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An Investigation of Recurrent Fish Kills at Maritime Heritage Fish Hatchery in Bellingham: Fall 1990 Study

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INTRODUCTION

Background

Maritime Heritage Fish Hatchery (MHFH) is located near the mouth of Whatcom Creek in downtown Bellingham (Figure 1). The hatchery is a cooperative venture of the Bellingham Vocational Institute and the city of Bellingham. Several species of anadromous salmonids are reared at the hatchery: coho, chinook, and chum salmon (*Oncorhynchus kisutch, O. tshawytscha, and O. keta*); steelhead trout (*O. mykiss*); and sea-run cutthroat trout (*O. clarki*).

The hatchery draws its water directly from Whatcom Creek at river mile 0.2, just upstream of a waterfall and the zone of tidal influence. Water flows from the screened intake into a settling pond. It then moves separately through two rearing ponds before discharging to the creek mouth.

MHFH was plagued with recurrent fish kills every fall until 1990. The kills coincided with the first heavy runoff after a storm (first flush), and affected only coho salmon.

Fall fish kills did not occur at MHFH in 1990 or 1991, although spring kills did occur in both of these years. In fact, spring fish kills at MHFH began occurring in 1989. The most severe kill, in spring 1990, reduced the fish population by 60 to 70 percent. The cause of the spring mortality has not been determined.

The Washington State Department of Ecology's (Ecology) Watershed Assessments Section conducted studies on Whatcom Creek and at MHFH in 1987, 1988, and 1989 to investigate the cause of the fall fish kills (Kendra, 1988; Kendra and Willms, 1990). Kendra isolated zinc, lead, and copper as the most toxic contaminants in both stormwater runoff and hatchery ponds.

In 1990, more intensive sampling was conducted. The purpose of the study included obtaining supporting evidence to determine whether elevated metal concentrations were the cause of fish mortality at MHFH during the first fall flush. However, this determination could not be made, since a fall fish kill did not occur in 1990.

Objectives

The purpose of this report is to:

1. Quantify the first flush effect in 1990;

2. quantify zinc, lead and copper concentrations at MHFH in 1990;

3. compare metal concentrations in Whatcom Creek and at MHFH to aquatic toxicity criteria for 1990;

4. identify locations where metals enter Whatcom Creek during dry and wet weather;

5. discuss the results of a fish pathology study in 1990;

6. explore possible reasons why a fish kill did not occur in 1990 by comparing hatchery conditions between sample years; and

7. determine whether a direct and consistent relationship exists between total and total recoverable metal concentrations.

METHODS

Ecology sampled Whatcom Creek and its tributaries during the dry season on September 5, 1990, and during the wet season on November 28, 1990. Samples were analyzed for lead, copper, zinc, hardness, pH, temperature, and conductivity. Sample locations are detailed in Appendix A.

Earl Steele, the MHFH manager, sampled rearing pond water from September 4 to November 19, 1990. He sampled weekly during dry weather, increasing to hourly during storm events. Samples were analyzed for lead, copper, zinc, and hardness (Appendix B).

In the 1987, 1988, and 1989 studies, only total metals were analyzed; the Environmental Protection Agency (EPA, 1976) recommends using total recoverable values for application of the toxicity criteria. If a direct relationship exists between total and total recoverable values, the 1987-1989 total values can be translated into their total recoverable equivalents.

Analyses for both total and total recoverable metals were performed on select samples, and data were compared using statistical regressions. Samples with metal concentrations at or below the analytical detection limits were eliminated from the regression analyses.

All samples were iced and sent to the Ecology/EPA Laboratory in Manchester, Washington. Sample containers, processing, and analysis conformed to APHA *et al.* (1989) and Huntamer and Smith (1989).

Fish samples were collected by the hatchery manager monthly and as storms approached. Two bottles were used, one to store coho, and the other for steelhead or chinook. Four to five fish were dissected and placed into each bottle, and Bouin's fixative was added. Samples were iced and sent to the U.S. Fish and Wildlife Service for analysis.

Quality Assurance

Laboratory data and qualifiers are reported in Appendices A and B. Replicate samples and transfer blanks were collected at two out of 15 sites (13%) on September 5, 1990, and two out of 14 sites (14%) on November 28, 1990. Values for replicates were well within accepted data quality requirements (EILS, 1991).

Procedural blanks for lead and copper were contaminated for the September 5, 1990, samples. Sample results less than ten times the amount found in the procedural blanks are flagged with a "JB" in Appendix A and Table 1. Toxicity criteria cannot accurately be applied to these samples.

RESULTS

Storm events occurred on October 4 and November 9, 1990. MHFH did not experience a fall fish kill in 1990.

Water Sample Analyses

Results for fall 1990 samples are presented in Appendices A and B. Most of the samples contained low levels of lead, copper, and zinc; however, some samples had quantifiable values, especially those collected from MHFH rearing ponds during storm events. Conductivity was high (above 220 μmhos/cm) in samples collected from the mouths of Lincoln Creek and Cemetary Creek, the James Street storm sewer, and the Valencia Street pipe on September 5, 1990. High conductivity did not consistently accompany high metal concentrations.

Regressional analyses were run to determine if there is a correlation between total and total recoverable metal concentrations at the sampling sites. Too few samples had concentrations above the analytical detection limits for a meaningful interpretation of the data (Figure 2).

The 1990 sample data are presented, along with federal toxicity criteria for ambient water quality, in Tables 1 and 2. Samples taken from Whatcom Creek (Table 1) exceeded chronic toxicity criteria for lead and copper at one site on September 5, 1990, and at one site for lead on November 28, 1990. At the MHFH rearing ponds, nine samples exceeded chronic toxicity criteria for copper and/or zinc, and four of those samples exceeded acute toxicity criteria during storms on September 4, October 4, and November 9, 1990. Lead concentrations exceeded the chronic toxicity criteria for all samples that were above the detection limit (Table 2).

The 96-hour LC_{50} values for lead, copper, and zinc toxicity to coho salmon are presented in Appendix C. The LC_{50} toxicity levels were not exceeded in 1990.

The first flush effect in Whatcom Creek has been characterized for 1990. As shown in Figure 3, concentrations of lead, copper and zinc increased by over 100 percent with 1.5 inches of rain over a 24-hour period on October 3 and 4, 1990, and diminished when the rain decreased. Metal concentrations during storms which occurred after the first flush reached smaller peaks, indicating that the first runoff carries most of the dry season build-up of particulate matter into the creek.

Metals appear to be entering Whatcom Creek in the vicinities of Lincoln Creek and Ellis Street (Table 1). These sites had values of lead and/or copper exceeding chronic toxicity levels during September and November sampling runs.

Fish Pathology

Results of the fish pathology study conducted in 1990 are presented in Appendix D. Although the salmon did not die as a result of hatchery pond conditions, they did show signs of stress. This was apparent in the sloughing of epithelial cells on the gills, and the evidence of chloride cells in the gill tissue of some of the coho samples. It is not clear whether this is related to metal toxicity or infection.

DISCUSSION AND CONCLUSIONS

The cause of recurrent fall fish kills at MHFH could not be determined, because a fall kill did not occur in 1990. However, data collected in 1990 does indicate a pattern of high metal concentrations with the first flush storm event in the fall. In addition, the results of the 1990 study can be used in conjunction with data collected in 1987, 1988, and 1989 to give possible explanations for why a kill did not occur in fall 1990.

First Flush Effects

The first flush corresponded to coho salmon mortality and/or stress in 1988, 1989, and 1990. A comparison of precipitation data prior to the fish kills of 1988 and 1989 shows that fish kills occurred during periods of high precipitation (Figure 4). Although the first heavy storm on October 4, 1990,did not correspond to a fish kill, fish collected after that date did show signs of stress.

Hatchery water analyzed during the October 4, 1990, storm exceeded toxicity criteria set by the EPA (EPA, 1986) for the protection of aquatic life for copper, lead, and zinc (Table 2). However, these high metal concentrations did not kill the fish. Metal concentrations in runoff samples during kill years (1987-89) are similar to or lower than those in 1990 (Table 3). This may be attributed to the first flush effect.

In 1987, 1988, and 1989, metal concentrations were probably higher than in 1990 during the actual times of the kills, but by the time the water was sampled, the concentrations had decreased. In 1987, samples were taken approximately 24 hours after the fish began to die; in 1988, samples were collected within approximately 6 hours of the onset of fish mortality; and in 1989 the water was sampled as the fish began to die. Toxic metal concentrations were probably reached well before the water was sampled in these years.

The 1990 metal concentrations are not significantly lower than other years during the first flush, and concentrations for copper and zinc did exceed toxicity criteria. Figure 5 shows that 1990 metals are similar to or higher than metals in 1987, 1988, and 1989 hatchery water. Thus, precipitation patterns and hatchery pond conditions in 1990 may have made the metals less toxic to fish.

Influence of Precipitation

Hatchery water may have been less toxic to fish in 1990 than in previous years because of different precipitation patterns and less crowded rearing ponds. Precipitation patterns can affect the speed with which toxic agents are carried through a waterbody. Heavy rainfall washes metals buildup into a creek quickly, whereas during diffuse storms, the runoff carries particles into a creek slowly. Fish have been shown to react to changing water chemistry with less acute symptoms when allowed to acclimate slowly as opposed to being exposed suddenly (Chapman, 1985). Preceding the first major storm, the rainfall pattern in 1990 was more diffuse than the previous two years, with a light rain over a 72-hour period; in 1988 and 1989, heavy rainfall occurred within a 14-hour period just prior to the fish kills (Figure 6). The diffuse rainfall in 1990 may have allowed the fish time to acclimate to changing chemistry in the pond associated with the first heavy rain of the season.

Rearing Pond Conditions

Fewer fish in the MHFH ponds in 1990 may have influenced the response of coho salmon to elevated metals in the water. Crowded conditions can make fish more stressed, and therefore more susceptible to toxic agents. MHFH rearing ponds contained approximately 25,000 fish during fall months until 1990. In 1990, the spring fish kill caused 60 to 70 percent mortality. As a result, the rearing ponds held only 4,000 to 5,000 fish in fall 1990 (Steele, 1991).

Fish Pathology

Disease was suspected as a possible cause of the fall coho mortality in earlier years because of the species-specific nature of the occurrences. To rule out disease as a cause of the fall kills, it was necessary for kill to occur with no evidence of disease. Since a fall kill did not occur in 1990, disease and infection have not been ruled out as the cause of fall MHFH coho mortality.

Total and Total Recoverable Comparison

An attempt was made to relate total and total recoverable metal concentrations so total metals from 1987, 1988, and 1989 could be more accurately used with the toxicity criteria. However, the sample size for a meaningful regressional analysis was too small; therefore, it was not possible to convert total metal values for 1987, 1988, and 1989 into total recoverable equivalents.

RECOMMENDATIONS

- Improve the quality of stormwater runoff into Whatcom Creek, specifically by reducing the concentrations of lead, copper and zinc. The city of Bellingham has been conducting surveys and making plans to improve the Whatcom Creek watershed. Changes are expected to be put into effect in the next three years (Pebles, 1991). It is hoped that metals loadings will be reduced as a result of these changes.

- MHFH should consider obtaining funds to do its own study, perhaps as part of a school or university program. This would allow students an opportunity to study and solve a real problem. Results would be better by virtue of having those conducting the study close by at all times. This would also be a cost-effective way for the hatchery to find solutions to its recurring fish mortality problems.

- Prioritize the spring fish kills as a problem to study and correct.

- Watch the fish carefully for signs of mortality during fall storms to determine whether fall fish kills are still a problem.

- Continue to move fish out of the ponds in anticipation of the fish kills. Earl Steele, the hatchery manager, began doing this in response to the spring fish kills.

- Toxicity criteria for lead for most of the 1990 samples are less than 1 μg/L, while the analytical detection limit for lead was 1 μg/L for this study. Many of the samples had lead concentrations at or below this number, and therefore could not be conclusively compared to the toxicity criteria. To prevent this problem in future studies, the detection limit for lead should be lowered to 0.1 μg/L.

- Future surveys should include analysis of water samples for both total recoverable and dissolved metals to further elucidate metals toxicity in the runoff and hatchery ponds.

ACKNOWLEDGEMENTS

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Steele, Earl, 1991. Personal Communication. November 4, 1991.

FIGURES

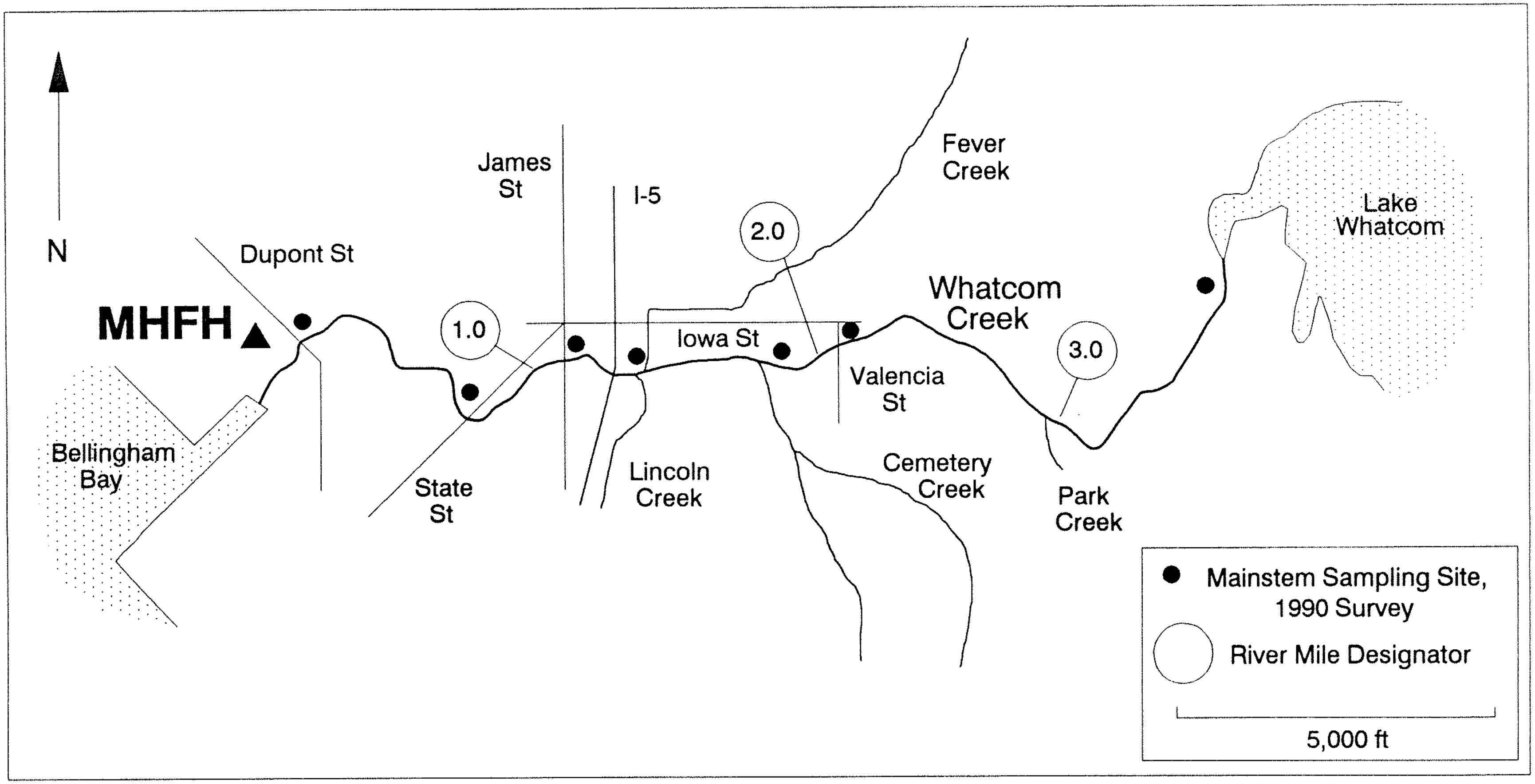

Figure 1. Map of Whatcom Creek showing location of Maritime Heritage Fish Hatchery and 1990 mainstem sampling sites in Bellingham, Washington.

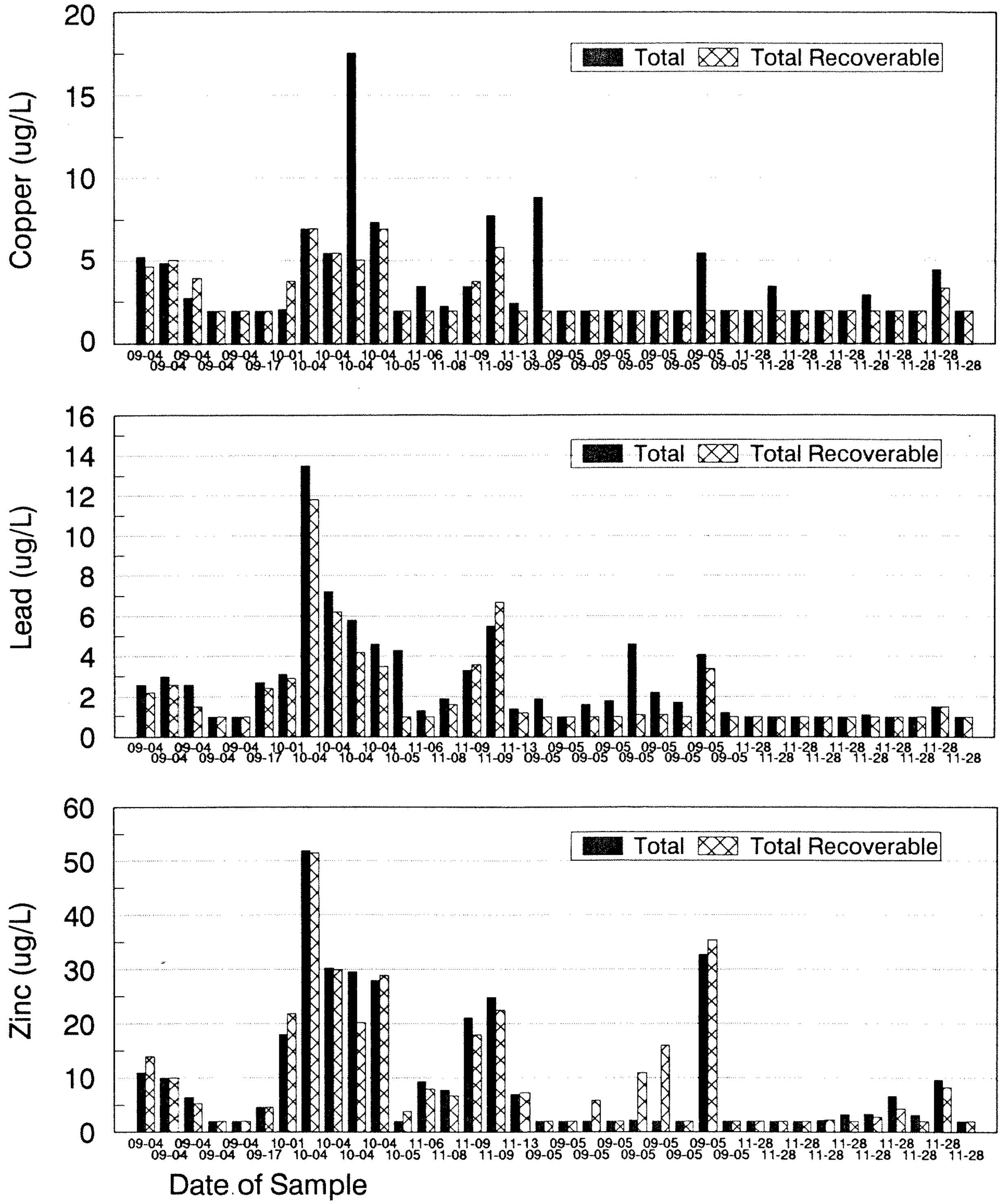

Figure 2. A comparison of total and total recoverable copper, lead and zinc concentrations for samples collected at MHFH and from Whatcom Creek in 1990. Sample size is too small for meaningful statistical analysis.

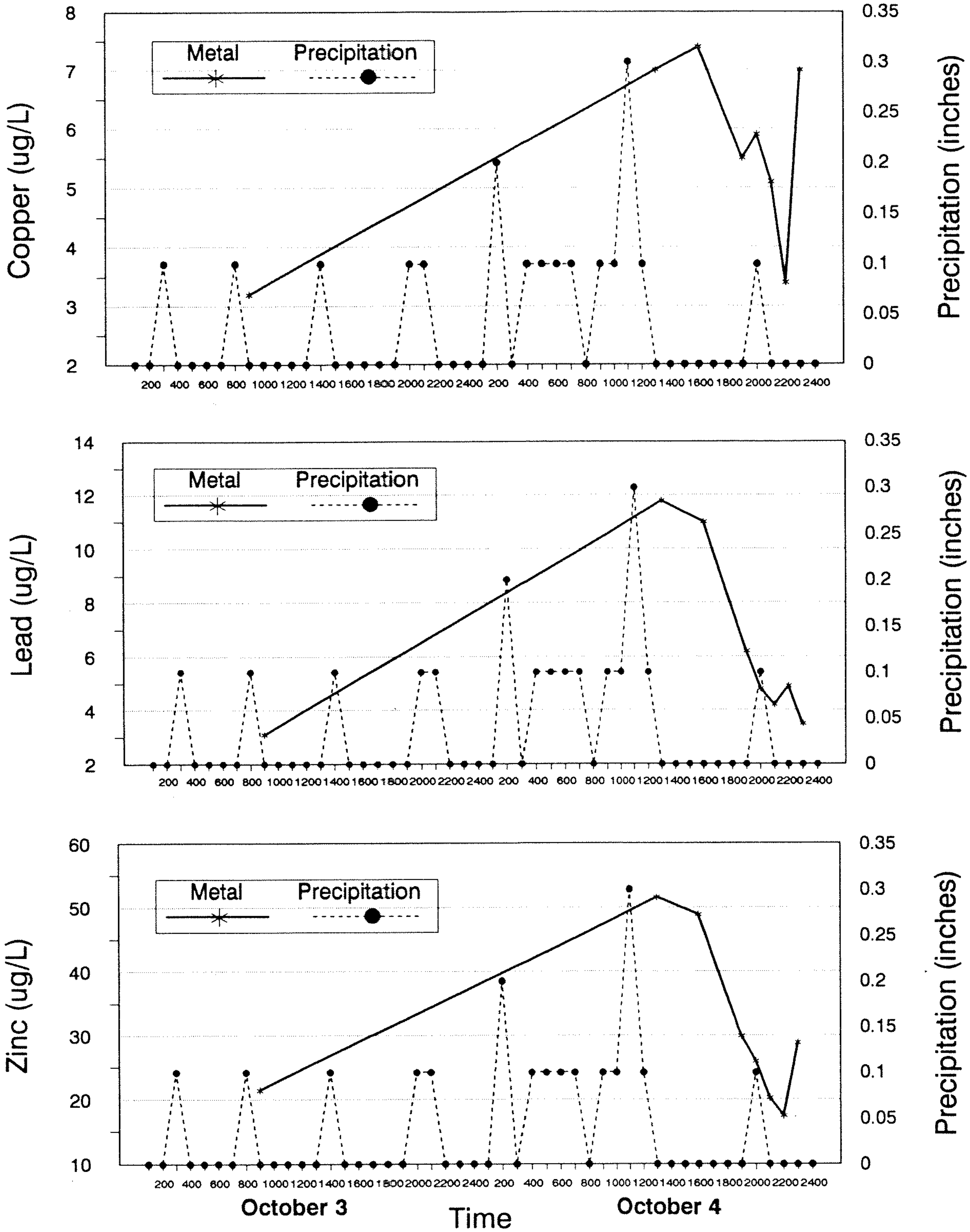

Figure 3. First flush effect at MHFH on October 3 and 4, 1990. Metal concentrations during and after the first storm event in the fall.

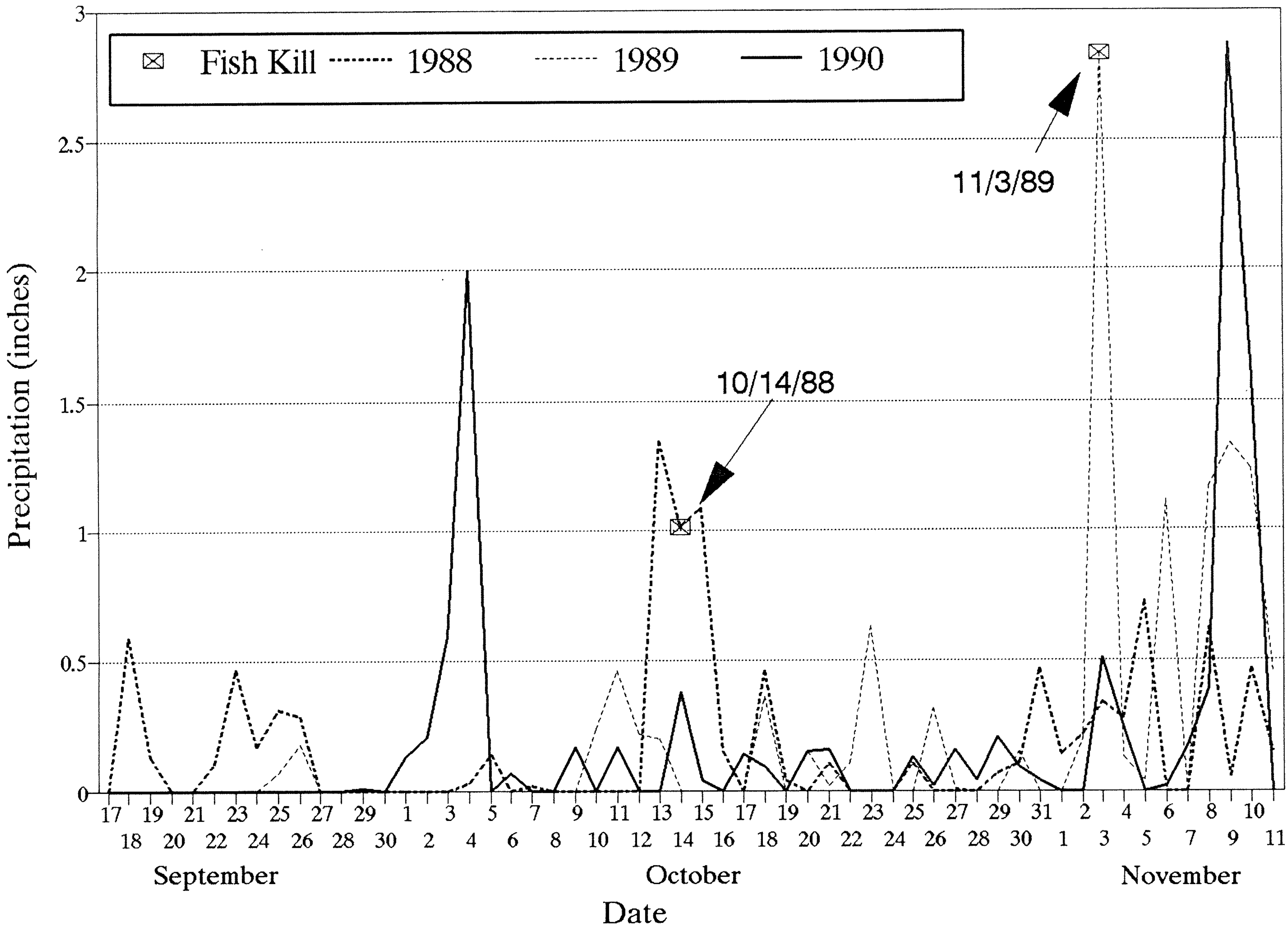

Figure 4. Daily precipitation in Bellingham from September 17 through November 11 for 1988, 1989, and 1990, with corresponding fish mortality dates (NOAA, 1988-1990). A fish kill did not occur in 1990.

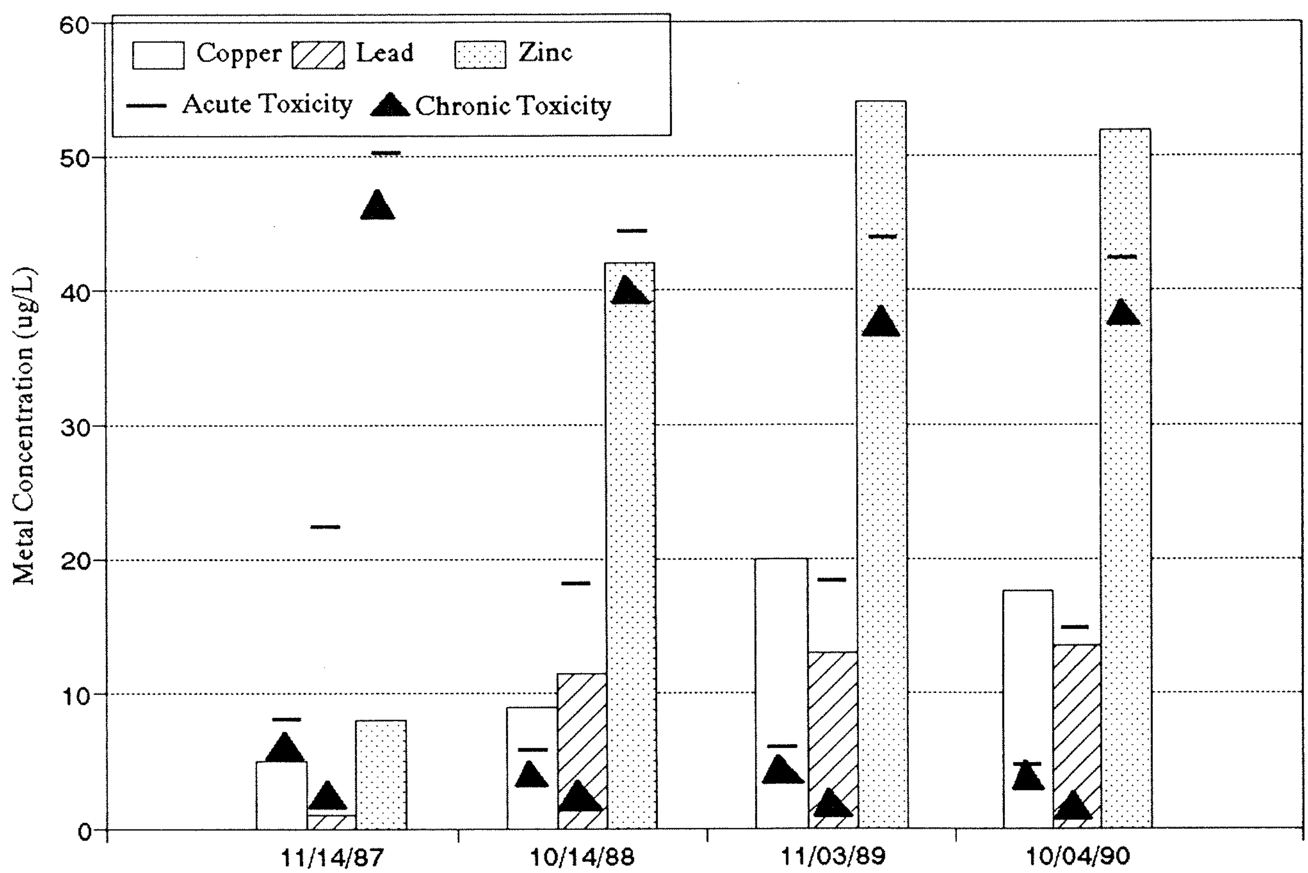

Figure 5. Total copper, lead, and zinc measured during fish kills and/or storm events at MHFH, 1987-1990. Acute and chronic toxicity criteria (based on total recoverable metals) are shown for reference.

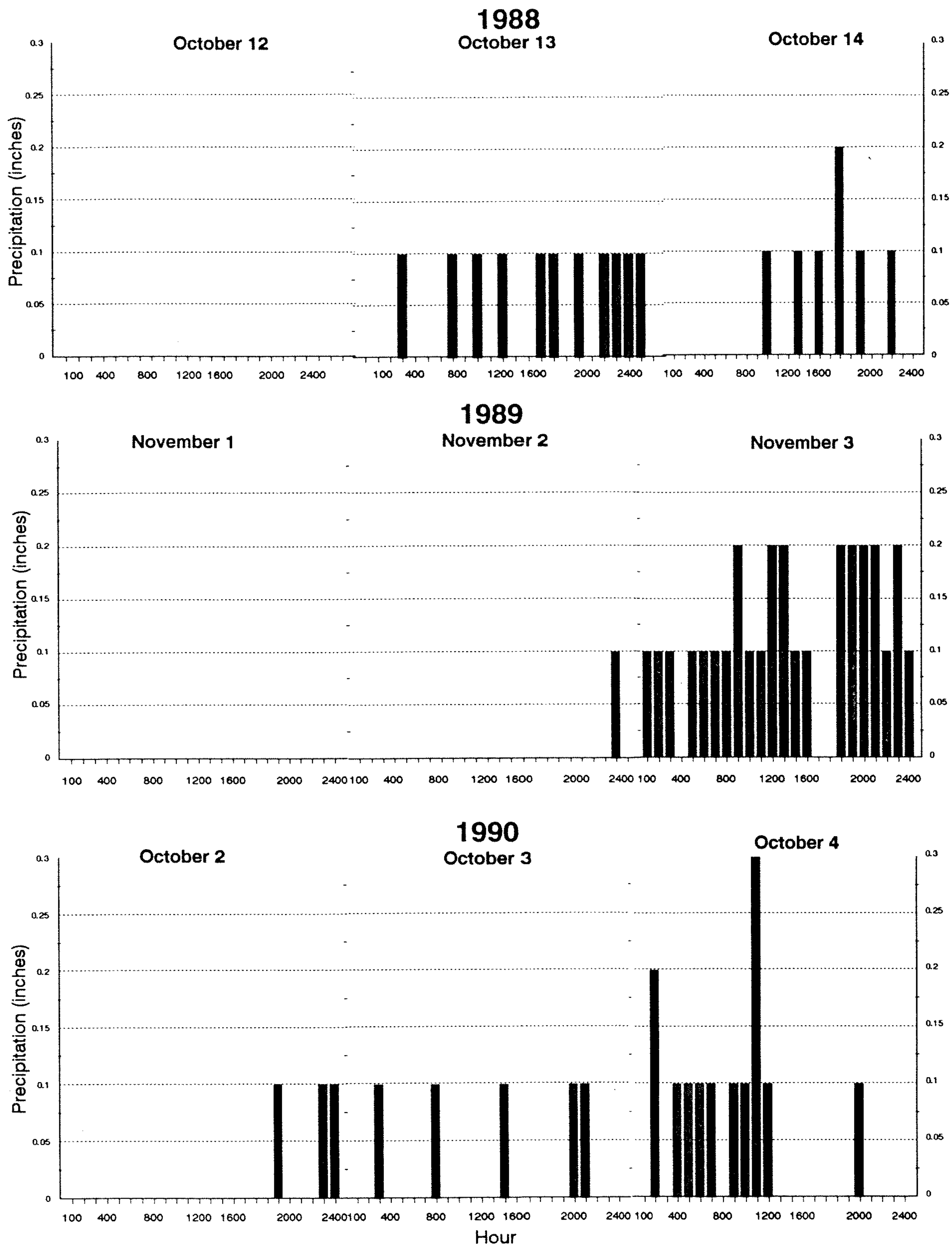

Figure 6. Hourly precipitation in Blaine, Washington for 72 hours prior to fish kills and/or storm events during 1988, 1989 and 1990 (NOAA, 1988-1990).

TABLES

Table 1. Summary of Whatcom Creek samples with values above detection limits and corresponding ambient water quality criteria for lead, copper, and zinc during fall of 1990. Values represent total recoverable (TR) analysis, and are given in ug/L. Criteria equations are presented in Appendix C.

Time	Site Description	River Mile	Hardness (mg/L)	Lead TR		Lead Acute	Lead Chronic	Copper TR		Copper Acute	Copper Chronic	Zinc TR		Zinc Acute	Zinc Chronic
September 5, 1990															
0855	WDW Hatchery pipe	3.22	26	1	U	14.70	0.57	2	U	4.98	3.74	8.3	J	37.37	33.85
1150	Valencia St. pipe	2.1	147	1.6	JB	133.33	5.20	2	U	25.48	16.43	20.1		162.19	146.91
1230	Above Cemetary Cr.	1.8	29	1	U	16.89	0.66	2	U	5.52	4.11	2.9	J	41.00	37.13
1330	James St. Storm Sewer	1.45	85	3.4	JB	66.39	2.59	2	U	15.21	10.29	35.5		101.97	92.36
1250	Lincoln Cr. Mouth	1.4	125	1	U	108.47	4.23	2	U	21.87	14.31	8.5	J	141.38	128.05
1320	Above James St.	1.1	31	1	U	18.38	0.72	2	U	5.88	4.35	5.9	J	43.38	39.29
1428	Ellis St. Pipe	0.8	36	13.1*		22.24	0.87	5.5*	J	6.77	4.94	25	J	49.24	44.60
1415	Below State St.	0.7	31	4	JB	18.38	0.72	2	U	5.88	4.35	4.5	J	43.38	39.29
1015	Above Dupont St.	0.2	30	1.1	JB	17.63	0.69	2	U	5.70	4.23	7.9	J	42.19	38.22
1040	MHFH rearing pond	0.1	31.5	1.1	JB	18.38	0.72	2	U	5.88	4.35	13.5		43.38	39.29
November 28, 1990															
1340	Park Cr.	2.8	25.9	1	U	14.62	0.57	2	U	4.96	3.73	2.7	J	37.25	33.74
1215	Above Cemetary Cr.	1.8	25.9	1	U	14.62	0.57	2	U	4.96	3.73	2.3	J	37.25	33.74
1325	West Fork Cemetary Cr.	1.75	41.7	1	U	26.81	1.04	2	U	7.77	5.60	3	J	55.77	50.51
1310	Lincoln Cr. Mouth	1.4	46.1	1.5*	J	30.47	1.19	3.4	J	8.55	6.10	8.3	J	60.72	55.00
1045	MHFH rearing pond	0.1	24.3	1	U	13.70	0.53	2	U	4.73	3.57	3.6	J	35.66	32.30

J Values are estimates.
JB Contamination found in associated procedural blank, so data is not valid.
U Actual value is less than value reported.
* Exceeds chronic toxicity criteria.

Table 2. Summary of Maritime Heritage Fish Hatchery rearing pond samples with values above detection limits, and corresponding ambient water quality criteria for lead, copper, and zinc. Values represent total recoverable (TR) analysis, and are given in μg/L. Criteria equations are presented in Appendix C.

Date	Time	Hardness	Lead				Copper				Zinc			
		(mg/L)	TR		Acute	Chronic	TR		Acute	Chronic	TR		Acute	Chronic
04-Sep	-	31.3	2.2*	J	18.61	0.73	4.7*	J	5.93	4.38	14	J	43.74	39.61
04-Sep	-	30.9	2.6*	J	18.31	0.71	5.1*	J	5.86	4.33	10	J	43.26	39.18
04-Sep	-	30.9	1.5*	J	18.31	0.71	4	J	5.86	4.33	5.3	J	43.26	39.18
10-Sep	-	32.7	3.7*	J	19.68	0.77	2.3	J	6.18	4.55	5.3	J	45.39	41.11
17-Sep	-	27.9	2.4*	J	16.08	0.63	2	U	5.32	3.97	4.6	J	39.68	35.94
24-Sep	-	28.1	1.1*	J	16.22	0.63	2	U	5.36	4.00	3.8	J	39.92	36.15
01-Oct	-	32.9	2.9*	J	19.83	0.77	3.8	J	6.22	4.57	21.9		45.62	41.32
03-Oct	-	34.5	3.1*	J	21.07	0.82	3.2	J	6.50	4.76	21.5		47.50	43.02
04-Oct	1300	33.3	11.8*		20.14	0.78	7*	J	6.29	4.62	51.6**		46.09	41.75
04-Oct	1600	30.7	11*		18.16	0.71	7.4**	J	5.83	4.31	48.9**		43.02	38.97
04-Oct	1945	31.7	6.2*		18.91	0.74	5.5*	J	6.00	4.43	30		44.21	40.04
04-Oct	2030	28.9	4.8*	J	16.81	0.66	5.9**	J	5.50	4.09	26		40.88	37.02
04-Oct	2130	29.9	4.2*	J	17.56	0.68	5.1*	J	5.68	4.21	20.3		42.07	38.11
04-Oct	2200	28.3	4.9*	J	16.37	0.64	3.4	J	5.40	4.02	17.5	J	40.16	36.37
04-Oct	2230	28.5	3.5*	J	16.52	0.64	7*	J	5.43	4.05	28.9		40.40	36.59
05-Oct	0400	34.3	3.2*	J	20.91	0.81	4	J	6.47	4.74	16	J	47.26	42.81
05-Oct	0800	31.3	1	U	18.61	0.73	2	U	5.93	4.38	3.9	J	43.74	39.61
08-Oct	0900	24.4	4.4*	J	13.55	0.53	2	U	4.69	3.54	4.4	J	35.42	32.08
15-Oct	0850	26.9	1	U	15.35	0.60	2	U	5.14	3.85	5.5	J	38.47	34.84
06-Nov	2150	25.9	1	U	14.62	0.57	2	U	4.96	3.73	8	J	37.25	33.74
07-Nov	1300	26.4	1.1*	J	14.98	0.58	3.2	J	5.05	3.79	7.2	J	37.86	34.29
08-Nov	2020	27.3	1.6*	J	15.64	0.61	2	U	5.22	3.90	6.8	J	38.95	35.28
09-Nov	0030	25.7	2.9*	J	14.48	0.56	3.2	J	4.93	3.70	14	J	37.01	33.52
09-Nov	0300	26.7	3.6*	J	15.20	0.59	3.8	J	5.11	3.83	18	J	38.23	34.62
09-Nov	0500	26.5	3.3*	J	15.06	0.59	2.8	J	5.07	3.80	17	J	37.98	34.40
09-Nov	1500	29.7	6.7*		17.41	0.68	5.9**	J	5.65	4.19	22.6		41.83	37.89
12-Nov	1945	24.6	5.1*		13.70	0.53	3	J	4.73	3.57	8.3	J	35.66	32.30
13-Nov	0615	25.1	1.2*	J	14.05	0.55	2	U	4.82	3.63	7.3	J	36.28	32.86
19-Nov	1200	25.3	1	U	14.19	0.55	2	U	4.86	3.65	2.5	J	36.52	33.08

U Actual value is less than value reported.
J Value is an estimate.
* Exceeds chronic toxicity criteria.
** Exceeds acute and chronic toxicity criteria.

Table 3. Lead, copper, and zinc concentrations in samples taken from MHFH rearing ponds during and/or after storms in the falls of 1987, 1988, 1989, and 1990.

	Date			
	14-Nov-87	14-Oct-88	03-Nov-89	04-Oct-90
Lead (μg/L)				
Total	<1	11.5	13	13.5
Total Recoverable	–	–	–	11.8
Copper (μg/L)				
Total	5	9 **	20 **	17.6 **
Total Recoverable	–	–	–	7.4 *
Zinc (μg/L)				
Total	8	42	54 **	51.9 **
Total Recoverable	–	–	–	51.6 *

* Exceeds federal acute toxicity criteria for the protection of aquatic life (Appendix C).

** Exceeds federal acute toxicity criteria for the protection of aquatic life, but criteria are based on total recoverable values.

APPENDICES

Appendix A. Dry and wet weather samples collected from Whatcom Creek and its tributaries in fall 1990.

Lab Number	Time	Site Description	River Mile	pH	Temperature	Conductivity	Hardness mg/L		Lead (ug/L)				Copper (ug/L)				Zinc (ug/L)			
								QA	Total	QA	Total Recoverable	QA	Total	QA	Total Recoverable	QA	Total	QA	Total Recoverable	QA
September 5, 1990																				
368141	1040	MHFH Rearing Pond	0.1	7.37	18.2	92	31		4.6	JB	1.1	JB	2	U	2	U	2.2	J	11	
368142	1040	MHFH Rearing Pond Replicate	0.1	7.40	18.2	92	32		2.2	JB	1.1	JB	2	U	2	U	2	U	16	
368143	1040	MHFH Rearing Pond Transfer Blank	0.1	-	-	-	1	U	1.7	JB	1	U	2	U	2	U	2	U	2	U
368139	1015	Above Dupont St.	0.2	7.45	17.9	92	30		-		1.1	JB	-		2	U	-		7.9	J
368137	1415	Below State St.	0.7	7.89	20.0	85	31		-		4	JB	-		2	U	-		4.5	J
368147	1428	Ellis St. Pipe	0.8	7.56	25.3	115	36		-		13.1		-		5.5	J	-		25	J
368136	1320	Above James St.	1.1	7.61	19.7	81	31		1.6	JB	1	U	2	U	2	U	2	U	5.9	J
368146	1250	Lincoln Cr. Mouth	1.4	7.20	17.3	375	125		-		1	U	-		2	U	-		8.5	J
368145	1330	James St. Storm Sewer	1.45	7.83	19.4	224	85		4.1	JB	3.4	JB	5.5	JB	2	U	32.8		35.5	
368144	1225	Cemetary Cr. Mouth	1.75	7.13	15.0	221	78		-		1	U	-		2	U	-		2	U
368135	1230	Above Cemetary Cr.	1.8	7.65	19.1	70	29		-		1	U	-		2	U	-		2.9	J
368149	1150	Valencia St. Pipe	2.1	7.95	17.2	351	147		-		1.6	JB	-		2	U	-		20.1	
368134	1210	Above Woburn St. Bridge	2.2	7.42	20.2	65	27		1	JB	1	U	2	U	2	U	2	J	2	U
368150	910	Screen House Overflow	3.21	7.43	17.9	72	27		1.2	JB	1	U	2	U	2	U	2	U	2	U
368132	855	WDW Hatchery Pipe	3.22	7.39	19.6	65	26		-		1	JB	-		2	U	-		8.3	J
368140	930	WDW Overland Flow	3.23	7.34	19.9	65	25		1.8	JB	1	U	2	U	2	U	2	U	2	U
368130	830	Lake Whatcom Outlet	3.8	7.80	19.7	64	25		1.9	JB	1	U	8.9	JB	2	U	2	U	2	U
368131	830	Lake Whatcom Outlet Replicate	3.8	7.77	19.8	64	26		-		1	U	-		2	U	-		2	U
368133	830	Lake Whatcom Transfer Blank	3.8	-	-	-	1	U	-		1	U	-		2	U	-		2	U
November 28, 1990																				
488431	1045	MHFH Rearing Pond	0.1	7.41	8.3	64	24.6		1.1	J	1	U	3	J	2	U	3.4	J	2.8	J
488432	1045	MHFH Rearing Pond Transfer Blank	0.1	-	-	-	1.2		1	U	1	U	2	J	2	U	3.2	J	2	U
488433	1045	MHFH Rearing Pond Replicate	0.1	7.48	8.3	64	24		1	U	1	U	2	J	2	U	6.7	J	4.4	J
488434	1035	Above Dupont St.	0.2	7.06	8.4	64	24.6		-		1	U	-		2	U	-		2	U
488438	1145	Below State St.	0.7	6.74	8.5	63	25.9		1	U	1	U	2	U	2	U	3.3	J	2	U
488439	1205	Above James St.	1.1	7.24	8.5	63	23.4		-		1	U	-		2	U	-		2	U
488442	1310	Lincoln Cr. Mouth	1.4	7.12	7.8	120	46.1		1.5	J	1.5	J	4.5	J	3.4	J	9.7	J	8.3	J
488443	1325	W.F. Cemetary Cr.	1.75	7.30	7.7	115	41.7		-		1	U	-		2	U	-		3	J
488444	1330	E.F. Cemetary Cr.	1.75	6.82	7.1	79	24.8		-		1	U	-		2	U	-		2	U
488440	1215	Above Cemetary Cr.	1.8	7.11	8.5	64	25.9		1	U	1	U	2	U	2	U	2.2	J	2.3	J
488441	1250	Above Woburn St. Bridge	2.2	7.18	9.1	64	23		-		1	U	-		2	U	-		2	U
488445	1340	Park Cr.	2.8	7.00	7.4	80	25.9		-		1	U	-		2	U	-		2.7	J
488446	1355	Screen House Overflow	3.21	7.09	8.9	71	24.2		1	U	1	U	2	U	2	U	2	U	2	U
488447	1405	WDW Hatchery Pipe	3.22	6.94	8.4	67	25.5		1	U	1	U	2	U	2	U	2	U	2	U
488448	1410	WDW Overland Flow	3.23	6.90	8.4	65	24		-		1	U	-		2	U	-		2	U
488435	1425	Lake Whatcom Outlet	3.8	7.29	8.4	62	24		1	U	1	U	2	U	2	U	2	U	2	U
488436	1425	Lake Whatcom Outlet Replicate	3.8	7.38	8.4	62	23.8		1	U	1	U	3.5	J	2	U	2	U	2	U
488437	1425	Lake Whatcom Outlet Transfer Blank	3.8	-	-	-	1	U	-		1	U	-		2	U	-		2	U

U Actual value is less than value reported.
J Analyte is present, but value is an estimate.
JB Analyte identified, but sample may have been contaminated. Value is an estimate.

Appendix B. MHFH rearing pond samples collected by Earl Steele, Hatchery manager, 1990.

Lab Number	Date	Time	Hardness (mg/L)	QA	Lead (ug/L) Total	QA	Total Recoverable	QA	Copper (ug/L) Total	QA	Total Recoverable	QA	Zinc (ug/L) Total	QA	Total Recoverable	QA
488400	04-Sep	-	31.3		2.6	J	2.2	J	5.3	J	4.7	J	11	J	14	J
488401	04-Sep	-	30.9		3	J	2.6	J	4.9	J	5.1	J	10	J	10	J
488402	04-Sep	-	30.9		2.6	J	1.5	J	2.8	J	4	J	6.5	J	5.3	J
488403	04-Sep	-	1	U	1	U	1	U	2	U	2	U	2	U	2	U
488404	04-Sep	-	1	U	1	U	1	U	2	U	2	U	2	U	2	U
488405	10-Sep	0830	32.7		-		3.7	J	-		2.3	J	-		5.3	J
488406	17-Sep	0830	27.9		2.7	J	2.4	J	2	U	2	U	4.6	J	4.6	J
488407	24-Sep	0830	28.1		-		1.1	J	-		2	U	-		3.8	J
488408	01-Oct	0830	32.9		3.1	J	2.9	J	2.1	J	3.8	J	18	J	21.9	
488409	03-Oct	-	34.5		-		3.1	J	-		3.2	J	-		21.5	
488410	04-Oct	1300	33.3		13.5		11.8		7	J	7	J	51.9		51.6	
488411	04-Oct	1600	30.7		-		11		-		7.4	J	-		48.9	
488412	04-Oct	1945	31.7		7.2		6.2		5.5	J	5.5	J	30.3		30	
488413	04-Oct	2030	28.9		-		4.8	J	-		5.9	J	-		26	
488414	04-Oct	2130	29.9		5.8		4.2	J	17.6		5.1	J	29.6		20.3	
488415	04-Oct	2200	28.3		-		4.9	J	-		3.4	J	-		17.5	J
488416	04-Oct	2230	28.5		4.6	J	3.5	J	7.4	J	7	J	28		28.9	
488417	05-Oct	0400	34.3		-		3.2	J	-		4	J	-		16	J
488418	05-Oct	0800	31.3		4.3	J	1	U	2	U	2	U	2	U	3.9	
488419	08-Oct	0900	24.4		-		4.4	J	-		2	U	-		4.4	J
488420	15-Oct	0850	26.9		-		1	U	-		2	U	-		5.5	J
488421	06-Nov	2150	25.9		1.3	J	1	U	3.5	J	2	U	9.4	J	8	J
488422	07-Nov	1300	26.4		-		1.1	J	-		3.2	J	-		7.2	J
488423	08-Nov	2020	27.3		1.9	J	1.6	J	2.3	J	2	U	7.8	J	6.8	J
488424	09-Nov	0030	25.7		-		2.9	J	-		3.2	J	-		14	J
488425	09-Nov	0300	26.7		3.3	J	3.6	J	3.5	J	3.8	J	21.1		18	J
488426	09-Nov	0500	26.5		-		3.3	J	-		2.8	J	-		17	J
488427	09-Nov	1500	29.7		5.5		6.7		7.8	J	5.9	J	24.9		22.6	
488428	12-Nov	1945	24.6		-		5.1		-		3	J	-		8.3	J
488429	13-Nov	0615	25.1		1.4	J	1.2	J	2.5	J	2	U	7.1	J	7.3	J
488430	19-Nov	1200	25.3		-		1	U	-		2	U	-		2.5	J

U Actual value is less than value reported.
J Analyte is present, but value is an estimate.

Appendix C. Toxicity criteria used for evaluating Maritime Heritage Fish Hatchery and Whatcom Creek lead, copper, and zinc concentrations. Concentrations are given in ug/L.

Criteria for the Protection of Aquatic Life (EPA, 1986)

	Acute*	Chronic**
Lead	$e^{(1.273[\ln(hardness)]-1.460)}$	$e^{(1.273[\ln(hardness)]-4.705)}$
Copper	$e^{(0.9422[\ln(hardness)]-1.464)}$	$e^{(0.8545[\ln(hardness)]-1.465)}$
Zinc	$e^{(0.8473[\ln(hardness)]+0.8604)}$	$e^{(0.8473[\ln(hardness)]+0.7614)}$

Coho Salmon 96-hour LC_{50}s

	Chapman (Unpublished data cited in EPA 1976)	Lorz and McPerson (1976)	Chapman and Stevens (1978)
Hardness	17-26	89-99	19-26
Lead	--	60-74	46
Copper	520-800	--	--
Zinc	--	4600	905

* Acute 1-hour average concentration (in ug/L) not to be exceeded more than once every 3 years on the average.

** Chronic 4-day average concentration (in ug/L) not to be exceeded more than once every 3 years on the average.

Appendix D.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Olympia Fish Health Center
3704 Griffin Lane SE, Suite 101
Olympia, WA 98501

March 10, 1992

Mr. Will Kendra
Washington Department of Ecology
Surface Water Investigations
Airdustrial Complex
Building 8, Mail Stop LH-14
Olympia, WA 98504

Dear Will:

The following samples from the Maritime Heritage Fish Hatchery Project were submitted for histologic examination:

Collection Date	Type of Sample
9-11-90	Coho salmon
10-01-90	Coho salmon
10-08-90	Coho salmon
11-06-90	Coho salmon, Steelhead trout
11-28-90	Coho salmon, Steelhead trout

Coho Salmon (COS)

Examination revealed that gill irritation, evidenced by a substantial amount of gill epithelial sloughing, was evident in the first sample (9-11-90) and continued to be observed until the 11-28-90 collection date. On this final collection date, gill condition appeared to be improving. Gill changes observed in fish collected on 10-8-90 were considered to be more severe than the two previous collection dates. This was evidenced by obvious necrosis (nuclear fragmentation) as opposed to sloughing of intact cells. In the 11-6-90 sample, there were (or appeared to be) increased numbers of chloride cells. Again, gills from the final sample (11-28-90) showed marked improvement.

Steelhead Trout (STT)

Samples were collected on two dates . Gill irritation was evident in both these samples but, unlike the COS samples, there was little epithelial sloughing. Two infectious agents were observed in the STT gills: (1) Epitheliocystis - this was considered a minor infection and is caused by a chlamydia\rickettsia agent (a very few organisms were observed in one COS collected on 11-6-90); and (2) the most probable cause of the irritation in the STT was a relatively severe infestation by the parasite Ichthyophthirius (ICH).

Sincerely,

John K. Morrison
Fishery Biologist