct an additional hydropower facility at Cowlitz Falls above Mossyrock Reservoir was filed with the FERC by the Public Utility District No. 1 of Lewis County in 1981. FERC issued a final environmental impact statement in 1983 (FERC/EIS-0032, 1983); however, no further actions have been taken. This project would be a concrete-gravity dam at Rm 88.6 extending 140 feet above the streambed. The reservoir at elevation 866 feet mean sea level would have a depth of 90 feet at the dam, flood 870 acres, and contain a total volume of 13,150 acre-feet. The reservoir would extend 12.3 miles up the Cowlitz River toward the town of Randle, Washington and 1.7 miles up the Cispus River. Two power intakes will lead to 18 foot diameter penstocks and kaplan turbines with an average head of 97 feet. This run-of-the-river reservoir will have a relatively short retention time due to a large inflow to volume ratio and is expected to have little effect on the thermal regime of Riffe Lake (R. W. Beck 1981). Fish passage facilities are not now a definite part of the project design, however, provisions for a downstream smolt collection facilities are being considered.

Upper Basin Fish Habitat

The salmonid spawning and rearing habitat in the Cowlitz River system upstream from Mayfield Dam was surveyed by Kray (1957). In the Cowlitz, Cispus and Tilton rivers 82.0, 33.5 and 27.0 miles of habitat, respectively, were identified. Easterbrooks (1980) made a subsequent survey which identified an additional 6.3 miles of habitat in six small tributaries. A total of 247.8 miles of salmonid spawning and rearing habitat has been identified to remain in the system (Table 2) following hydropower development. The potential productivity and utilization of this habitat for anadromous salmonid production above Mayfield Dam will be explored throughout the remainder of this report including the potential utilization of both existing reservoirs.

Table 2. Salmonid spawning streams in the Cowlitz River system upstream from Mayfield Dam. Stream listings include mileage from mouth to upstream barrier for those waters where spawning activity has been noted.[1] (Source: Wood, et al., 1981)

		Mileage
Cowlitz River		82.0
Sulphur Creek		1.5
Landers Creek		1.5
Rainy Creek Basin		16.9
Siler Creek		2.6
Kiona Creek		5.5
Silver Creek		2.7
Davis Creek[4]		2.0
Kilborn Creek		0.7
Williams Creek		0.5
Smith Creek[4]		1.0
Johnson Creek		4.0
Hall Creek		2.0
Skate Creek		9.0
Butter Creek[4]		1.5
Lake Creek		2.0
Coal Creek		0.7
Clear Fork		1.5
Chanapecosh		0.5
Cispus River		33.5
Quartz Creek		2.7
Crystal Creek[4]		0.5
Iron Creek		3.0
Greenhorn[4]		2.0
Yellowjacket Creek		5.2
North Fork		6.0
Tilton River		27.0
North Fork Basin		8.0
East Fork		5.0
South Fork		4.0
West Fork Basin		6.5
Additional Streams[2]		6.3
	TOTAL	247.8[3]

[1]Kray (1957).

[2]Additional salmonid rearing habitat surveyed during September 1979 (Easterbrooks 1980) including Camp Creek, East Canyon Creek, Squaw Creek, Burton Creek, Muddy Fork Cowlitz River, Purcell Creek.

[3]Total corrected from Wood et al. 1981.

[4]Easterbrooks 1980 identified these streams had little value for anadromous fish spawning due to floods or channelization.

ADULT MIGRANT COUNTS AND UPSTREAM SHIPMENT

Spring Chinook (*Oncorhynchus tshawytscha*)

Documentation of the number and disposition of anadromous adult salmonids using the Cowlitz River fish facilities at Mayfield Dam (1961-67) and the barrier dam-fish facility at the Cowlitz River salmon hatchery (1968 to present) has been made by the Washington Department of Fisheries personnel. Annual counts of spring chinook adults and jacks using the Cowlitz fish facilities and the number passed upstream are shown in Table 3. During the period 1962 to 1966 all fish were passed upstream over Mayfield Dam. Since 1967 a portion of the returning adults have been retained at the hatchery for egg take and some of the remaining surplus passed upstream. The upstream locations where the adults and jacks were planted are shown in Table 3. It is apparent that adult or jack spring chinook have not been trucked above the Cowlitz separation facility since 1980. Prior to 1980 the distribution of spring chinook hauled to the Tilton and upper Cowlitz Rivers was intended to contribute to a small sport fishery and yield some natural production above Mayfield and Mossyrock Dams, respectively.

Fall Chinook (*O. tshawytscha*)

Yearly counts of fall chinook salmon have been kept from 1961 to the present (Table 4). All fish were passed upstream over Mayfield Dam until 1967 when a portion of each run was retained for egg take. Small numbers of fall chinooks were hauled to the Tilton and upper Cowlitz rivers until 1980 when upstream transport was suspended. Few adult fall chinooks have been transferred upstream due to low escapements and the inability to achieve the mitigation goal of 8,300 adults. The transfers of this species have only involved small numbers of jacks.

Table 3. Yearly counts of spring chinook salmon using Cowlitz River fish facilities, from 1962 through 1984. The mitigation level established for this species is 17,300 adults.

Source	Year	Adults	Passed upstream	Jacks	Passed upstream	Total	Remarks
Thompson and Rothfus 1969	1962	2,998		740		3,738	Passed upstream
"	1963	2,854		1,945		4,799	"
"	1964	11,335		2,282		13,617	"
"	1965	17,274		3,487		20,761	"
"	1966	9,139		2,552		11,691	"
Hager et al. 1970	1967	4,347	2,153	2,966		7,313	
"	1968	4,142	2,099	4,298		8,440	
Hager & DeCew 1970	1969	6,210	2,950	4,697		10,907	
Hager 1973	1970	6,998	2,798	2,065		9,063	
Phinney 1972	1971	6,200	0	1,828		8,028	
Phinney & DeCew 1974	1972	2,181	0	2,448		4,629	
Phinney and Bauersfeld 1976	1973	5,595	0	5,045		10,640	
Seidel & Hopley 1978	1974	15,182	8,981***	4,873	777***	20,055	
"	1975	16,712	3,259***	11,165	6,876***	27,877	
Peterson-Cowlitz Hat.	1976	19,509	4,083***	13,478	589*	32,987	
"	1977	15,896	8,614**	11,563	11,468**	27,459	
"	1978	9,329	2,537***	17,570	9,718***	26,896	
"	1979	7,561	0	3,664	2,000***	11,225	
"	1980	15,860	1,000**	3,041	2,119***	18,901	
"	1981	20,862	None	4,247	None	25,109	
"	1982	12,236	None	3,486	None	15,722	
"	1983	13,319	None	4,580	None	17,899	
"	1984	13,645	None	1,334	None	14,979	
	1985	6,806	None	4,644	None	11,450	

Planted: *Tilton R.
**Upper Cowlitz
***Both

Table 4. Yearly counts of fall chinook salmon using Cowlitz River fish facilities, from 1961 through 1984. The mitigation level established for this species is 8,300 adults.

Source	Year	Adults	Passed upstream	Jacks	Passed upstream	Total	Remarks
Meekin & Birtchet 1963	1961	4,339		1,596		5,935	Passed upstream
Thompson and Rothfus 1969	1962	2,236		562		2,798	"
"	1963	3,244		1,927		5,171	"
"	1964	8,125		2,210		10,335	"
"	1965	5,518		5,188		10,706	"
"	1966	6,492		3,773		10,265	"
Hager et al. 1970	1967	4,018	1,672	5,986		10,004	
"	1968	3,189	671	4,677		7,866	
Hager & DeCew 1970	1969	3,369	344	11,828		15,197	
Hager 1973	1970	11,088	161	8,648	2,623*	19,736	
Phinney 1972	1971	12,684	1,165***	2,120	1,951***	14,804	
Phinney & DeCew 1974	1972	3,581	0	1,135	1,346***	4,716	
Phinney and Bauersfeld 1976	1973	5,833	915**	1,473	408***	7,306	
Seidel & Hopley 1978	1974	3,721	0	1,024	187***	4,745	
"	1975	6,138	0	1,934	614***	8,072	
Peterson-Cowlitz Hat.	1976	2,797	0	745	481**	3,542	
"	1977	2,579	0	1,286	1,084**	3,865	
"	1978	2,860	0	1,792	2,075***	4,652	
"	1979	6,155	0	801	0	6,956	
"	1980	1,968	0	221	70***	2,189	
"	1981	4,697	None	976	None	5,673	
"	1982	4,284	None	1,130	None	5,414	
"	1983	5,969	None	498	None	6,467	
"	1984	5,117	None	586	None	5,703	

Planted: *Tilton R.
**Upper Cowlitz
***Both

Coho (*O. kisutch*)

Annual counts of coho salmon indicate this species is the most abundant salmon in the Cowlitz River system (Table 5). All fish were passed upstream over Mayfield Dam until 1967 when a portion of each run was retained for egg take. Relatively large numbers of adult and jack coho salmon have been trucked upstream to both the Tilton and upper Cowlitz rivers. Upstream transport was temporarily interrupted in 1981 and 1982 but resumed in 1983. Since 1980 adult and jack coho salmon plants have provided the only opportunity for a sport fishery on adult anadromous salmon above Mayfield Dam.

Steelhead (*Salmo gairdneri*)

Records of the annual counts (Table 6) of steelhead trout using the Cowlitz River fish facilities up to 1971-72 are presented. Recent records from 1972-73 to the present are more difficult to interpret due to downstream recycling of steelhead to increase the sport catch. The number of adult steelhead hauled upstream to the Tilton River from 1967-68 to 1979-80 (Tipping, personal communication) supported a small sport fishery. Steelhead trout have not been transported upstream since 1980.

Sea-run Cutthroat Trout (*S. clarki*)

Annual counts of sea-run cutthroat trout were found (Table 7) for the period 1961 to 1984. All fish were passed upstream from 1961 to 1966 when upstream passage of sea-run cutthroat trout was terminated.

Upstream Shipments

The number of adult and jack spring and fall chinook and coho salmon

Table 5. Yearly counts of coho salmon using Cowlitz River fish facilities, from 1961 through 1984. The mitigation level established for this species is 25,500 adults.

Source	Year	Adults	Passed upstream	Jacks	Passed upstream	Total	Remarks
Meekin & Birtchet 1963	1961	23,388					Passed upstream
Thompson and Rothfus 1969	1962	22,701					"
"	1963	22,083					"
"	1964	25,546					"
"	1965	22,774					"
"	1966	31,001					"
Hager et al. 1970	1967	18,801	12,289	6,580		25,381	
"	1968	12,636	6,473	5,423		18,059	
Hager & DeCew 1970	1969	4,913	833	56,352		61,265	
Hager 1973	1970	63,407	28,486*	68,496	28,485*	131,903	
Phinney 1972	1971	33,263	8,659**	36,804	26,974***	70,067	
Phinney & DeCew 1974	1972	16,364	2,520***	20,874	17,161***	37,238	
Phinney and Bauersfeld 1976	1973	19,954	2,639***	42,172	9,147***	62,126	
Seidel & Hopley 1978	1974	17,627	777***	26,236	1,398***	43,863	
"	1975	23,000	1,806***	77,076	11,300***	100,076	
Peterson-Cowlitz Hat.	1976	25,166	2,538***	18,041	285**	43,207	
"	1977	10,299	0	50,194	20,497***	60,493	
"	1978	19,381	158**	16,545	7,130***	35,926	
"	1979	13,912	18***	15,843	2,517***	29,755	
"	1980	28,776	3,100***	16,488	1,112***	45,264	
"	1981	27,003	None	12,183	Shipped	39,186	
"	1982	22,528	None	16,577	Shipped	39,105	
"	1983	22,788	3,360(38♀)	10,591	6,103	33,379	
"	1984	26,149	4,396(142♀)	4,754	2,031	30,903	

Planted: *Tilton R.
**Upper Cowlitz
***Both

Table 6. Yearly counts of steelhead trout using Cowlitz River fish facilities, from 1961-62 through 1979-80.

Source	Year	Adults	Adults passed upstream	Remarks
Meekin & Birtchet 1963	1961-62	10,698		
Thompson & Rothfus 1969	1962-63	7,459		
"	1963-64	11,497		
"	1964-65	13,155		
"	1965-66	11,240		
Young 1973	1966-67	19,062		
Young 1973 and Tipping 1985	1967-68	17,906	9,410	
"	1968-69	11,583	7,691	Tilton R. plants
"	1969-70	4,329	1,386	"
"	1970-71	10,099	2,912	"
"	1971-72	19,299	3,299	"
Tipping 1985 (Per. Com.)	1972-73		3,319	"
"	1973-74		3,726	Tilton R. plants*
"	1974-75		3,392	"
"	1975-76		3,069	"
"	1976-77		1,458	"
"	1977-78		2,001	"
"	1978-79		1,700	"
"	1979-80		1,690	"

*No steelhead to upper Cowlitz River after Riffe Lake traps removed.

Table 7. Yearly counts of adult sea-run cutthroat trout or "trout" using Cowlitz River fish facilities, from 1961 through 1972.

Source	Year	Adults	Adults passed upstream
Meekin & Birtchet 1963	1961	5,458	All
Thompson & Rothfus 1969	1962	5,545	passed upstream
"	1963	7,193	"
"	1964	12,324	"
"	1965	12,006	"
"	1966	6,422	"
Young 1973	1967	5,573	No
"	1968	3,743	further upstream
"	1969	2,565	transfers
"	1970	2,239	"
"	1971	2,546	"
Tipping (Per. Comm.)	1972	1,495	"
"	1973	4,217	"
"	1974	2,652	"
"	1975	764	"
"	1976	816	"
"	1977	1,465	"
"	1978	3,235	"
"	1979	4,111	"
"	1980	1,689	"
"	1981	4,577	"
"	1982	6,103	"
"	1983	3,282	"
"	1984	3,323	"

shipped upstream to the Tilton and Upper Cowlitz rivers is summarized in Table 8 for the period 1974 to 1984. Spring chinook were shipped upstream in variable numbers depending on the surplus in excess of those needed for brood stock. Adult fall chinook have not been transferred upstream due to the inability to achieve the mitigation level set for this species; however, small numbers of jacks were shipped. Upstream transfer of both spring and fall chinook was terminated in 1981 due to the positive occurrence of an incurable and highly infective disease. Adult coho have been shipped upstream whenever a surplus beyond the mitigation level has been achieved; however, jack coho have contributed most to the upstream shipments. Transfers of coho were interrupted during 1981 and 1982 due to disease considerations but resumed in 1983 and 1984 with both adults (male and female) as well as jacks transferred.

Behavior of Hauled Adults and Sport Catch

The behavior of adult and jack coho and fall chinook hauled and released into the Tilton River above Mayfield Dam was reported by Hager (1973) and Phinney and DeCew (1974) (Table 9). In two tests a minimum of 50 and 58.9 percent of the jack coho and 29 and 50.1 percent of the jack fall chinook returned downstream over Mayfield Dam. A higher percentage of adult coho remained in the Tilton River with only 9.8 and 12 percent returning downstream over Mayfield Dam. This information suggests that hauling adult and jack salmon upstream to provide a sport fishery in the Tilton River may not be efficient especially with jacks of either species because of a high fall back rate over Mayfield Dam. A higher percentage of adults may remain in the Tilton River to spawn and become more vulnerable to the sport fishery. Punch card data of the Tilton River catch in 1970 estimated a catch of 353 fish, or 2.8% of the number hauled into the system. The upper Cowlitz, Cispus and

Table 8. Summary Cowlitz salmon hatchery upstream adult shipments. (WDF data).

Brood	Notes	Spring chinook		Fall chinook		Coho	
		Adult	Jack	Adult	Jack	Adult	Jack
1974	Total upstream	8981	777	0	187	777	1398
1975	Tilton River	286	3004	0	14	903	5600
	Upper Cowlitz	2973	3872	0	600	903	5700
1976	Tilton River	410	589	0	0	144	0
	Upper Cowlitz	3673	0	0	481	2394	285
1977	Tilton River	5	0	0	0	0	7206
	Upper Cowlitz	8609	11,468	0	1084	0	13,291
1978	Tilton River	339	3386	0	756	0	2304
	Upper Cowlitz	2198	6332	0	1319	158	4826
1979	Tilton River	0	1000	0	0	9	1000
	Upper Cowlitz	0	1000	0	0	9	1517
1980	Tilton River	0	949	0	35	60	149
	Upper Cowlitz	1000	1170	0	35	3040	963
1981	Tilton River	0	0	0	0	0	0
	Upper Cowlitz	0	0	0	0	0	0
1982	Tilton River	0	0	0	0	0	0
	Upper Cowlitz	0	0	0	0	0	0
1983	Tilton River	0	0	0	0	568	3707
	Upper Cowlitz	0	0	0	0	2792	2396
1984	Tilton River	0	0	0	0	2671	1380
	Upper Cowlitz	0	0	0	0	1725	651

Table 9. Capture of adult salmon released into the Tilton River and recovered at the Mayfield downstream migrant counting station.

Year	Species	Released in Tilton	Captured at Mayfield	Percent downstream over Mayfield (minimum)	Source
1970-71	Adult coho	2,661	261	9.8	Hager 1973
1970	Jack coho	7,484	4,409	58.9	"
1970	Jack chinook	2,623	1,315	50.1	"
1972*	Adult coho	1,920	223	12	Phinney & DeCew 1974
1972*	Jack coho	9,831	4,953	50	"
1972*	Jack fall chinook	966	272	29	"

*Mayfield counting station was closed for repairs on 1 August and not reopened until 29 September.

Ohanapecosh rivers were also monitored for fishing effort and success. Fishing pressure was light and only corresponded to adult release sites. Snagging became a chronic enforcement problem at each release site. Only 24 fish were caught in 1970 in the upper Cowlitz.

During 1971, fall chinook and coho salmon were trucked to the upper Cowlitz and Tilton rivers. A total of 19,296 salmon was released in the upper Cowlitz while a total of 19,453 was released in the Tilton River. Punch card returns indicated a catch of only 148 salmon in the Tilton River and none in the Cispus and Ohanapecosh rivers in spite of the large numbers released. During 1972 a total of 12,717 salmon was hauled to the Tilton River. Although prompt movement was recorded downstream a sport catch of 606 fish was recorded (5% of the number released in the river) and represents the only harvest of any magnitude since upstream hauling was initiated (Phinney and DeCew 1974). In 1973, 13,109 chinook and coho salmon were hauled to the Tilton and upper Cowlitz rivers. Salmon punch card returns indicated a catch of only 73 in the Tilton River and none in the Cispus River (Phinney and Bauersfeld 1976). In addition, since most of these fish were hatchery surplus there was limited use of the upstream habitat for spawning and rearing due to poor upstream movement exhibited by spring chinook (Table 10), further reducing the overall success of upstream hauling.

Adult steelhead plants to the Tilton River were evaluated from punch card information by Tipping (1985) (Table 11). For the period 1969-70 to 1979-80 the percent harvest ranged from 0.9 in 1970-71 to 22.7 in 1977-78 and averaged only 6.6 percent of the number planted for the eleven year period. The fall-back rate over Mayfield Dam or the number surviving to spawn in the Tilton River is unknown.

Table 10. Upper Cowlitz River spring chinook index counts.

Year	River		Total	Source
	Ohanapecosh	Cispus		
1950	69	157	226	Thompson & Rothfus 1969
1951	343	167	510	"
1952	121	256	377	"
1953	92	208	300	"
1954	150	75	225	"
1955	184	54	238	"
1956	220	188	408	"
1957	N.S.	N.S.		"
1958	N.S.	N.S.		"
1959	62	54	116	"
1960	188	77	265	"
1961	142	170	312	"
1962	242	45	287	"
1963	166	62	228	"
1964	262	282	544	"
1965	531	480	1,011	"
1966	551	236	787	"
1967	77	2	79	Hager 1973
1968	194	52	246	"
1969	245	23	268	"
1970	31	8	39	"
1971				
1972				
1973				
1974	9	5		Seidel & Hopley 1978
1975	10	9		"

Table 11. Number of adult steelhead hauled and released to the Tilton River and the percent harvest determined from punchcard information. (Source: J. Tipping 1985)

Year	# Steelhead planted	Punchcard harvest	% Harvest
1967-68	9,410		
1968-69	7,691		
1969-70	1,386	31*	2.2
1970-71	2,912	27*	0.9
1971-72	3,299	254*	7.7
1972-73	3,319	128*	3.9
1973-74	3,726	132*	3.5
1974-75	3,392	78*	2.3
1975-76	3,069	137	4.5
1976-77	1,458	65	4.5
1977-78	2,001	454	22.7
1978-79	1,700	111	6.5
1979-80	1,690	235	13.9
Average	3,466	150	6.6

*Corrected for punchcard bias.

JUVENILE PLANTS

Following the general lack of success of hauling adult salmon to the upper Cowlitz River to achieve natural production and recognizing the difficulties in capturing significant numbers of smolts in Riffe Lake for downstream transport, a policy change was made to plant surplus hatchery coho and spring chinook fry in an effort to achieve some production from the large rearing area available (Table 2). Table 12 presents the number and distribution of planted juvenile coho and spring chinook salmon in the upper Cowlitz and Tilton rivers from 1974 to 1984. The large numbers of fry indicated in this table can be misleading because all sizes from unfed fry to larger fingerlings have been included. It has become increasingly evident that large numbers of unfed fry probably don't contribute much to the population due to low survival. In recent years coho fingerlings have been planted in larger sizes in an effort to yield a larger angler harvest. It has become recognized the plants above Riffe Lake make a substantial contribution to a popular sport fishery in this reservoir (Tipping and Buckley, 1979) particularly by the coho which are caught in large numbers. Coho salmon are also predominant in the Mayfield Reservoir sport catch (Tipping and Buckley 1979). Juvenile coho and spring chinook salmon planted in the Tilton River and Winston Creek have better access to the lower Cowlitz River through the Mayfield Dam downstream migrant facilities and may contribute to the anadromous fishery downstream. Juvenile spring chinook fingerlings have not been planted above Mayfield Dam since 1981 due to disease considerations. Juvenile coho plants have been continued in support of the resident sport fishery in both Riffe and Mayfield reservoirs.

Since this planting program has been based on surplus production at the Cowlitz Salmon Hatchery there has been no effort to selectively manage

Table 12. Numbers of spring chinook and coho salmon fry and fingerlings planted in the tributaries of the upper Cowlitz River, Tilton River, Winston Creek and Mayfield Lake by the Cowlitz Salmon Hatchery 1974-84. (Modified from Easterbrooks, 1980 with Coleman and Rasch, 1981; Castoldi and Rasch, 1982; Castoldi 1983; Don Peterson from Cowlitz Hatchery planting records).

	1974		1975		1976		1977		1978		1979	
Stream planted	Coho	Spring chinook	Coho	Spring chinook	Coho	Spring chinook	Coho	Spring chinook	Coho	Spring chinook	Coho	Spring chinook
Upper Cowlitz River	1,468,284	584,209	691,878	1,396,954	756,000	2,520,000	1,058,243	0	50,000	1,141,000	297,998	
Cowlitz Falls	0	0	0	0	0	0	0	0	0	0	0	120,393
Johnson Creek	243,900	0	179,900	0	198,730	840,000	237,405	297,500	132,354	0	57,018	0
Butter Creek	281,691	0	80,750	0	91,808	0	60,880	0	130,419	0	81,989	109,805
Skate Creek	378,698	0	156,480	0	216,990	820,800	300,636	0	150,000	0	86,064	114,433
Hall Creek	64,600	0	74,250	0	22,250	0	0	0	0	0	0	0
Lake Creek	0	0	0	0	24,500	0	0	297,500	0	432,600	0	0
Smith Creek	0	0	0	0	0	0	0	459,000	0	0	0	0
Siler Creek	76,505	0	29,100	0	48,450	0	0	0	0	0	0	0
Ohanepecosh River	296,293	0	239,085	0	178,000	944,400	379,848	272,000	257,152	456,000	134,993	0
Riffe Lake	0	0	0	0	0	0	0	0	0	0	0	0
Cispus River	297,990	345,190	287,744	521,400	141,768	315,600	441,092	297,500	320,266	0	166,541	60,000
N.F. Cispus River	461,380	0	0	0	162,360	1,260,000	277,640	297,500	0	348,600	53,040	105,260
Woods Creek	367,933	0	199,176	0	61,500	0	0	0	0	0	0	0
Yellowjacket Creek	160,359	0	0	0	91,808	525,600	39,342	297,500	125,116	545,900	181,305	112,917
Iron Creek	0	0	0	0	24,000	00	47,512	297,500	132,330	328,000	0	91,107
S.F. Cispus	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	4,097,633	929,399	1,938,363	1,918,354	2,018,664	7,226,400	2,842,598	2,516,000	1,297,637	3,468,100	1,058,948	713,915
Tilton River	1,042,537	822,034	193,499	724,057	185,850	1,050,000	577,803	297,500	79,872	0	226,981	0
Winston Creek	283,677	0	298,851	174,900	124,620	315,600	214,576	0	0	312,000	0	0
Mayfield Lake	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	1,326,214	822,034	492,350	898,857	310,470	1,365,600	792,379	297,500	79,872	312,000	226,981	0
Grand Total	5,423,847	1,751,433	2,430,713	2,817,311	2,329,134	8,592,000	3,634,977	2,813,500	1,377,509	3,780,100	1,285,929	713,915

Table 12. (continued)

Stream planted	1980 Coho	1980 Spring chinook	1981 Coho	1981 Spring chinook	1982 Coho	1982 Spring chinook	1983 Coho	1983 Spring chinook	1984 Coho	1984 Spring chinook
Upper Cowlitz River	1,701,986	120,393	0	0	439,400	0	0	0	275,300	0
Cowlitz Falls	0	1,272,000	0	172,400	0	0	0	0	0	0
Johnson Creek	0	0	170,300	69,300	227,500	0	0	0	117,600	0
Butter Creek	71,040	109,805	0	238,050	165,000	0	0	0	164,800	0
Skate Creek	69,000	114,433	0	254,050	0	0	0	0	54,600	0
Hall Creek	0	0	0	0	0	0	0	0	0	0
Lake Creek	0	0	0	0	107,800	0	0	0	0	0
Smith Creek	0	0	0	0	0	0	0	0	0	0
Siler Creek	0	0	0	0	0	0	0	0	0	0
Ohanepecosh River	158,425	0	157,200	0	252,500	0	0	0	115,800	0
Riffe Lake	0	0	0	0	138,600	0	1,912,600*	0	282,200	0
Cispus River	109,020	60,000	0	189,200	192,000	0	0	0	210,400	0
N.F. Cispus River	0	105,260	0	162,260	0	0	0	0	0	0
Woods Creek	0	0	0	0	0	0	0	0	0	0
Yellowjacket Creek	66,820	112,917	0	111,230	0	0	0	0	0	0
Iron Creek	75,200	91,107	0	177,598	43,610	0	0	0	64,900	0
S.F. Cispus	0	0	0	51,600	0	0	0	0	0	0
Subtotal	2,251,491	1,985,915	327,500	1,425,688	1,566,410	0	1,912,600	0	1,285,600	0
Tilton River	286,000	0	201,400	360,950	0	0	0	0	337,100	0
Winston Creek	0	0	328,200	87,416	0	0	0	0	0	0
Mayfield Lake	0	0	71,875	0	87,740	0	496,600	0	275,500	0
Subtotal	286,000	0	601,475	448,366	87,740	0	496,600	0	612,600	0
Grand Total	2,537,491	1,985,915	928,975	1,874,054	1,654,150	0	2,409,200	0	1,898,200	0

*Numerous streams above Riffe Lake.

particular stocks of each species in the upper Cowlitz River tributaries. The original wild stocks have been overwhelmed by the large production of hatchery fish. To implement such a policy would require marking all downstream migrants to allow identification upon return to the hatchery and the taking and segregation of the eggs throughout rearing. Such a program would appear to offer little in terms of the additional costs which would result.

DOWNSTREAM MIGRANT COUNTS

Thompson and Rothfus (1969) reported the passage of coho, chinook, steelhead-rainbow and cutthroat trout juveniles through the fish bypass facilities at Mayfield Dam during 1964, 65 and 66 (Table 13). Relatively large numbers of smolts (over 400,000 coho, 700,000 chinooks, 80,000 steelhead and 7,000 cutthroat in 1966) were recorded through the facilities during this period. These smolts are thought to have resulted from the natural spawning of adults passed upstream over Mayfield Dam prior to the operation of Mossyrock Dam and prior to the initiation of supplemental plants of fry and fingerlings by the Cowlitz Salmon and Trout hatcheries.

Following the filling of Mossyrock reservoir (Riffe Lake) in 1968 an effort was made over the next six years to trap downstream migrants in Riffe Lake for transfer around Mossyrock Dam to the Cowlitz River below Mayfield Dam. Numerous modifications of a Merwin trap facility were made and tested over the six-year period but none could overcome general inefficiency. The catch of smolts averaged about 145,000 coho, 4,000 chinook, 217 steelhead-rainbow and 25,500 cutthroat. The strong thermal stratification of Riffe Lake, the small sampling area to lake volume ratio of the traps, wind generated wave action and other problems rendered the trapping program ineffective. Fish enumerations at Mayfield Dam fish facilities from 1971-73 confirmed that a very low rate of smolt passage occurred with only an average of 40,276 coho, and 4,375 chinooks and small numbers of remaining species. Few smolts pass through Riffe Lake due to the extremely deep turbine intakes. Smolt passage from Riffe Lake has only been observed following spill conditions at Mossyrock Dam. A high rate of smolt residualization in Riffe lake reduces the urge to move downstream. One demonstrable positive benefit is the creation of a sport fishery for resident fish for which Riffe Lake has

Table 13. Juvenile downstream migrant catches in Riffe and Mayfield reservoirs and downstream transfers.

		Riffe Lake (Mossyrock) trap catches				Mayfield Dam facilities			
Source	Year	Coho	Chinook	Steelhead-rainbow	Cutthroat	Coho	Chinook	Steelhead-rainbow	Cutthroat
Thompson and Rothfus 1969	1964					271,387	241,448	59,064	3,227
"	1965					359,774	231,081	63,093	4,680
"	1966					416,221	719,510	80,377	7,978
	1967								
Hager 1973	1968	163,361	16,965	346	50,484				
"	1969	257,262	5,046	587	59,528				
"	1970	92,221	921	369	17,384				
Phinney 1972	1971	10,121	77		1,527	17,662	5,225	12,209	4,826
Phinney and DeCew 1974	1972	172,041	385		24,072	83,812	7,489		
Phinney and Bauersfeld 1976	1973	175,096	755		946	19,355	2,411		6,868
	1974	← Trapping terminated →				← Enumeration discontinued →			
	1975								
	1976								
	1977								
J. Tipping (Pers. Comm.)	1978					10,717	1,223	3,398	213
"	1979(A)					2,771	644	1,302	60
"	1980(B)					2,124	455	2,481	536
"	1981					15,349	24,648	5,114	2,382(C)
"	1982					5,707	282	1,376	88
"	1983					570	4	297	78
"	1984					No data →			
"	1985					15,545	0	656	327

(A) trap closed during May.
(B) trap closed end of May for repairs to dam.
(C) legal cutthroat planted Tilton River and Winston Creek.

become noted (Tipping and Buckley 1979). Recent counts of juveniles (Table 13) through the Mayfield Dam fish facilities indicate small numbers of all species continue to pass downstream (Tipping, personal communication), probably from the Tilton River and Winston Creek.

SPORT FISHERY

Riffe Reservoir.

An important sport fishery has developed on Riffe Lake. Tipping and Buckley (1979) reported the results of a creel census which showed anglers expended 28,557 days of effort (99,838 hours) to catch 77,955 coho (86.2%), 6,026 rainbow (6.7%), 4,305 chinook (4.8%), and 2,143 cutthroat (2.4%) between April 1978 and March 1979. Study of the limnological features of Riffe Lake indicate that the successful sport fishery is due to thermal stratification providing water column stability allowing the production of phytoplankton and zooplankton to occur in the lake. The very deep location of the penstocks contributes to water column stability and minimizes the entrainment loss or active passage of fish from the reservoir. The heavy plants of coho fry in the streams tributary to Riffe Lake each year provide the recruitment for the reservoir fish populations which support the sport catch. The estimated sport catch for Riffe Lake in the period June-October 1985 (Table 14) indicates angler effort remains high with coho salmon and cutthroat trout predominant in the catch (Tipping, personal communication). It is apparent that the management of Riffe Lake for resident sport fish production has created an important fishery resource for upper Cowlitz River basin anglers.

Mayfield Reservoir.

A resident sport fishery has also been documented in Mayfield reservoir by Tipping and Buckley (1979). They estimated 13,649 angler days (37,505 hours) were expended to catch 7,860 coho (72.4%), 2,522 rainbow (23.2%), 272 chinook (2.5%), 105 cutthroat trout (1.0%), and 97 adult steelhead (0.9%) during the period April 1978 to March 1979. Operation of Mayfield reservoir as a run-of-river impoundment reduces its stability for aquatic production. The surface location of the penstock intakes also reduces the stability of the reservoir as well as increases the entrainment loss of fish emigrating downstream through the fish passage facilities. The sport catch estimated for Mayfield reservoir in 1985 (Table 14) is small in comparison to Riffe Lake with coho salmon and cutthroat trout predominant (Tipping, personal communication). Present management efforts are to improve the resident sport fishery in Mayfield Reservoir with the production of smolts emigrating downstream given a secondary importance. The management of Mayfield reservoir for resident sport fish is less productive than Riffe Lake; however, the downstream migrant fish facilities at Mayfield Dam indicate the best management strategy could be for anadromous fish if residualization and mortality of smolts in the reservoir can be reduced to achieve adequate adult returns.

Table 14. Estimated sport catch in Riffe and Mayfield, 1985 (J. Tipping, WDG).

Month	Effort (hrs)	Coho salmon	Cutthroat trout	Rainbow trout	Brown trout	Crappie	Bass	Bullhead
Riffe								
Jun	49,436	14,177	1,615	126	41	0	20	72
Jul	46,088	17,121	1,514	107	47	13	0	52
Aug	19,793	11,807	254	0	0	0	0	0
Sep	7,096	3,900	212	19	0	6	8	0
Oct	2,221	1,499	58	15	10	0	0	0
Nov	1,122	1,549	29	0	0	0	0	0
Dec	3,832	5,544	7	3	3	0	0	0
Mayfield								
Jun	895	66	15	0	0	0	0	0
Jul	1,303	30	15	0	0	0	0	0
Aug	3,749	49	50	7	0	0	0	0
Sep	2,625	548	93	12	0	0	0	0
Oct	1,430	1,125	64	5	0	0	0	0
Nov	335	558	5	5	4	0	0	0
Dec	243	13	0	0	0	0	0	0

FISH DISEASES

The Cowlitz River salmon hatchery and the steelhead trout hatchery were constructed by Tacoma City Light as a major part of the effort to mitigate the impacts on fish runs due to the construction of Mayfield and Mossyrock dams. These hatcheries utilize the salmon and steelhead stocks returning each year to propagate each species by artificial means through the science and art of fish culture. A critical requirement in the culture of salmonids is the control of important bacterial and viral diseases encountered by these populations and remains the single most important factor in the successful production of fish. Throughout the operational history of the Cowlitz hatcheries there has been an increased realization of the necessity to avoid infectious agents in order to maintain healthy stocks of fish to maintain the mitigation levels. Many of the diseases encountered reoccur on an annual basis in response to seasonal changes in water temperature (Fig. 4), susceptibility of species, density, life history stage, diet, etc. Many of these diseases are controlled by treatment with chemotherapeutic substances; however, some diseases do not respond to any known treatment (e.g., viruses, drug resistant bacteria and certain deep tissue protozoans) and constitute a very serious threat to the continued success of all fish cultural operations of which the Cowlitz River hatcheries are no exception.

Infectious diseases carried by salmon and steelhead have occurred frequently at the Cowlitz salmon and trout hatcheries throughout their operation. Routine disease examinations are required as a means for early diagnosis and rapid treatment of each species age group processed through each annual culture cycle (Appendix Table 1). Disease diagnosis and control is complicated in the hatchery by the culture of fish with a 14-month spread in age, large production resulting in crowding, high natural incidence of disease

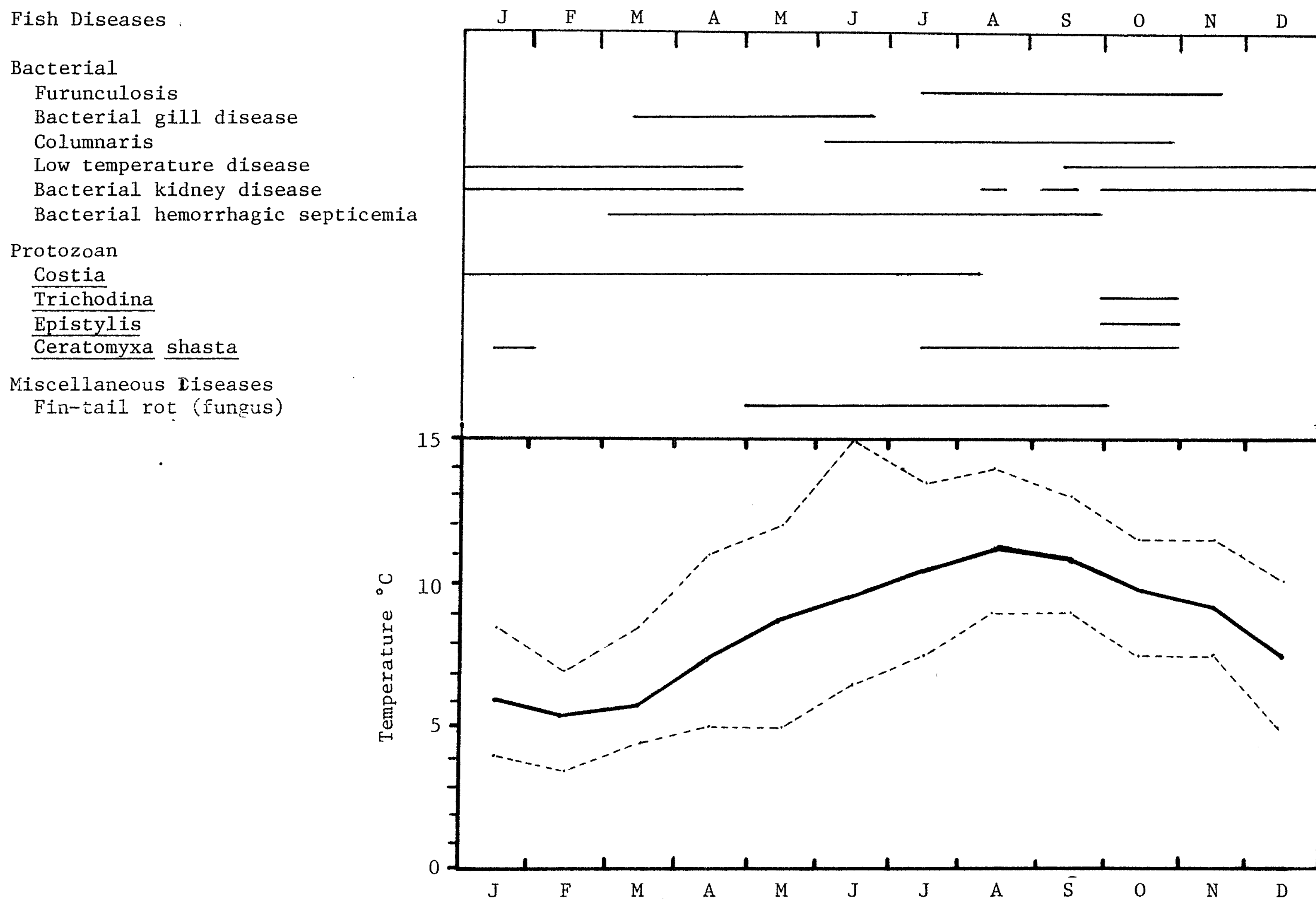


Fig. 4. Seasonal occurrence of some of the diseases affecting salmonids at the Cowlitz River Salmon and Trout Hatcheries and the maximum, minimum, and mean monthly water temperatures for the post-reservoir period 1974-82 (WDF and U.S.G.S. data).

in the Cowlitz-Lower Columbia River system and annual changes in weather affecting the quality of surface water supplies used by both hatcheries. Some diseases reoccur each year for which a standard prophylaxis is applied; however, newer diseases continue to be discovered which do not have immediate remedies. In these cases, attempts are made by fish health scientists to find alternate or new disease control methods; however, the search for new techniques provides little for immediate application in an operating hatchery other than to institute a conservative management strategy.

The severity of disease problems varies among the species cultured (Table 15) and the length of time necessary to hold adults and juveniles. The disease problems of chinook salmon are more prevalent and difficult to control than those of the coho salmon. Both spring and fall chinook encounter similar diseases in the first four months. The fall chinook are liberated in May and June (some in September), while the spring chinook are reared at least 10 months longer and encounter additional diseases. Adult spring chinook encounter diseases due to earlier freshwater entry during higher water temperatures which result in a 5-month holding period prior to spawning. Fall chinook, coho salmon and winter steelhead adults are held for a shorter period of time at lower water temperatures and experience fewer disease problems.

At least nineteen fish diseases are indigenous to Cowlitz River salmon and steelhead (Table 16). Thus far all diseases have more or less been successfully controlled except for C. shasta which causes high mortality at the trout hatchery each year. None of the diseases have been eliminated from the populations. A few diseases for which controls are limited result in occasional epidemics and associated high fish mortalities. DeCew (1985) reviewed the characteristics of the most important diseases requiring continual control in fish cultural operations at the Cowlitz hatcheries. He

Table 15. The species and life stages affected by diseases diagnosed in the Cowlitz River salmon and steelhead hatcheries. (Compiled from WDF and WDG Fish Health Diagnostic Reports.)

Spring Chinook Salmon

Adult

Furunculosis, Columnaris, Bacterial Kidney Disease, Bacterial Hemorrhagic Septicemia, Infectious Hematopoietic Necrosis Virus

Fry to Yearling

Furunculosis, Bacterial Gill Disease, Columnaris, Low Temperature Disease, Bacterial Kidney Disease, Bacterial Hemorrhagic Septicemia, *Costia*, *Trichodina*, *Ceratomyxa shasta*, *Nanophyetus salmincola*, *Sanguinicola* spp., Fin Rot, Eye Opacity

Fall Chinook Salmon

Fry to Fingerling

Furunculosis, Bacterial Gill Disease, Low Temperature Disease, Bacterial Kidney Disease, Bacterial Hemorrhagic Septicemia, *Costia*, *Ceratomyxa shasta*, *Nanophyetus salmincola*, *Sanguinicola* spp.

Coho Salmon

Fry to Fingerling

Furunculosis, Bacterial Gill Disease, Low Temperature Disease, Bacterial Kidney Disease, *Costia*, *Trichophera*, *Epistylis*, *Myxabolus kisutchi*, *Sanguinicola* spp., Fin Rot, Viral Erythrocytic Necrosis (Salmon Anemia Disease), Eye Opacity

Winter and Summer Steelhead, Sea-Run Cutthroat, and Legal Rainbow Trout

Fry to Adult

Furunculosis, Columnaris, Low Temperature Disease, *Costia*, *Trichodina*, *Ichthyophthirius*, *Hexamita*, *Ceratomyxa shasta*, Infectious Hematopoietic Necrosis Virus, *Gyrodactylus* sp.

Table 16. List of diseases encountered by salmonids cultured at the Cowlitz River salmon and steelhead hatcheries. (Compiled from WDF and WDG Fish Health Diagnostic Reports.)

Bacterial Diseases

- Furunculosis
- Bacterial Gill Disease
- Columnaris
- Low-Temperature Disease
- Bacterial Kidney Disease
- Bacterial Hemorrhagic Septicemia

Protozoan Diseases

- *Costia*
- *Trichodina*
- *Ichthyophthirius*
- *Hexamita*
- *Epistylis*
- *Ceratomyxa shasta*
- *Myxabolus kisutchi*

Viral Diseases

- Infectious Hematopoietic Necrosis
- Viral Erythrocytic Necrosis (Salmon Anemia Disease)

Worm Parasites

- *Nanophyetus salmincola* (salmon poisoning fluke)
- *Sanguinicola* spp. (blood fluke)
- *Gyrodactylus* spp.

Miscellaneous Diseases

- Fin-Rot or Tail-Rot Disease
- Eye Opacity--undiagnosed cause(s)

identified seven primary diseases of Cowlitz chinook and coho salmon and steelhead trout. These are infectious hematopoietic necrosis virus (IHNV), bacterial kidney disease (BKD), Ceratomyxa shasta, furunculosis, Enteric red mouth, viral erythrocytic necrosis/salmon anemia disease (VEN/SAD) and low-temperature disease (LTD).

Viral Diseases

Infectious hematopoietic necrosis virus (IHNV) - is the most important disease to recently affect Cowlitz River steelhead trout and chinook salmon. IHNV became epidemic in juvenile trout at Mossyrock Hatchery, which is upstream from the Cowlitz Salmon and Trout hatcheries. IHNV was detected in broodstock steelhead at the Cowlitz Trout Hatchery in February 1981. The Mossyrock hatchery had received eggs from the Cowlitz hatchery and both outbreaks were from the same February 1981 adult brood. Epizootics occurred in summer 1981 and 1982 affecting juvenile winter and summer steelhead, sea-run cutthroat and legal rainbow trout. Loss in the Cowlitz Trout Hatchery rearing ponds in 1982, due to the combined effects of the myxosporidian protozoan Ceratomyxa shasta and IHNV was 86% and 67% for summer and winter steelhead trout respectively. IHNV positive broodstock sea-run cutthroat, summer and winter steelhead were found in 1982 and 1983.

Subsequently, IHNV was detected in the 1984 Cowlitz spring chinook adults and 1.42 million eggs were destroyed in an attempt to eradicate the disease. Some 25 million eggs and fish have been destroyed in the Columbia River system in the past four years in an attempt to eradicate IHNV. Both steelhead and chinook salmon in the Cowlitz River may carry IHNV for several seasons as a result of these prior infections detected in 1980 through 1984. IHNV has not been found at the Cowlitz trout hatchery since the spring of 1983.

Coho salmon are not susceptible nor carriers of this disease. IHNV is believed to be transmitted through the water (horizontal) and from parent to offspring through the gametes (vertical). There is no known control agent other than total destruction of infected populations. Efforts were begun in 1981 at the Cowlitz hatcheries to control this virus by culling out gametes from virus positive broodstock. It is expected that this program will continue until an effective treatment can be found; however, it is certainly not a preferred procedure to apply because it can impact the ability to achieve the hatchery mitigation goals of affected species.

Viral Erythrocytic Necrosis/Salmon Anemia Disease (VEN/SAD) - was first described by Laird and Bullock (1969), as a pathological condition in the erythrocytes of three fish species from the coastal waters of eastern Canada and northeastern USA (Winton et al. 1983). Additional studies of this disease in Atlantic cod have been reported. Viral erythrocytic necrosis has also been reported in fish from the Pacific Coast of North America. Evelyn and Traxler (1978) observed VEN/SAD in chum and pink salmon reared in pens in British Columbia. The virus has also been found in adult chinook, coho and chum salmon, steelhead trout and herring from the coastal waters of Oregon (Rohovec and Amandi 1981).

Limited progress in understanding this disease is anticipated until the infectious agent can be isolated and propagated. At the present time it is not known if a single viral agent or a group of related viruses is responsible for this disease.

VEN/SAD occurred in 1983 Cowlitz brood coho yearlings during May 1985 (DeCew 1985). This virus appears to cause extensive debilitation and low resistance to bacterial and fungal infection. Over 10,000 fish died due to the secondary infectious agents (BKD, LTD, fungus) that were precipitated by the viral disease. Even more important was the high prevalence of severe anemia among the 0.5 million yearling coho that were released. Such high losses in yearling coho associated with VEN/SAD have occurred at Bonneville Salmon Hatchery as well as at Cowlitz Salmon Hatchery in yearlings scheduled for release June 1, rather than the more common release date of May 1.

Inspections of the Cowlitz River hatcheries and stocks routinely conducted by the Washington Department of Fisheries indicate tests for two additional viruses (Infectious Pancreatic Necrosis and Viral Hemorrhagic Septicemia) have been negative.

Bacterial Diseases

Bacterial kidney disease (BKD) - remains one of the most serious bacterial infections of salmonids. This disease does not respond effectively to any of the readily available chemotherapeutic substances and because of the slow, insidious nature of the disease may continue to produce deaths over long periods of time (Winton et al. 1983). All salmonid species are susceptible and the disease is present in many stocks of fish throughout the Northwest. The optimal temperature for growth of this disease causing bacterium is 15-18°C. The rate of transmission remains unclear because it has been transmitted experimentally through infected food, water and possibly the ovarian fluid. No effective control method for the disease is known.

Bacterial kidney disease was endemic to the Cowlitz River where it had been diagnosed in wild juvenile chinook salmon passing Mayfield Dam (Phinney and DeCew 1974, citing Wood, personal communication, 1972) prior to the operation of the salmon and trout hatcheries. The disease has been epidemic in Cowlitz chinook adult and juvenile stocks during each of the 17 years of operation. Evidence supported by micro-tag returns and laboratory seawater experiments suggests that BKD significantly reduces the ability of salmon to survive after entering saltwater (Ellis et al. 1978).

Furunculosis. One of the most intensively studied bacterial pathogens of fish is the disease known as furunculosis (Winston et al. 1983). The disease is ubiquitous among populations of cultured salmonids and has been responsible for severe mortality. The disease may occur in an acute or chronic form depending upon water temperature, host resistance, number of bacteria and virulence of the strain. All salmonid species are susceptible to infection with Aeromonas salmonicida, the causative agent. The bacterium is considered an obligate pathogen of freshwater fish, but may be found free-living for short periods of time. Carrier fish are the main reservoir and transmission occurs primarily via water. Infected fish may exhibit either chronic or acute disease depending on host resistance, strain virulence and environmental factors such as temperature. The disease is most prevalent in summer and autumn when temperatures are higher. The optimum for furunculosis outbreaks ranges from 13-19°C (McGraw 1952). Death occurs more rapidly at higher temperatures.

This disease is commonly controlled by feeding chemotherapeutic substances such as sulfa drugs or oxytetracycline. In recent years drug resistant strains have emerged which cannot be controlled with either of the above antimicrobial compounds; however, new compounds are under development. Furunculosis appears to occur most often during the fall at the Cowlitz hatcheries. DeCew (1985) reported that this disease caused significant loss of adult spawning fall chinook held in the Cowlitz salmon hatchery in 1985. Since some control of this disease is available it amounts to an added insult to chinook salmon rearing programs at the Cowlitz salmon hatchery.

Enteric Redmouth - is caused by an organism known as *Yersinia ruckeri*, a disease which is known to occur among populations of many salmonid species throughout most of the United States (Winton et al. 1983). Enteric redmouth is characterized by a bacteremia with inflammation and hemorrhage of the jaw and palate. A chronic form of the disease accompanied by low mortality is common, however, epizootics may occur if environmental conditions become unfavorable for the fish. Transmission is through the water from infected individuals. The disease can often be controlled with oxytetracycline and sulfa drugs although many drug-resistant strains exist. Since control of this disease is available it results in an added insult to chinook salmon rearing programs.

Low-Temperature Disease (LTD) - A bacterium known as *Cytophaga psychrophila* is the disease causing organism. It is common among cultured coho salmon fry in the coastal streams of western Oregon and Washington when water temperatures are in the range of 5 to 10°C (Winton et al. 1983). The disease can usually be controlled by the use of oxytetracycline substances provided the fish have been transferred to ponds and are taking food. LTD is particularly severe among young fry in hatchery troughs where treatment is difficult. Annual epizootics of cold-water disease occur among cultured coho salmon at hatcheries where the bacterium is endemic.

LTD is a bacterial infection that has reoccurred in Cowlitz yearling coho each season for 17 years. DeCew (1985) states this disease requires repeated antibiotic treatments and inflicts the survivors with scoliosis and probably other damage that has not been identified. A high incidence of eye cataracts has frequently been observed in yearling salmon but the etiology is not known. Although Wood (1974) reported that LTD was most prevalent in coho fry, DeCew (personal communication) reported the disease has not been observed in coho fry at the Cowlitz hatchery and the reason is unknown. Although LTD primarily affects yearling coho at the Cowlitz hatchery it also constitutes a further insult to rearing juvenile chinook salmon.

Protozoa

Ceratomyxa shasta - Wood (1974) and DeCew (1985) reported observing *Ceratomyxa shasta* infections in juvenile chinook salmon every season in the Cowlitz salmon hatchery. This disease has not caused significant mortality in juvenile chinook except in 1968 when water temperatures were elevated during the filling of Mossyrock Reservoir. *C. shasta* has infected and caused serious fish loss throughout the history of the Cowlitz trout hatchery (Tipping and Kral 1985). Loss of steelhead and cutthroat juveniles commonly exceed 30 percent and sometimes 80 percent with most of this loss due to this disease (Tipping et al. 1985). There appears to be a low level of *C. shasta* in the upper Cowlitz drainage above the salmon hatchery; however, it is common throughout the lower Columbia River drainage (Wood 1974). This disease seems to be most prevalent where upstream lakes and reservoirs occur; however, Riffe and Mayfield reservoirs appear to have low infectivity levels. Tipping and Kral (1985) found high infection rates below the salmon hatchery and the presence of infectious units in the salmon hatchery raceway sediments. They suggest the salmon hatchery upstream of the trout hatchery may be the major reservoir of infection for the Cowlitz trout hatchery.

There is no known chemotherapeutic agent which is effective in the treatment and control of *C. shasta*. When a susceptible species is exposed in an infected water supply and the water temperature exceeds 10°C, the fish will show evidence of the disease in approximately 38 days (Leitritz and Lewis 1980). The incubation period shortens as the water temperature increases. The most common management technique to preclude infection is avoidance of the infected waters or the utilization of certain strains of trout which have developed partial resistance to the disease.

Control of the infective stage of C. shasta has been achieved by treatment of hatchery water supplies with ultraviolet irradiation or chlorination; however, both methods have disadvantages. Tipping and Kral (1985) have initiated the evaluation of a pilot ozone water treatment system at the Cowlitz Trout Hatchery. If these studies which are in progress indicate ozone as an effective control procedure for C. shasta a proposal by the Washington Department of Game will be made to develop a full-scale treatment facility for the hatchery water supply. A similar system for the salmon hatchery would probably be impractical due to the much larger volume of water utilized compared to the trout hatchery.

Present management practice for the control of C. shasta instituted in 1982 was to eliminate plants of infected fish from the Cowlitz salmon and trout hatcheries into upstream reservoirs (Riffe and Mayfield) above the hatcheries. The species affected in both adult and juvenile stages are chinook salmon, steelhead-rainbow and cutthroat trout. Coho salmon adults and juveniles, brown trout juveniles and rainbow trout legals from other sources which do not carry the disease continue to be planted in these reservoirs to support an important resident sport fishery.

Discussion

It is apparent the diseases carried by Cowlitz chinook salmon and steelhead trout are a very significant threat to the fishery resource of the Cowlitz River. Planting these infected fish in the Upper Cowlitz River would most likely establish infections in resident fish populations and these infections could be transmitted back downstream to the salmon and trout hatcheries. Outbreaks of IHNV occurred in steelhead juveniles in spring 1981 at the Mossyrock and Cowlitz Trout hatcheries. IHNV was detected in steelhead at the Cowlitz Trout Hatchery and it was suspected Mossyrock steelhead eggs shipped from Cowlitz could and subsequently were found to be infected. The disease was detected again in adult chinook salmon at the Cowlitz Salmon Hatchery in 1984.

Planting coho adults and juveniles in the upper Cowlitz presents less of a threat because diseases in coho are less serious and the water temperatures are relatively lower during the adult coho migration. This lower temperature suppresses diseases such as *Ceratomyxa shasta*, BKD, LTD and furunculosis, which are carried by adult coho. The fact that coho do not carry IHNV is an important difference. The occurrence of VEN/SAD virus in coho stocks is disturbing, but generally is not viewed as being as pathogenic and damaging as IHNV.

POTENTIAL OPTIONS FOR REINTRODUCTION

A series of thirteen potential options has been identified for consideration in an attempt to reintroduce anadromous salmon and steelhead to the Tilton and upper Cowlitz rivers. These options have been prioritized on the basis of overall feasibility with primary consideration focused on sound biological principals in the management of fisheries in the upper Cowlitz River basin. Each option entails a number of actions which are consistent with the life cycle requirements of anadromous salmonids, the existing modifications of the habitat, future modifications required and the need to protect the Cowlitz hatcheries from unnecessary exposure to incurable fish diseases. The goal of each option is to attempt to "reinstate the natural salmon and steelhead trout fish runs" (Chapter 77.04 RCW) above Mayfield and Mossyrock Dams which may be managed on a sustained basis in the future.

Option 1. Provide volitional access for all adult anadromous salmonids above Mayfield and Mossyrock dams, pass smolts downstream over both dams and treat hatchery water supplies.

Option 2. Provide volitional access for all adult anadromous salmonids above Mayfield and Mossyrock dams, pass smolts downstream over both dams and develop offstream water supplies for both hatcheries.

Option 3. Provide volitional access for all adult anadromous salmonids only above Mayfield Dam, pass smolts downstream over the dam and treat hatchery water supplies.

Option 4. Provide volitional access for all adult anadromous salmonids only above Mayfield Dam, pass smolts downstream over the dam and develop offstream water supplies for both hatcheries.

Option 5. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams, pass smolts downstream over both dams and treat hatchery water supplies.

Option 6. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams, pass smolts downstream over both dams and develop offstream water supplies for both hatcheries.

Option 7. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams, collect smolts at the proposed Cowlitz Falls Dam and haul to the lower river, pass Tilton River smolts over Mayfield Dam and treat hatchery water supplies.

Option 8. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock Dams, collect smolts at the proposed Cowlitz Falls Dam and haul to the lower river, pass Tilton River smolts over Mayfield Dam and develop offstream water supplies for both hatcheries.

Option 9. Haul only adult coho salmon above Mayfield and Mossyrock dams, pass smolts downstream over both dams.

Option 10. Haul only adult coho salmon above Mayfield and Mossyrock dams, collect upper river smolts at the proposed Cowlitz Falls Dam and improve passage of Tilton River smolts over Mayfield Dam.

Option 11. Haul only adult coho salmon above Mayfield Dam and pass smolts from the Tilton River and Winston Creek over modified Mayfield Dam fish facilities.

Option 12. Haul only adult coho salmon above Mayfield Dam and pass smolts from the Tilton River and Winston Creek over existing Mayfield Dam fish facilities.

Option 13. No action.

A review of the potential uses of the existing habitat is presented in the following section prior to evaluation of these options. The results of research and management efforts previously conducted should be understood before any assessment and evaluation of the forgoing options can be undertaken.

POTENTIAL USES OF THE EXISTING HABITAT

The single purpose development of the upper Cowlitz River for hydroelectric generation has lead to the demise of anadromous fish runs above Mayfield Dam. Construction of the dams without upstream fishway facilities has forever precluded the natural migration of adult salmon and steelhead to upstream tributaries. The construction of fishways for these dams might allow a remnant of the original runs to be developed; however, dams with the height of Mayfield and Mossyrock have rarely been laddered due to the limited effectiveness in moving fish and may not be cost effective.

Reintroduction of anadromous salmonids into the upper Cowlitz River basin must be evaluated in terms of the major habitat modifications due to dam construction and the concern for disease control at the downstream Cowlitz Salmon and Trout hatcheries. Potential uses should also consider the trade-offs involved in trying to arrive at the best utilization of the habitat as it now exists. The technical evidence and past fisheries management experience are reviewed beginning in the upper watershed and moving downstream to the salmon and trout hatcheries.

Riffe Lake and Tributaries

The potential maximum productivity of stream habitat in the upper Cowlitz River watershed above Riffe Lake for anadromous salmon production was estimated by Easterbrooks (1980) to be approximately 200,000 coho and 55,000 spring chinook salmon under natural spawning conditions. The study assumed that all adults trucked past the dams to the upper watershed successfully maximized the use of the spawning habitat in the available tributaries. Although fall chinook were included in the analysis this species was not recommended by WDF for inclusion in a program because adult escapement to the Cowlitz Hatchery has remained below the mitigation level. In addition, the relatively short freshwater rearing time (3 to 6 months for fall chinook compared to 12 to 14 months for coho and spring chinook) did not constitute effective use of this habitat.

Hauling adult and jack salmon to the upper watershed was designed to provide a sport fishery; however, the reported catch shows that few fish were caught by anglers. Adults hauled above the dams were not only difficult to catch using legal angling methods but many jacks promptly migrated downstream toward the hatchery which reduced availability to the angler. The behavior of hauled adults suggests the spawning utilization of the habitat may not be maximized contrary to the assumption by Easterbrooks (1980). The chief reason for this is the behavior of the adult fish released upstream. Apparently, most of the fish hauled upstream were not from the upper watershed genetic stocks, but were of the lower river stock. Hence, the poor dispersion into the upstream habitat and movement downstream. It has not been practical to identify the upriver stocks at the hatchery trapping site. The difficulties and costs involved in upriver stock identification are compounded by the ratio of large numbers of hatchery produced fish released to the lower river which have overwhelmed the very small numbers produced from upstream. It might be possible to develop a genetically separate stock for propagation up river or to select a stock for introduction with a unique time of return. However, the costs associated with the successful development of a unique fish run above Mossyrock Dam might be substantial and other factors require consideration before such a decision could be justified.

Annual fry plants of surplus hatchery produced salmon in the upper Cowlitz River were also evaluated by Easterbrooks (1980). He assumed that hatchery fry plants would yield a lower smolt production than would natural spawning because access to streams by hatchery trucks for planting was limited and therefore only included rearing habitat below access points. However, considering the poor upstream homing of hauled adults this estimate may be more realistic. He estimated that a maximum of about 170,000 coho and 45,000 spring chinook adult salmon could be produced without assuming any loss for collection or transportation mortality which would most likely occur. Large numbers of surplus spring chinook salmon fry were planted from 1974 to 1982 before upstream distribution of this species was discontinued. A fry planting program has been maintained from 1974 to the present for coho salmon. The large plants of coho fry have been mainly responsible for the development of a resident sport fishery in Riffe Lake.

It must be recognized any plan to utilize the habitat above Riffe Lake for anadromous fish production has not been successful simply because most of the smolts cannot migrate through Riffe Lake. The thermal stratification of the reservoir, extreme drawdown, infrequent surface spill and the great depth of the penstock intakes result in the residualization of most entering smolts preventing downstream passage. No means have been devised to efficiently collect the downstream salmon migrants in Riffe Lake for transport below Mayfield Dam. The proposed Cowlitz Falls hydroelectric project might present a future opportunity to collect smolts before reaching Riffe Lake if juvenile salmon collection facilities are incorporated in the dam.

Planting salmon and steelhead trout adults and juveniles into the upper watershed has become further restricted following efforts to control communicable fish diseases at the Cowlitz Salmon and Trout hatcheries. Following the occurrence at the hatcheries of IHNV in steelhead and chinook salmon which carry the disease these species have no longer been planted upstream in an effort to prevent the spread of the disease to the hatchery water supplies and susceptable upstream fish populations. Coho salmon are neither susceptable to IHNV nor a vector in transmission of the disease; hence, present less of a threat. Thus, coho salmon is the only anadromous species which can safely be stocked above the Cowlitz hatcheries.

Techniques to cull IHNV positive chinook and steelhead at the Cowlitz hatcheries are employed to eliminate the virus by destroying gametes from virus positive broodstock. This method of control can impact the ability to achieve the mitigation goal, a procedure used only as a last resort. Whether upstream plants of chinook and steelhead could ever be resumed is unknown at this time. It may be this virus will be eliminated after several cycles; however, it is not clear if this is possible with the comingling of Cowlitz stocks with others in the lower Columbia River where infected fish or water may be encountered.

The concern for planting infected fish upstream may be reduced if the hatchery water supplies were isolated. This could be done by the development of groundwater sources through numerous wells. An alternative approach could include construction of redundant water treatment systems (e.g., chlorination-dechlorination or ozone) at each hatchery to eliminate the transmission of diseases through the surface waters presently used. Development of absolute fail-safe disease control on the volume of water (156 cfs) used buy the Cowlitz Salmon Hatchery cannot be guaranteed. Most treatment methods have associated negative side effects which must also be considered. It perhaps should be clarified at this point that the salmon hatchery is the facility at significantly increased risk while the trout hatchery is already at risk to diseased fish. This is due to the point of water intake which is above the barrier dam for the salmon hatchery and below the barrier dam and salmon hatchery for the trout hatchery. Upstream plants of diseased fish will increase the risk of epidemic to both hatcheries; however, the WDG Trout

Hatchery must eventually rely on water treatment to solve this problem.

Of course all disease would not be eliminated in the hatcheries, only that which may enter through the water supply since infected fish returning to the hatcheries will still carry diseases. The overriding importance of the Cowlitz hatcheries to successfully mitigate the impacts of the dams cannot be compromised by introduction of incurable fish disease to the upper watershed.

Utilization of the watershed above Riffe Lake for anadromous fish production is not presently the best use of the habitat. This conclusion is largely supported on the basis that presently it is not prudent to plant any species upstream except coho salmon because of the need to protect the downstream Cowlitz hatcheries and to control the disease IHNV; therefore, eliminating the use of spring chinook salmon. Coho smolts from tributary fry plants enter and reside in Riffe Lake and produce a significant sport fishery in the upper basin. Anadromous coho salmon in the lower river are maintained at near the mitigation level creating little need to produce additional anadromous coho in the upper tributaries above Riffe lake.

Utilization of the stream habitat above Riffe Lake for the rearing of resident ("landlocked") coho fry minimizes conflicts for hatchery rearing space for lower river anadromous stocks. The hatchery production of anadromous coho salmon is limited by the space available for rearing because the culture requires from 12 to 14 months. Rearing in the tributaries is important to the maintenance of a robust sport fishery in Riffe Lake because the smolts enter the reservoir at a larger size, resulting in higher survival rates and more fish to the angler's creel. The alternative of direct fry plants to the reservoir is less productive due to higher predation rates and less desirable rearing habitat; however, an exception occurs when fry are reared to a larger size in the hatchery. Studies in progress by the

Washington Department of Game (Tipping, pers. comm.) in cooperation with the Department of Fisheries (P. Peterson, pers. comm.) indicate that direct plants of coho fingerlings ($\sim$60/lb) into Riffe Lake recruit to the sport fishery by June of the following year. It appears that the Riffe Lake sport fishery for resident coho salmon can be managed either by planting the tributaries with smaller fry or by direct reservoir plants with hatchery reared fingerlings of a larger size. The principal advantage of direct reservoir plants of larger coho fingerlings is to reduce competition for rearing space with rainbow and cutthroat trout in the tributaries. Informal arrangements have been made between WDF and WDG at the field level to reserve certain streams for rainbow and cutthroat trout while others are planted with coho salmon fry.

A resident coho planting and rearing program in the upper tributaries is dependent on the successful downstream passage of smolts through the proposed Cowlitz Falls project. This may be accomplished by utilizing turbines with demonstrated low fish passage mortality rates; however, mortality ranging from 10 to 15% is predicted for this facility (FERC-EIS, 1983). Provisions should be made to install downstream fish diversion, guidance, and collection facilities to achieve high downstream passage survival. The proposed Cowlitz Falls facility will have a detrimental effect on the utilization of Riffe Lake tributaries by blocking the access of adult resident spawning populations to upstream tributaries. Maintaining stream access for spawning resident adfluvial cutthroat and rainbow trout has been shown to be one of the most important requirements for fisheries management in upper Columbia River storage impoundments (May et al. 1979; May and Huston 1979). Wood et al. (1981) reported small numbers of "landlocked" coho and chinook salmon moved upstream into the Cowlitz and Cispus rivers from Riffe Lake. The utilization of upstream tributaries by spawning populations of cutthroat and rainbow trout from Riffe Lake was suggested by Wood et al. (1981); however, this aspect requires further detailed study to determine if significant populations are involved. The maintenance of upstream access is the primary means of achieving natural production of wild cutthroat and rainbow trout in most Northwest reservoirs. The loss of natural production will require the future reliance on hatchery plants of rainbow and cutthroat trout to maintain the reservoir sport fishery.

The proposed Cowlitz Falls Dam will have the greatest impact on the resident fishes in Riffe Lake since anadromous fishes have already been sacrificed with the construction of Mossyrock Dam. Consideration of a trap-and-haul facility or other means may be in order to maintain upstream passage if significant populations are found. The need for downstream passage facilities for coho salmon smolts and juvenile cutthroat and rainbow trout utilizing the upper watershed should also be considered in order to maintain the complete use of upstream fisheries habitat. In the future, if adequate disease controls are found, the upper tributaries may once again be considered for rearing spring chinook salmon in which case a smolt collection facility in the proposed Cowlitz Falls Dam would be needed. Achieving a design for cost effective fish facilities in this dam which is adaptable to changing management priorities will require further detailed study by the utility (Lewis County P.U.D.) and the fisheries agencies.

Mayfield Reservoir and Tributaries

Because of the previously discussed fish disease considerations only coho salmon will be considered here. There are 50.5 miles of salmonid spawning and rearing habitat in the Tilton River and tributaries. Easterbrooks (1980) estimated that 18 percent of the coho salmon spawning in the Cowlitz River above Mayfield Dam spawned between Mayfield Dam and Cowlitz Falls. Most are assumed to have utilized the Tilton River drainage. Prior to the construction of Mayfield Dam, Winston Creek was inaccessable to anadromous fish due to a falls near the mouth. It is now accessible from the reservoir and presents a small amount of additional habitat which has not been quantitatively assessed in previous surveys. The procedure utilized by Easterbrooks (1980) to estimate the potential maximum production of the upper watershed was partially applied to provide a general estimate for the Tilton River drainage. A maximum adjusted baseline smolt production of 627,000 coho was calculated resulting in 47,000 adults and jacks. This assumed natural spawning with complete utilization of the spawning and rearing habitat and safe passage for all downstream migrants. Maximum use of the spawning habitat is possible if a stock can be developed which will home to this habitat. Realization of a significant percentage of the maximum estimated potential return will require a focused reintroduction strategy and greater understanding of the reservoir environmental interactions.

Prior to the construction of Mayfield Dam Stockley (1961) reported coho salmon reared to varying sizes in the Cowlitz River before migrating. He found coho fry migrated during March-June and yearlings peaked during May with some movement in January. Phinney and DeCew (1974) reported trap catches of coho salmon in Mayfield Reservoir every month except August-September when traps were ineffective and closed for repair. The number of smolts trapped in Mayfield Lake was highest in May and June. Thompson and Rothfus (1969) reported that at least 90% of the coho passed the Mayfield fish facilities between mid-May and mid-July with most being smolts. Small numbers moved from the reservoir during other months with a minor peak in November and December. Length frequency data indicated most migrants leaving the reservoir during spring and summer (1964, 65, and 66) were yearlings. Later emigrating coho indicated the presence of 2-year classes in the reservoir. What has not been established is how much each group of coho rearing for different time intervals in Mayfield Reservoir contributes to the anadromous stocks. It was found in a review by Stober et al. (1979) that anadromous juvenile salmon may become residents in reservoirs failing to emigrate or if temporarily delayed to emigrate during a time less favorable to their survival. This aspect requires additional evaluation during the development of a self-sustaining anadromous coho run in the tributaries of Mayfield reservoir to achieve adequate adult returns.

Although juvenile coho salmon migrate downstream through the Mayfield Reservoir fish facilities a certain amount of delay in a segment of the population occurs which may if reduced improve adult returns. The surface withdrawal of water into the Mayfield Dam penstocks aids the movement of fish through the reservoir until surface temperatures begin to increase in mid-July. With surface thermal increases juvenile salmonids move deeper into the water column, a fact demonstrated by the lack of trapping success in both Cowlitz River reservoirs (Allen 1965; Phinney 1972; Hager 1973; Phinney and DeCew 1974; Phinney and Bauersfeld 1976). Very few juvenile salmonids can be expected to remain in the warm surface water of Mayfield reservoir during the mid-July to mid-September period. Although sufficient information has not been found to demonstrate the depth distribution of smolts in deeper layers of Mayfield reservoir it is believed that most of the smolts concentrate at or just below the thermocline in water which has limited movement downstream due to the large volume of dead storage in this reservoir. If cooler water from just below the thermocline were induced to upwell into the Mayfield penstock intakes the number of smolts residing in the reservoir may be reduced. An upwell induction system to alter the water temperature regime may be justified at Mayfield Dam to increase the downstream coho smolt passage efficiency to minimize losses in the reservoir due to residualization, predation, resident sport fishery, etc. It may be necessary to increase movement of smolts through the reservoir to obtain significant adult returns of the upstream stock to the hatchery.

The temporary or permanent residualization of some coho salmon juveniles in Mayfield reservoir may not be considered lost if harvested in the reservoir sport fishery. Although these fish will certainly not contribute to reintroduction of an anadromous run to the tributaries, there may be a need to provide a summer-fall sport fishery in this reservoir for local anglers. This fishery presently takes larger numbers of coho salmon than other species with largest numbers caught in October (Table 14). If an anadromous run is to be developed priority management of Mayfield reservoir should be placed on anadromous coho salmon with a portion of the rearing juveniles contributing to the resident sport fishery. The existing predator-prey interactions in Mayfield reservoir are unknown; however, current data on the survival of marked coho planted in the Tilton River and the reservoir indicate only 1.3 to 2.3% survival to the Mayfield fish facility (Tipping, per. com.). The factors contributing to low reservoir survival need identification (e.g., size of fingerlings, predator density, etc.) and appropriate actions taken in order to increase survival to a level which may result in an anadromous population. There may be a conflict in the simultaneous management of a resident sport fishery on this reservoir which takes a portion of the coho run. However, if the survival of fish moving through the reservoir can be increased it may be possible to manage for both resident and anadromous fishes. The enhancement of the emigration survival rate of coho salmon smolts from the reservoir utilizing a variety of techniques including renovation of the Mayfield Dam downstream migrant facilities may be needed to achieve adequate downstream passage sufficient to result in a self-sustaining coho run. The sport fishery in the reservoir could focus on additional resident species such as cutthroat, rainbow, or brown trout.

EVALUATION OF THE POTENTIAL OPTIONS

All thirteen options have been presented to indicate the full range of possibilities, the interactions of various actions and the degree of difficulty in trying to reintroduce a sustained run of anadromous fish above Mayfield Dam. Each option has been expanded into a number of actions necessary for its execution. All options may be considered possible prior to the consideration of cost which in many options is strongly associated with technical feasibility of various engineering alternatives. Cost approximations of the major engineering modifications indicated under many of the options were developed in consultation with Mr. Milo Bell. The reader is advised that the approximate costs presented are not estimates. Estimates require a far more detailed evaluation than was possible in this study. The approximate costs presented in this evaluation are for comparative purposes only and none have been weighted. The reader is also strongly cautioned that some approximations are based on a number of assumptions which are all positive. These assumptions could be found to be in error with additional information which is presently unavailable and the potential engineering modification would not be possible therefore eliminating the option. Table 17 lists the actions included in each option with the associated approximate cost.

Option 1. Provide volitional access for all adult anadromous salmonids above Mayfield and Mossyrock dams, pass smolts downstream over both dams and treat hatchery water supplies.

Action 1A. Provide upstream fish passage at the Cowlitz Salmon Hatchery barrier dam: Volitional access of salmon and steelhead over the Cowlitz Salmon Hatchery barrier dam could be achieved with a small fish ladder. This would defeat the present purpose of this barrier which is to direct

Table 17. List of action items included under each option and the approximate associated cost. (See text for explanation of each option).

Action						Potential Options								Cost (millions)
	1	2	3	4	5	6	7	8	9	10	11	12	13	
1A. Upstream passage at Barrier Dam	x	x	x	x										0.150
1B. Mayfield adult fishway	x	x	x	x										35.0
1C. Mossyrock adult fishway	x	x												45.0
1D. Mossyrock smolt passage facilities	x	x			x	x			x					5.0
1E. Mayfield reservoir smolt passage	x	x	x	x	x	x	x	x	x	x	x	x		0.180
1F. Modify Mayfield Dam smolt passage facilities	x	x	x	x	x	x	x	x	x	x	x			2.5
1G. Hatchery water treatment	x		x		x		x							12.0
2G. Hatchery ground-water supply		x		x		x		x						20.3
5A. Haul all species above both dams					x	x	x	x						0.050
7B. Smolt collection at proposed Cowlitz Falls Dam							x	x		x				12.86
9A. Haul only coho above both dams									x	x				0.025
11A. Haul only coho above Mayfield Dam											x	x		0.020
12A. Use existing Mayfield Dam smolt facilities												x	x	0.0
13A. No action.														0
Total Cost (Millions of $)	100	108	50	58	20	28	27.6	36	7.7	15.6	2.7	0.2	0	

returning adults into the hatchery separation facilities. A ladder would allow large numbers of returning adults to move to the base of Mayfield Dam which would reduce the efficiency of the hatchery operation and reduce the ability to achieve the mitigation goal for each species. A new ladder would not be necessary if the ladder to the existing fish separation facilities at the salmon hatchery were used. Fish entering these facilities could be arbitrarily selected for placement upstream; however, with the large numbers of fish homing to the hatchery there is no way to determine the small numbers of fish which would continue to migrate upstream. Herein lies a very important biological problem, that of identifying small numbers of individual fish with different homing instincts without destroying the very qualities for which one is trying to select.

At the present time there is no efficient non-destructive marking technique that would allow development and complete separation of upstream stocks from the large numbers of fish homing to the hatchery. Such a system would require the marking of each juvenile produced in the upper basin with a unique lifetime tag which could be automatically decoded upon return of each adult fish. The feasibility of this type of tagging system which would be required is presently undergoing research and development by Prentice et al. (1985). It is not expected that such a system will become operational on a large scale for the next several years in time to meet the legislative mandate for run development by 1991. Even then the insertion of a tag into each individual juvenile smolt produced above Mayfield Dam will be very labor intensive and costly.

In addition to these very difficult biological considerations for which cost cannot yet be approximated, the approximate cost of constructing a small fish ladder over the 12-foot high barrier dam is $150,000. The existing fish separation facilities at the hatchery could be modified for shunting arbitrarily selected fish upstream for about half the cost or approximately $75,000.

Action 1B. Construct a fishway at Mayfield Dam for upstream adult fish passage: Construction of a fish ladder to allow the passage of adult anadromous salmonids over Mayfield Dam would require the development of engineering solutions to problems associated with construction in unstable rock formations. Mayfield Dam is 185 feet high and is located in an area of the Cowlitz River canyon which is very unstable. This is evidenced by the fact that the original downstream passage facilities located below Mayfield Dam and attached to the canyon walls were destroyed by a rock slide. Because it would be very difficult to attach a fish ladder to the canyon walls with reliability it may be necessary to consider a tunnel fishway which would be about 1850 feet in length at an approximate cost of $35 million. Since this fishway would provide access to only 20% of the remaining upstream habitat, it is unlikely the high cost of construction would be recouped in the commercial and sport fisheries even if the entire estimated production potential of 47,000 adults and jacks could be realized.

Action 1C. Construct a fishway at Mossyrock Dam for upstream adult fish passage: Construction of a fishway to allow the passage of adult anadromous salmonids over Mossyrock Dam would encounter similar engineering problems as those anticipated for Mayfield Dam. In addition, Mossyrock Dam is 140 feet higher than Mayfield Dam and has a total height of 325 feet. A tunnel fishway 3,250 feet in length is considered the likely design plus the annual 130 foot reservoir fluctuation will require an additional exit structure on the Mossyrock dam. It would take a salmon about one full day to migrate through this tunnel if proper lighting could be included as part of the system. The cost is approximately $45 million. It is not likely that such a fishway would attract and successfully pass enough adults to be cost effective. A fishway on a dam of this height is unknown.

Action 1D. Construct collection and passage facilities for downstream migrant smolts at Mossyrock Dam: The considerable effort expended in the cooperative studies between Tacoma City Light and WDF to develop and test floating traps to collect downstream migrating salmonids on Mossyrock reservoir (Riffe Lake) was not successful. The higher surface temperatures which develop in Riffe Lake cause the juvenile salmonids to seek cooler water at depths greater than the traps were designed to fish efficiently. Hence, the floating trap systems made to efficiently collect and transport smolts downstream in cold water reservoirs with weak thermal stratification were not successful in Mossyrock reservoir. A renewed effort would be required to design a floating trap facility which incorporated an upwell induction and large pump system to move cool attraction water and juvenile salmonids from the variable depth of smolt concentration. Such a system would have to be operational over the 130 foot annual fluctuation of this reservoir and be constructed to withstand the high wind and wave action which occur on this reservoir. The approximate cost of such a system is about $5 million. Screening should also be considered to prevent the passage of smolts through the deep turbine intakes if complete downstream passage facilities were to be developed for Mossyrock Dam; however, the cost of screening has not been included. The probability of developing a successful cost effective downstream migrant system for this dam remains low.

Action 1E. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction, and monitoring) and achieve additional disease control benefits at the downstream hatcheries: Evidence suggests that the smolt survival during passage through Mayfield reservoir is much too low (1-2%) to provide sufficient downstream passage to result in the development of an anadromous run. The survival rates of emigrant smolts should be further evaluated in the next two years to determine the exact causes of significant mortality (i.e. delay, smolt size, health, predation, etc.).

Predator Assessment and Control

The predator densities in Mayfield reservoir should be evaluated. The abundance of squawfish is suspected to have reached levels which are responsible for low smolt survival. If this is the case the areas of squawfish concentrations should be identified in Mayfield reservoir to determine if methods for control could be devised. Potential predator control methods may include beach seining or trapping stream mouths during squawfish spawning season, beach seining coves where squawfish concentrations may occur, purse seining squawfish concentrated in warm surface waters, etc. Chemical control techniques might include the use of squoxin, a selective squawfish toxicant; however, this chemical remains to be certified for use by the U.S. Food and Drug Administration.

Due to the close proximity of Mayfield reservoir to the downstream salmon and trout hatcheries any chemical control technique must be very carefully considered to avoid compromising production at the hatcheries. It should also be recognized that most fish predator control programs have met with limited success and generally must be repeated each year. The approximate initial cost of the assessment of smolt survival and predator densities and first year control is $100,000.

Upwell Induction

An upwell induction system is proposed to minimize residualization of smolts in Mayfield reservoir. This system is proposed to induce upwelling of cooler water and increase the entrainment of smolts into the Mayfield Dam fish facilities during the period mid-June to mid-September. This method may be more effective than the use of a stop-log skimmer wall reported by Hager et al. (1970) and Tipping and Kral (1985) to entrain cooler water from the mid-reservoir depths. It will also not affect the power production potential by restricting the opening of the penstock intakes.

A 20 x 60 foot grid (4 foot centers) of 4 inch diameter perforated PVC pipe is proposed for suspension in the water column at a depth of about 5 meters below the thermocline. A separate grid will be positioned in front of each penstock intake structure in Mayfield reservoir. Each grid will be anchored in position with proper floatation and attached to an air compressor large enough to supply about 600 cfm through a high pressure air hose. The air expressed through the grid will bubble in a column to the surface and induce the upwelling of a column of cool water.

To achieve the greatest efficiency during the low flow high temperature period it will be necessary to match the volume of upwelling water to the penstock withdrawal rates. The system should be sized so that the total volume of upwelling cool water is drawn into the penstocks with no loss or recirculation. If upwelling water volumes are smaller than the intake volume, warm surface water will be entrained. When upwelling volumes of cool water are in excess of the intake volume, some of the cool water will not be drawn off and will sink and recirculate in the reservoir. It is therefore important to size the upwell induction system to match the water volumes used for power generation. During the years 1975-82 the flow of the river averaged 5460, 3884, 2407 and 2669 cfs during June, July, August and September, respectively, below Mayfield Dam (USGS data). This flow is split between two intakes therefore each upwelling system will be affecting a volume ranging from 1204 to 2730 cfs. The system will be most effective during late July to mid-September when the flows are lowest and the system most needed. A reasonable design flow per penstock opening would be about 1500 cfs.

Since two intake facilities exist tests should be conducted to measure the changes in fish entrainment rates with alternately operating upwelling systems. Testing should be conducted to determine the depth distribution and number of fish emigrating during day and night to determine the most effective operating depths and schedule. Of course the pumps for the secondary separator at the Mayfield Dam fish facilities which are normally turned off on July 1 each year must remain in use during the upwell induction period in order to maintain fish passage efficiency. Induction of cooler water out of Mayfield reservoir during the summer will improve circulation below the thermocline, increase the rate of downstream fish migration from the reservoir during the stratified period, and probably increase resident fish production of some species through better lake stratification. A similar air injection system has been successfully tested by Duke Power Co. in a strongly stratified North Carolina reservoir to achieve upwelling of cool water for a thermal power plant cooling water intake (B. Foris, per. comm.).

The development and testing costs for the first year for this system is approximately $50,000.

Monitoring

In order to determine if smolt survival and passage are improving through Mayfield reservoir it will be necessary to monitor the fish passage rate through the Mayfield Dam downstream migrant facilities. This should be done under all options because the monitoring would be designed to assess the results of other fisheries management actions in the basin and would be compared to other years when similar data has been collected. The approximate monitoring cost is $30,000 per year.

Thermal Control of Fish Diseases at Cowlitz Hatcheries

The control of fish disease at the Cowlitz hatcheries is a constant concern which intensifies each summer when maximum ambient temperatures occur in the hatchery water supplies. The upwell induction system proposed for Mayfield reservoir (Action 1E) can be used to reduce the temperature of the Cowlitz River downstream. A reduction in the water temperature will reduce the progress of infection of the following diseases: furunculosis, columnaris, bacterial hemorrhagic septicemia, *Ceratomyxa shasta*, fin-rot, and tail-rot (Figure 4). Virtually all communicable diseases of fishes become less infective with decreased temperature except perhaps for low temperature disease (LTD) and bacterial kidney disease (BKD) (Winton et al. 1983). Water temperature is the only controlling environmental variable and a temperature of 10°C may retard _C. shasta_ (Wedemeyer and Smith 1976) one of the most damaging diseases occurring at the trout hatchery (Tipping and Kral 1985, and Tipping et al. 1985). Lowering the mean summer water temperature may exacerbate LTD and BKD slightly by extending the infective period; however, this should be of minor importance since the reservoirs already mitigate low water temperatures during the cold period of the year.

The average monthly water temperatures in the Cowlitz River below Mossyrock Dam are considerably cooler during the spring and summer months than the average temperatures found below Mayfield Dam (Figure 5). The maximum temperatures below Mossyrock Dam of 15°C in June and August occurred during brief periods of suspension of outflow from the dam or surface water released over the spillway. During the months of June, July, August and September the mean temperature from Mossyrock Dam was from 2.3 to 3.0°C lower than that from Mayfield Dam. It is apparent that the warming of the surface of Mayfield Reservoir is the primary contributor to the increase in summer temperatures downstream.

The detailed limnological studies of Mayfield reservoir by Westley and Goodwin (1967) and the comparative studies by Goodwin (1967) prior to the operation of Mossyrock Dam showed the natural river, usually colder and denser, flowed as a density current under the warmer surface layer in Mayfield reservoir. This condition is even more pronounced now with a continual supply of cool water from Mossyrock Dam during the summer months. The general movement of water through Mayfield Reservoir during the summer months results from the inflow of cool water at an intermediate depth in Mayfield which displaces warmer less dense surface water drawn off by the penstock intakes. Cooler water is trapped below

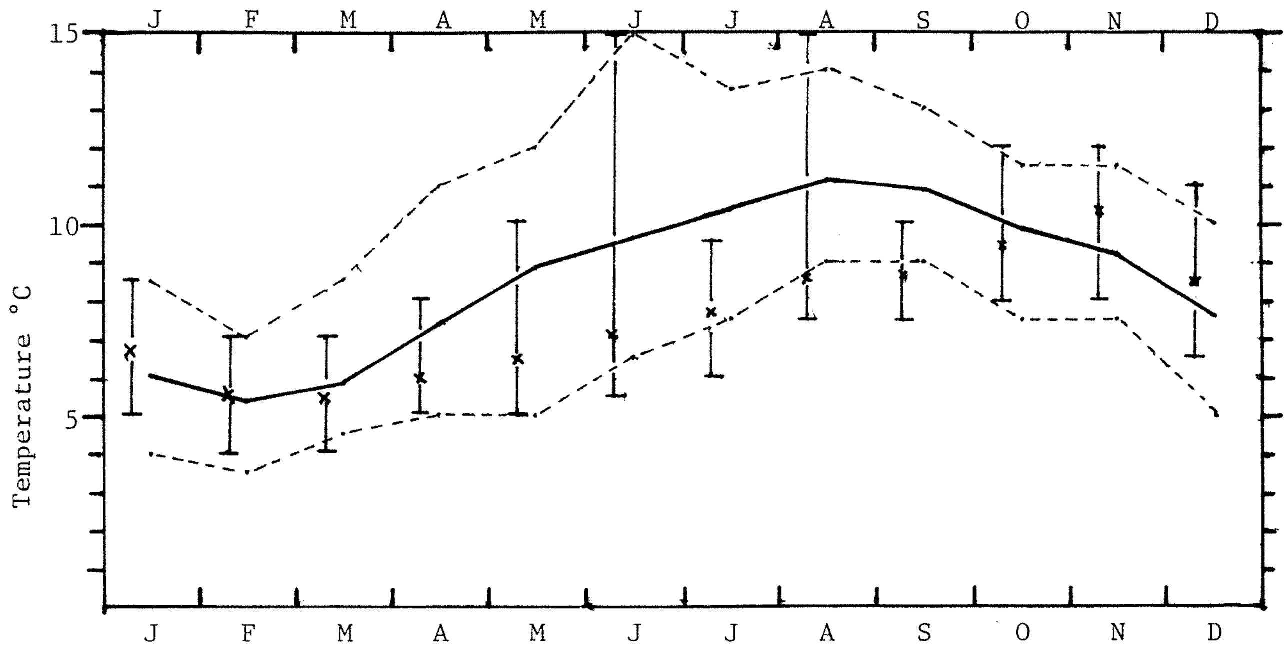


Figure 5. Comparison of monthly maximum, minimum and mean Cowlitz River water temperatures below Mossyrock Dam (vertical bars) and below Mayfield Dam (dotted and solid curves) for the period 1974-1982 (U.S.G.S. Water Supply Data 1975 to 1982).

the inflowing density layer and shows a decline in dissolved oxygen content while the entire warming influence of the surface of Mayfield reservoir is passed downstream. Thermal profiles taken in 1984 show the reservoir is essentially isothermal below the depth of 3 meters (Tipping and Kral 1985) with some depletion in dissolved oxygen concentration below 18 meters. Thermal profiles for 1985 (Tipping, pers. comm.) show that with the use of a stop-log skimmer wall (upper 15 feet) the thermocline was moved to a greater depth in the water column and the temperature of the upper 10 feet increased and remained stable during the summer.

The depth of the inflowing water from Mossyrock Dam should be determined during placement of the upwell induction system. If the level is known it will be possible to induce upwelling of the density layer (water inflowing from Mossyrock Dam) into the Mayfield penstocks and thus take advantage of the cooler water for downstream temperature control during the summer. Depending on the depth of the density layer the depth of the aeration grids can be adjusted to select the water temperature desired. The entrainment of cool water through Mayfield Reservoir could reduce the average water temperature from 2 to 3°C with no mixing with warmer reservoir surface water provided the volume is matched with penstock intake requirements. A reasonable goal is to achieve a water temperature in the trout hatchery averaging 10°C with as little deviation as possible from mid-July to mid-September. The river water warms about 1°C between Mayfield tailrace and the trout hatchery requiring an additional 1°C reduction. The average reduction in water temperature of 1.3°C in July, 2.1°C in August and 1.9°C in September probably could be achieved. Environmental temperature control in both hatcheries by the upwell induction of cool water from Mayfield Reservoir could aid in the control of most diseases. The control of infections through thermal management will reduce the frequency of use of chemotherapeutic substances which are not without side effects and increased costs. Lower mean summer water temperatures may reduce the growth rates of rearing stocks especially steelhead and cutthroat to desired size since fish grow slower at cooler temperatures. Smaller smolt size has been shown to reduce survival to adults. This effect could be artificially offset by heating the incubation water in the hatchery. However, with the control of mean summer water temperature, more fish should survive and be released in better health achieving a higher overall production.

If the upwell induction system is developed to reduce smolt residualization in Mayfield reservoir, the benefits of additional temperature and disease control at the hatcheries will be obtained at no additional cost.

Action 1F. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: The existing smolt separation, collection and passage facilities at Mayfield Dam were improperly constructed and require modification to increase the fish passage efficiency. These facilities should be modified to meet minimal WDF specifications which should include an increase in the width of the throat in each louver system to 4 feet, rescreening, and an enlargement in the pump capacity to increase the attraction water to about 200 cfs. The approximate cost of renovation is about $2.5 million.

Action 1G. Construct disease control water treatment systems for the Cowlitz Salmon and Trout Hatcheries: If all anadromous species are allowed to move above the water supply intake for the Salmon Hatchery, action must be taken to prevent the transmission of communicable fish diseases to the hatchery stocks. Spring chinook salmon and steelhead trout have recently been found to be infected with the IHN virus for which there is no control. This virus as well as many other diseases can be transmitted through the water to infect the hatchery stocks resulting in their destruction. This option therefore requires treatment of the water supply systems for both hatcheries to prevent the recycling of disease from fish ascending above the barrier dam. The Salmon Hatchery pumps 156 cfs and the Trout Hatchery pumps 55 cfs continuously from the Cowlitz River. There are several possible water treatment technologies; however, only chlorination-dechlorination and ozone are reasonable methods. Each method would have to be tested on the Cowlitz River water and the negative side effects of treatment evaluated on the fish culture operations. The treatment systems should be redundant to prevent transmission of disease during breakdowns; however, the absolute fail-safe control of disease cannot be guaranteed. It would require a pioneering effort to develop a system which could reliably treat a volume of 156 cfs without fail. The approximate cost of a water treatment system for the Salmon Hatchery is about $10 million, a treatment system for the Trout Hatchery is approximately $2 million. The WDG is presently testing a pilot ozone treatment system at the Trout Hatchery.

Total approximate cost of Option 1 is about $100 million.

Option 2. Provide volitional access for all adult anadromous salmonids above Mayfield and Mossyrock dams, pass smolts downstream over both dams and develop offstream water supplies for both hatcheries.

Action 2A. Provide upstream fish passage at the Cowlitz Salmon Hatchery barrier dam: (see Action 1A).

Action 2B. Construct a fishway at Mayfield Dam for upstream adult fish passage: (see Action 1B).

Action 2C. Construct a fishway at Mossyrock Dam for upstream adult fish passage: (see Action 1C).

Action 2D. Construct collection and passage facilities for downstream migrant smolts at Mossyrock Dam: (see Action 1D).

Action 2E. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 2F. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

Action 2G. Develop offstream groundwater supplies for the Cowlitz Salmon and Trout Hatcheries: If all anadromous species are allowed to move above the barrier dam action must be taken to prevent the transmission of communicable fish diseases to the hatchery stocks. Another approach is to isolate the hatcheries by complete reliance on disease free groundwater supplies requiring no further dependence on surface waters. The deep groundwater resources are not presently well known near the salmon and trout hatcheries. During development of these hatcheries a limited number of shallow groundwater wells were developed and used but the volume of groundwater was never adequate to completely serve either hatchery. For example, the Trout Hatchery has 9 wells about 30 feet deep which only produce about 6 cfs at high river flow (Tipping, personal communication). Since well production is directly dependent on river discharge it cannot be certain that these wells are free of viral diseases due to the close association with the river. Exploration for groundwater resources below 100 feet and of sufficient age to demonstrate no direct association with the river would be needed in a number of locations near both hatcheries to determine if development were possible. The approximate minimum cost of assessment and development of deep groundwater supplies for the Salmon Hatchery is at least $15 million (156 cfs) while the cost for the Trout Hatchery is at least $5.3 million (55 cfs). It is very likely that exploration will not discover adequate deep groundwater supplies to isolate the hatchery water supplies therefore eliminating this option.

The total approximate cost of Option 2 is at least $108 million.

Option 3. Provide volitional access for all adult anadromous salmonids only above Mayfield Dam, pass smolts downstream over the dam and treat hatchery water supplies.

Action 3A. Provide upstream fish passage at the Cowlitz Salmon Hatchery barrier dam: (see Action 1A).

Action 3B. Construct a fishway at Mayfield Dam for upstream adult fish passage: (see Action 1B).

Action 3C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 3D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

Action 3E. Construct disease control water treatment systems for the Cowlitz Salmon and Trout Hatcheries: (see Action 1G).

Total approximate cost of Option 3 is about $50 million.

Option 4. Provide volitional access for all adult anadromous salmonids only above Mayfield Dam, pass smolts downstream over the dam and develop offstream water supplies for both hatcheries.

Action 4A. Provide upstream fish passage at the Cowlitz Salmon Hatchery barrier dam: (see Action 1A).

Action 4B. Construct a fishway at Mayfield Dam for upstream adult fish passage: (see Action 1B).

Action 4C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries:

(see Action 1E).

Action 4D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

Action 4E. Develop offstream groundwater supplies for the Cowlitz Salmon and Trout Hatcheries: (see Action 2G).

The total approximate total cost of Option 4 is about $58 million.

Option 5. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams, pass smolts downstream over both dams and treat hatchery water supplies.

Action 5A. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams: This option presents an alternative to the construction of fishways on both dams. Adults of each species would be hauled and released above both dams. The problem of how to identify the specific individuals to haul upstream indicated in Option 1A remains. Arbitrary selection of a portion of the run of each species could be made for upstream transport, however, if this does not coincide with those individuals which have some urge to home upstream a sustained run will not be developed. Due in part to poor upstream homing of hauled fish, past experience has shown that few if any adult fish were taken by legal means in an upstream sport fishery.

The approximate cost of hauling adults of all species above both dams is about $50,000 per year.

Action 5B. Construct collection and passage facilities for downstream migrant smolts at Mossyrock Dam: (see Action 1D).

Action 5C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 5D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

Action 5E. Construct disease control water treatment systems for the Cowlitz Salmon and Trout Hatcheries: (see Action 1G).

Total approximate cost of Option 5 is about $20 million.

Option 6. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams, pass smolts downstream over both dams and develop offstream water supplies for both hatcheries.

Action 6A. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams: (see Action 5A).

Action 6B. Construct collection and passage facilities for downstream migrant smolts at Mossyrock Dam: (see Action 1D).

Action 6C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 6D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

Action 6E. Develop offstream groundwater supplies for the Cowlitz Salmon and Trout Hatcheries: (see Action 2G).

The total approximate cost of Option 6 is at least $28 million.

Option 7. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams, collect smolts at the proposed Cowlitz Falls Dam and haul to the lower river, pass Tilton River smolts over Mayfield Dam and treat hatchery water supplies.

Action 7A. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams: (see Action 5A).

Action 7B. Construct collection facilities in the proposed Cowlitz Falls Dam and truck smolts to the river below Mayfield Dam: Construction of the proposed Cowlitz Falls hydroelectric project, a 140 ft high run-of-river facility, if built, would present the opportunity to collect juvenile downstream migrant salmonids above Riffe reservoir. This could be done only if juvenile fish diversion, collection and holding facilities were designed and constructed as a part of the dam. It has been estimated in an evaluation by Weller et al. (1980) and R. W. Beck (1981) that a smolt collection facility would range in cost from $6.6 million for submersible traveling screens to $11.4 million for a louver system. Respective annual O and M costs including collection and transport were estimated at $1.46 million for the submersible traveling screens and $1.16 million for the louver system.

Although juvenile salmonids are generally surface oriented they will sound in a run-of-river reservoir and follow the major water flow through the penstocks. The shallow reservoir depth, short water retention time and high flow rate through the turbines will draw most of the juveniles into the penstocks. It is not certain if submersible traveling screens in the presence of high debris loads will be effective on this facility due to limited fish screening efficiency and high associated O and M costs experienced at other facilities. More detail on the design and operation of a louver system is needed to determine potential effectiveness at this facility. The penstock fish diversion system (Eicher 1982) should be included in further considerations with the fisheries agencies prior to final design by Lewis County PUD.

As previously pointed out construction of the Cowlitz Falls Dam as presently conceived may exert the most serious impacts on the resident sport fish populations in Riffe reservoir.

Action 7C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 7D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see (Action 1F).

Action 7E. Construct disease control water treatment systems for the Cowlitz Salmon and Trout Hatcheries: (see Action 1G).

The total approximate cost of Option 7 is about $27.6 million.

Option 8. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams, collect smolts at the proposed Cowlitz Falls Dam and haul to the lower river, pass Tilton River smolts over Mayfield Dam and develop offstream water supplies for both hatcheries.

Action 8A. Haul adults of all anadromous salmonid species above Mayfield and Mossyrock dams: (see Action 5A).

Action 8B. Construct collection facilities in the proposed Cowlitz Falls Dam and truck smolts to the river below Mayfield Dam: (see Action 7B).

Action 8C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 8D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

Action 8E. Develop offstream groundwater supplies for the Cowlitz Salmon and Trout Hatcheries: (see Action 2G).

The total approximate cost of Option 8 is at least $36 million.

Option 9. Haul only adult coho salmon above Mayfield and Mossyrock dams, pass smolts downstream over both dams.

Action 9A. Haul early coho salmon above both Mayfield and Mossyrock dams: The utilization of coho salmon as the only species introduced in the watershed above the hatcheries eliminates the need to consider water treatment or offstream groundwater for both hatcheries. Selecting only early coho salmon simplifies the problem of identification of which portion of the run to consistently transport upstream.

The following procedure could be used for reintroduction of coho salmon to the Tilton River and Winston Creek. Coho salmon return to the Cowlitz hatchery from late August to mid-March (Hager and Hopley 1981). Early coho are arbitrarily designated those returning prior to October 15 (P. Peterson, pers. comm.). The late coho stock (returning in November and later) is the largest segment of the population because it has been selected for preferential development by WDF to achieve a greater harvest in Washington State. Selection of the early coho salmon stock for exclusive reintroduction into the Tilton River and Winston Creek would facilitate identification at the hatchery, develop genetic purity in time and facilitate the imprinting of the early stock to the upstream habitat. Fingerling plants should be used to initiate reintroduction and at the same time all further upstream plants of adults and fry from the late Cowlitz River coho stocks should be suspended. The downstream migration of coho smolts should be monitored at the Mayfield Dam fish facilities for numbers, age, growth and timing during the initial years of this program. A significant number of these smolts should be marked for later positive identification in order to determine the run segment contributing most to the adult returns. Use of the early coho stock will simplify identification at the hatchery without the reliance on mark detection and identification. During the first five years of program initiation sufficient numbers of adults should be held at the Cowlitz Hatchery for brood stock to ensure adequate egg take, with only the surplus jacks and adults trucked upstream. After the run becomes established adequate numbers of returning adult and jack coho should be trucked to the Tilton River and Winston Creek to provide a controlled sport fishery in these streams.

An early returning coho stock timed with the fall returning chinook salmon should be protected by the fall chinook catch restrictions on the lower Columbia River allowing adequate escapement to the Cowlitz hatchery. The goal of this program is to establish a sport fishery for anadromous adult coho in the tributaries of Mayfield Reservoir. Following establishment of the run the escapement remaining in this habitat will provide the natural production for the next year class allowing fingerling plants to be suspended or only used on a supplemental basis. A strict policy must be followed to plant only early run coho in these tributaries to redevelop the genetic purity of the upriver stock.

The approximate cost of hauling early coho salmon above both dams is about $25,000 per year.

Action 9B. Construct collection and passage facilities for downstream migrant smolts at Mossyrock Dam: (see Action 1D).

Action 9C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 9D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

The total approximate cost of Option 9 is about $7.7 million.

Option 10. Haul only adult coho salmon above Mayfield and Mossyrock dams, collect upper river smolts at the proposed Cowlitz Falls Dam and improve passage of Tilton River smolts over Mayfield Dam.

Action 10A. Haul early coho salmon above both Mayfield and Mossyrock dams: (see Action 9A).

Action 10B. Construct collection facilities in the proposed Cowlitz Falls Dam and truck smolts to the lower river: (see Action 7B).

Action 10C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 10D. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

The total approximate cost of Option 10 is about $15.6 million.

Option 11. Haul only adult coho salmon above Mayfield Dam and pass smolts from the Tilton River and Winston Creek over modified Mayfield Dam fish facilities.

Action 11A. Haul only early adult coho salmon above Mayfield dam: At the present time the only action which may be justified in an attempt to reintroduce an anadromous fish run is to begin by attempting to establish anadromous early coho salmon in the Tilton River and Winston Creek. The approximate cost of hauling adult coho is $20,000 per year.

Action 11B. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

Action 11C. Modify existing collection and passage facilities for downstream migrant smolts at Mayfield Dam: (see Action 1F).

The total approximate cost of Option 11 is about $2.7 million.

Option 12. Haul only adult coho salmon above Mayfield Dam and pass smolts from the Tilton River and Winston Creek over existing Mayfield Dam fish facilities.

Action 12A. Utilize existing collection and passage facilities for downstream migrant smolts at Mayfield Dam without modification and renovation: The smolt monitoring costs of $30,000 per year identified in Action 1E should be included with use of the existing facility.

Action 12B. Haul early coho salmon above Mayfield Dam: (see Action 11A).

Action 12C. Minimize residualization and loss of smolts in Mayfield reservoir (predator assessment and control, upwell induction and monitoring) and achieve additional disease control benefits at the downstream hatcheries: (see Action 1E).

The total approximate cost of Option 12 is about $200,000.

Option 13. No action (13A).

RECOMMENDATIONS

This analysis has identified some of the more important biological problems which must be solved if the reintroduction of anadromous fish is to succeed. The actions required under each option are consistent with the life cycle requirements of anadromous salmonids, the existing habitat, future modifications required and the need to protect the Cowlitz hatcheries from unnecessary exposure to incurable fish diseases. The technical difficulties in attempting to achieve a self-sustaining anadromous fish run compounds with the number of species and increases in complexity with the upstream distance one attempts to manage anadromous fish above the Cowlitz River barrier dam. The possibility of engineering solutions to these problems becomes more costly and many are so difficult that reliability using present day technology cannot be guaranteed.

Evaluation of the potential options proceeds from 1-13 with a declining number of actions required in each succeeding option. The approximate cost declines accordingly and the feasibility increases although it is by no means certain that smolt survival sufficient to achieve a return can be established through Mayfield reservoir. Achieving adequate Mayfield reservoir smolt passage is an action requiring solution in every option. Until smolt passage survival through Mayfield reservoir is increased, other actions are not recommended. If action is to be taken Option 12 is the only recommended choice because it focuses efforts on improving smolt passage survival through Mayfield reservoir. Proceeding at this time with other options is not indicated by this analysis. Option 12 will attempt to establish a run of early coho salmon in the Tilton River and Winston Creek.

Options 11 and 12 are similar except that Option 11 includes renovation of the Mayfield Dam downstream fish passage facilities to improve the efficiency and operation of these structures. Renovation of these facilities is not justified as a precondition to reintroduction of a coho run to the Tilton River. Therefore, if action is taken Option 12 is the only recommendation which can be made to initiate the process of reintroducing early coho salmon to the Tilton River and Winston Creek. Suggestions for improving smolt passage survival through Mayfield reservoir include: 1) assessment of the size and condition of fingerlings planted in the Tilton River; 2) reservoir predator densities and methods of control; 3) the induction of coolwater from smolt depths into the Mayfield Dam fish facilities to decrease residualization in the reservoir; and 4) the monitoring of smolt passage through the Mayfield Dam fish facility to assess the survival of marked fish. If plants of fingerling early coho salmon are made in the Tilton River during the next 5 years and smolt passage is improved through Mayfield Reservoir returns of early coho to the hatchery would begin in 1989 ahead of the legislative deadline of 1991. The possibility of run establishment by this deadline for any other option than 12 is less likely. The approximate costs associated with Option 12 should be evaluated in light of ongoing activities by both WDF and WDG.

The potential for smolt collection at the proposed Cowlitz Falls Dam, if and when it is built, should remain a viable possibility. However, construction of the Cowlitz Falls Dam will have the greatest impacts on the resident fish movements between the upper watershed and Riffe Lake where an important sport fishery has been developed. Passage facilities at this dam should be carefully reconsidered by both state fisheries agencies from the standpoint of resident fishes and the potential future rearing of spring chinook salmon in the upper watershed if control of IHN and other viruses can be achieved.

SUMMARY

The technical evidence and fisheries management experience in the upper Cowlitz River basin is reviewed for the possible reintroduction of anadromous fish above Mayfield Dam. Thirteen potential options are developed and evaluated ranging in approximate cost from $108 million to about $200,000. If action is to be taken, the least cost option to establish a run of early coho in the Tilton River and Winston Creek is recommended. This option must achieve adequate smolt passage survival through Mayfield reservoir to succeed and is a key condition of all options. This review identifies opportunities for specific fisheries and environmental management techniques which can be applied to the system to improve smolt passage as well as alleviate some of the chronic fish disease control problems at the Cowlitz Salmon and Trout hatcheries.

Efforts to control the horizontal (through water) and vertical (parent to offspring) transmission of presently incurable fish diseases at the Cowlitz hatcheries dictate that susceptible species which can also be carriers should not be planted above the hatcheries. These include chinook salmon (spring and fall), steelhead, sea-run cutthroat and legal rainbow trout which have been affected by IHNV at these hatcheries. The only method of control available is total destruction of all affected stocks which can seriously hinder the achievement of mitigation goals for these species. The anadromous species presently available for reintroduction upstream is the coho salmon which is not susceptable nor a carrier of IHNV and poses a less serious threat of transmitting other diseases upstream.

The salmonid habitat in the upper Cowlitz River basin has been modified by the construction of Mayfield and Mossyrock dams. These dams have created two very different types of reservoirs. Riffe Lake behind Mossyrock Dam is a

large annual storage reservoir which develops strong thermal stability during the summer due to very deep penstock intakes and lacks fish passage facilities. Salmon smolts do not migrate through this reservoir and thus become residents providing an important sport fishery along with other resident species. The best use of the stream habitat above Riffe Lake is for the rearing of resident coho salmon from annual hatchery fry plants and the spawning and rearing of wild cutthroat and rainbow trout from Riffe Lake to support the resident sport fishery. This will remain possible only if adequate upstream and downstream fish passage can be included in the proposed Cowlitz Falls Dam. In contrast, Mayfield reservoir is a small run-of-the-river facility which develops weak summer thermal stratification due to surface penstock withdrawal. Downstream smolt passage occurs through the fish passage facilities constructed in this dam. The Tilton River and Winston Creek which are tributaries of Mayfield reservoir should receive management priority for reintroduction of the Cowlitz River early run coho salmon. An early coho run imprinted to home to these tributaries could be easily identified at the Cowlitz salmon hatchery and transported upstream creating an anadromous fishery above Mayfield Dam. Secondary management priority should be placed on the resident sport fishery in Mayfield reservoir.

Smolts migrate through Mayfield reservoir but survival rates of only 1-2% have been measured. Suggestions for improving smolt passage survival include: 1) size and condition of fingerlings planted; 2) predator densities and control methods; 3) upwell induction of cool water and smolts from the reservoir; and 4) monitoring of fish passage survival through the fish facilities. The upwelling of cool water from Mayfield Reservoir can also be used to reduce the temperature of the Cowlitz River from mid-June to mid-September to provide the added benefit of disease control at the hatcheries, particularly for the protozoan _C. shasta_. The abundant cool water discharged during the summer from Mossyrock Dam flows as a density current into the mid depths of Mayfield reservoir. If this water were entrained to the lower river with minimal warm surface water the temperature of the river could be lowered enough to reduce the rate of infection of diseases which reoccur each year; and hence improve the production of larger numbers of salmonids in better health.

Appendix Table 1. Cowlitz Hatchery: Summary of diseases and treatments January 1979 - April 1983. Source: WDF Fish Health Diagnostic Reports.

Date of Exam	H_2O temp.	Brood year species	Fish size	Bacteria	Parasites	Treatment	Results comments
1-2-79	45-44	77 coho	50	low temp	--	TM 50	
1-28-79	42-41	"	50	low temp, BKD	--	TM 50	
"	"	77 springs	10-17	low temp	--	TM 50	
1-30-79	42-41	78 springs		--	costia	formalin	
2-2-79	42-41	"		--	costia	formalin	
2-6-79	43-40	"		--	costia	formalin	
2-27-79	42-41	78 falls	100	--	--	--	coag. yolk
3-13-79	43-41	77 coho	33	low temp	--	TM 50	
3-17-79		78 springs		--	costia	"feed fish, not pond"	environ. gill dis
3-23-79	43-42	"	250	BGD (light)	costia	formalin	clean pond
4-1-79	49-49	78 falls	400-700	--	costia	formalin	
4-14-79		78 coho		--	costia	formalin	
4-30-79	48-44	77 coho		low temp	--	TM 50	
"	"	78 coho	620	--	costia	formalin	
"	"	78 falls	550	--	costia	formalin	
5-7-79	"	78 springs	100	--	costia	formalin	
5-16-79	50-47	"	85	--	costia	formalin	
5-22-79	50-48	"	85	BHS	--	TM 50	
5-31-79	48	78 falls		--	costia	formalin	
6-5-79	50	78 coho	400	--	costia	formalin	
6-15-79		78 falls		--	costia	formalin	
6-28-79	50-49	"	100	--	costia	formalin	
7-1-79	50-49	78 springs		BHS	--	TM 50	
"	"	78 falls		--	costia	formalin	
7-24-79	52	78 coho	100	furunculosis	costia	formalin, TM 50	high loading
9-17-79	52-51	78 coho	100	furunculosis	Trichophera (heavy)	TM 50	
10-8-79	51-48	78 springs	11	low temp	--	TM 50	
10-29-79	49-49	78 coho	30-39	low temp.	--	TM 50	
11-29-79	48-48	"		low temp	--	TM 50	low level
12-2-79	48-48	78 springs	8	BKD	fungus-gills	none	
12-21-79	46-45	79 springs	900	--	--	--	coag. yolk

Appendix Table 1. (continued)

Date of Exam	H_2O temp.	Brood year species	Fish size	Bacteria	Parasites	Treatment	Results comments
1-8-80	44-44	79 springs	700-800	--	costia	formalin	
1-22-80	42-41	78 springs	8	BKD	--	none	
2-28-80	43-41	"	6	BKD, BHS	--	Gallimyein 50	
3-10-80	41-41	78 coho	24	low temp		TM 50	
3-13-80	41-41	79 falls	900	--	costia	formalin	coag. yolk
4-18-80	44-43	"	350	BGD	--	Diquat then Hyamine	
5-9-80	46-45	79 springs	113-177	--	costia	formalin, TM50 prophylactic-B	
7-7-80	50-48	79 coho	220	--	costia	formalin	
9-15-80	51-49	79 springs	22	furunculosis	--	TM 50	
9-26-80	52-49	"	10	BHS, low temp	--	TM 50	
10-30-80	51-50	79 falls	16	furunculosis	--	TM 50	
11-14-80	51-51	79 falls	22	" , low temp	--	TM 50	
"	"	79 springs		low temp	--	TM 50	
"	"	79 coho		low temp	--	TN 50	
12-29-80	46-46	"	35	low temp	--	TM 50	
1-2-81	46	79 coho		low temp	--	TM 50	
"	46	79 springs		BKD	--	none	
1-13-81	.	80 springs		--	costia	formalin	
1-22-81	44-44	"	600	--	costia	formalin	
"	"	79 falls	11	BKD	<u>Ceratomyxa</u> <u>s.</u>	none	
2-2-81	44-44	80 falls		--	costia	formalin	
"	"	80 falls	600	--	costia	formalin	
3-13-81		79 falls	6	BKD	--	none	
3-20-81	45-44	"	9	BKD	--	none	release
"	"	79 springs	6	BKD, BHS	--	TM 50	
4-7-81	"	80 springs		light BGD	costia	formalin	
"	"	80 falls	200-800	--	costia	formalin	
4-21-81	"	80 springs		--	costia	formalin	
4-28-81	45	79 coho	23	BKD, light low temp	--	TM 50 prophylactic	low temp, fu be careful (BG did viral assay
5-18-81	49-48	80 falls	100-300	light BGD	costia	formalin	

Appendix Table 1. (continued)

6-15-81		80 falls		BHS	--	TM 50
6-18-81	48-46	"	80-136	light BGD	costia	formalin
8-5-81	53-50	80 coho	133	--	costia	formalin
8-17-81	52-50	80 springs		BKD, BHS	--	TM 50
8-28-81	53-50	80 springs	15	BHS, furunculosis	--	TM 50
9-24-81		"	20	BKD	--	Gallimycin 50
1-15-82	44	80 coho		low temp	--	TM 50
3-8-82		"		low temp	--	TM 50
4-8-82	44-43	81 springs	150-200	BGD	costia	Hyamine, then formalin
4-27-82	45-44	81 falls	200-600	--	costia	formalin
"	"	81 coho	700-1000	--	costia	formalin
6-28-82	48-47	81 springs	50	BHS	--	TM 50
7-19-82		81 coho		--	costia	formalin
7-28-82		81 springs	50	BHS	--	TM 50
8-5-82	53-51	81 falls	65	BHS	--	TM 50
"	"	81 coho	100-200	--	costia	TM 50
10-14-82	54-54	81 coho	61	low temp	Tricophera, epistylis	formalin
2-4-83	43-40	81 coho	35	low temp	--	TM 50
2-7-83	43-42	82 springs	300	--	costia	formalin
3-21-83	43-41	82 springs	100	light BGD	--	reduce loadings
4-13-83		82 springs	84-103	light BGD	costia	formalin
"		82 falls	100-500	--	costia	formalin

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