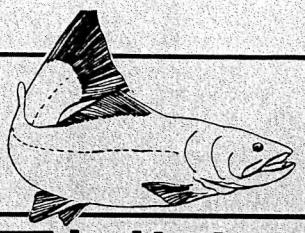
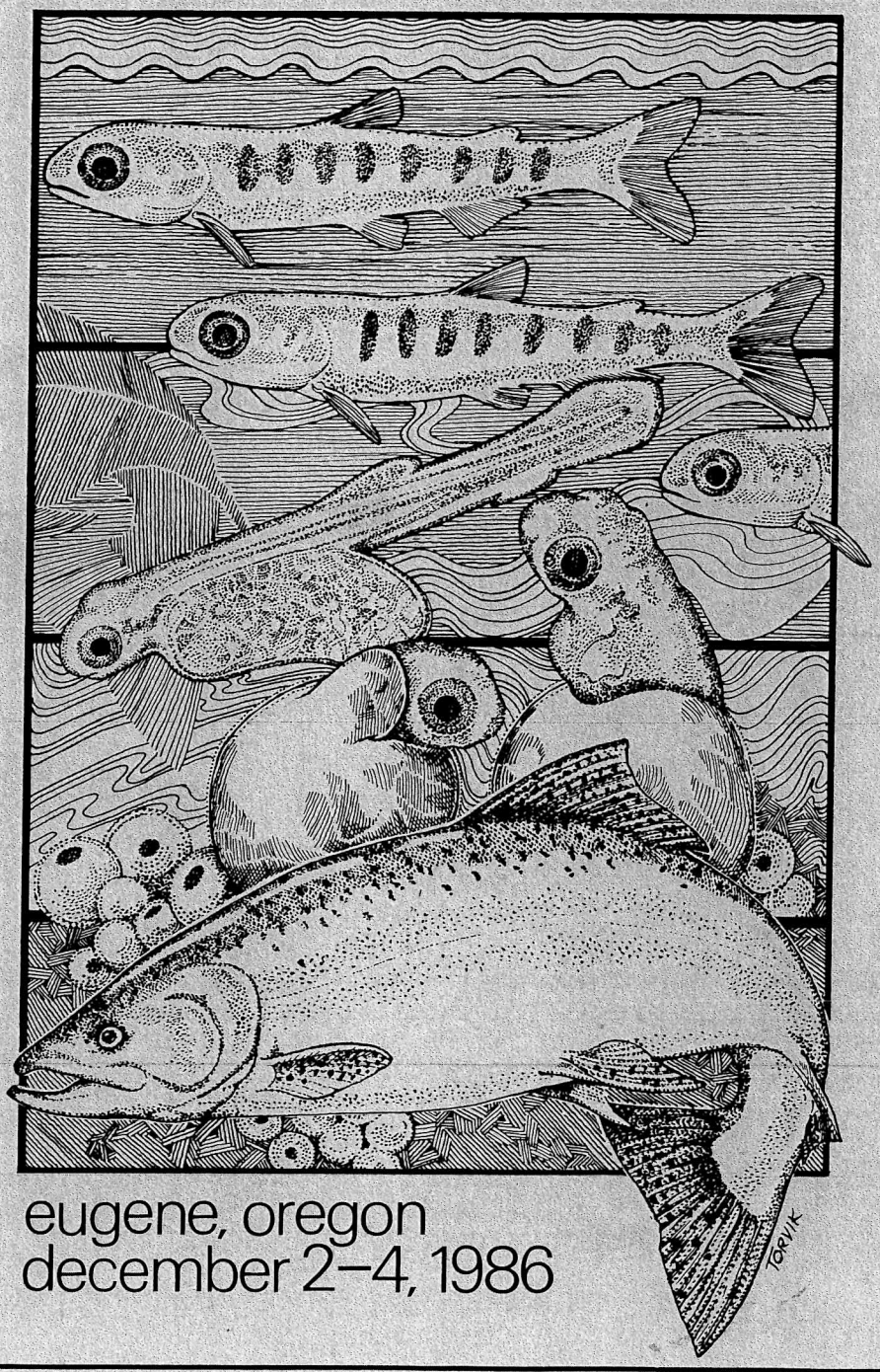


NORTHWEST FISH CULTURE CONFERENCE



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Challenges of the Future

Jim Martin, Fisheries Harvest Manager
Oregon Department of Fish and Wildlife

Our purpose today is to reflect on the trends of the past to help us anticipate and prepare for the challenges of the future. In general, in fish culture and in management, we've come a very long way!

Consider the transition from small, isolated hatcheries which were often geographically remote with primitive facilities. Today we have high tech complexes which look like the inside of a spaceship. Computers, water monitoring systems, complex automatic feeding systems and state-of-the-art communications are installed in our most modern facilities.

Facilities aren't all that have changed! So have our people. Remember the gruff old hatchery manager of the past. The isolation of his era caused him to be ingenious, self sufficient and creative. He did it his way, for sure! Today we have a new generation of managers who work as a team. Our systems of production now involve movement of eggs, fry, smolts and adults between facilities to maximize the multiple crop opportunities. We rarely see empty ponds in many of today's hatcheries. As one crop leaves, another moves in.

So much has changed in the last 30 years, how can we guess what challenges lie ahead?

My crystal ball sees three major areas of emphasis for the future:

1. Increasing dependence on hatchery fish
2. A closer focus on individual management objectives as articulated in written plans
3. Increased coordination between management agencies and tribes in a regional management effort

We will need hatchery fish more than ever in the future. Hatcheries will be the key to the U.S.-Canada rebuilding strategy for north Pacific chinook populations. We will set lids on mixed stock harvest, and then we will increase production of hatchery fish to allow the natural stocks to rebuild more rapidly. Alaskan chinook enhancement and the production of Columbia River fall chinook salmon are examples we can already point to.

In the Columbia River, we are embarking on a plan to rebuild the runs which were decimated by the dams. Our plan is to increase the production of adults by 2.5 million adult fish. Hatcheries will produce most of these fish. Outplanting from hatcheries will be the key to utilization of much of the vacant habitat in the upper basin. To realize these goals we will have to develop strategies to deal with logistics, disease, genetics, evaluation and management cost. These are very great challenges, but the power system will help foot the costs and the potential benefits to the region are great indeed.

Aquaculture will be the source of extensive new production in the Northwest. The Norwegians have put the world on notice that a new day is dawning in the world salmon market. Aquaculturists in Alaska, Canada, Puget Sound, and Oregon are in high gear to develop new techniques and markets. We owe much to the private hatcheries in Oregon for the new techniques they have developed or sponsored. Ocean release, controlled maturation, genetic evaluation and outcrossing, oxygen injection, and mass transit to saltwater acclimation are only a few of their pioneering developments.

We can anticipate that the aquaculture industry will continue to have political growing pains as it impacts the salmon scene in the northwest. Market competition, concerns about strays and genetics, and harvest manipulations will be a concern that agencies and companies will deal with over the next 10 years. I see plenty of problems in my crystal ball!

Management expenses will continue to increase while many traditional sources of funds will decrease. Objectives will be tighter and cost overruns will be less tolerable in the future. Evaluations will be more rigorous. "Cost effective" will be a term we will hear more often than in the past. We will search for more politically stable sources of funds for our hatcheries and management programs. In some areas, cutbacks and hatchery closures may be needed to improve efficiency.

Disease will continue to be a major obstacle. The dreaded virus will continue to create instability in our programs and uncertainity as to effects on natural populations. New diseases will create problems as we import or export them between facilities. Major breakthroughs in drug use may be needed to allow expansion from status quo programs. The paralysis caused by the withdrawal of malachite green is one notable example.

The maintenance of genetic diversity among hatchery and natural fish populations will be an increasing concern. We will see the emergence of genetic resources management programs designed to maintain adaptedness while avoiding the problems of inbreeding and domestication.

In the meantime we will have to deal with the oversimplistic attitudes from some "wild fish nuts" who enjoy the holy war against hatchery fish. Hopefully we can use animal science technology to deal with genetics issues on a scientific basis.

The problems of mixed stock harvest will continue to plague us. We simply must develop secondary, select stock fisheries to reduce pressures to achieve full benefits of hatchery production in mixed stock fisheries. Many of you will continue to take the rap for causing hatchery surpluses. Eventually, we will learn that the problem is not hatchery surplus which is the natural byproduct of good survival.

We will meet the challenge of the future with our number one resource, our people. It will be your dedication and hard work that will meet the challenges we've discussed today.

For all you do for the resource and the people who depende on it, THANKS!

Recent Advances in the Search for Fungicides to Replace Malachite Green

T.A. Bailey[1], L.G. Mitchell[2], J.G. Nickum[3], and S.M. Jeffrey[1]

All life stages of fish are susceptible to infection by freshwater fungi (Oomycetes) and are economically significant to intensive aquaculture (Pickering and Willoughby 1982). Untreated infections are lethal, and transmission of the infection throughout the population is probable.

A number of researchers are presently involved with the screening of compounds to identify chemotherapeutants that could replace malachite green (Alderman and Polglase 1984; Bailey 1984; Lio-Po, et al. 1985). The lack of available data on chemicals that are effective against pathogenic Saprolegniales is a direct result of the effectiveness of malachite green as an aquatic fungicide. Although the data base has been increased recently, a broader spectrum of aquatic fungal species and chemical classes must be tested.

Objectives of this study were to test candidate compounds against two species of aquatic fungi in artificial culture, to compare their effectiveness with that of malachite green, and to identify those compounds that would warrant further testing in vivo with fish and fish eggs.

The majority of the compounds tested in our work are presently used as antibiotics or antifungal agents against fungi that are pathogenic to plants, domesticated animals, or man. Since these chemical agents have known efficacy against non-aquatic fungal species, their efficacy against aquatic fungal species was investigated.

The aquatic fungi, Achlya flagellata (ATCC 13566) and Saprolegnia hypogyna (ATCC 28275), were chosen to represent fungal species that are pathogenic to fish and fish eggs. Test procedures used were those decribed by Bailey (1983a,b, 1984). The method involves a preliminary in vitro screening techinque modified from that of Golden and Oster (1947). Candidate fungicides were tested for activity against A. flagellata and S. hypogyna on cornmeal agar.

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An additional experiment included an egg/agar transfer test to establish concentrations that would control fungal growth on a natural substrate (dead rainbow trout eggs) for 48h (Bailey 1984). Dead (cold shocked) rainbow trout eggs were exposed to candidate chemicals at concentrations of one or two orders of magnitude greater than their respective minimum inhibitory concentration values. The egg/agar transfer experiment provides a confirmatory test and is indicative of the in vivo activity of a compound. Levels of inhibition are those concentrations that prevent growth of fungi on either the egg surface or agar.

In vivo experiments using live rainbow trout eggs were conducted in vertical incubation units using four test groups (positive control, negative control, treatment group, and reference group). Each test group consisted of 800 eggs (400 per replicate). All but the negative control group were inoculated with fungus, and the positive control group was untreated. The reference group was treated with 5.0 mg/L malachite green for 15 min.

Of the nearly 150 chemicals investigated for their antifungal activities, 22 compounds warranted further study. In minimum inhibitory concentration (MIC) experiments, (Table 1) copper-8-quinolinolate, crystal violet, Phaltan, and 8-quinolinol were effective at concentrations of 1.0 mg/L or less. This compared favorably with the reference compound malachite green, which was effective at 1.0 mg/L and 0.5 mg/L against A. flagellata and S. hypogyna respectively. The remaining test compounds were 1/10 to 1/100 less effective against either species of fungus. More than half the chemicals tested showed greater antifungal activity against Saprolegnia. Length of exposure seemed to be of less significance, since only 36% of the compounds screened exhibited greater effectiveness after 60 min of exposure as compared to a 15 min treatment.

Thirteen of the top candidate fungicides also were tested against the zoospore stages of the test fungi (Table 2). Although these data are preliminary,8-quinolinol, 8-quinolinol sulfate, Thiram, Dithianon, Busan 30, 5-hydroxy-1,4-naphthoquinone, and Phaltan prevented zoospore germination within the same range of concentration (>1<10) as malachite green. Accordingly, the above candidate compounds may prove useful in prophylactic usage. Amical 48, copper--quinolinolate, and Dodine were effective at concentrations >10<100, but Polyphase (17WD and P-100) and Thiabendazole did not inhibit zoospore germination at concentrations less than 100.0 mg/L.

Effective concentrations for egg/agar transfer tests (Table 3) ranged from 10.0 to 1,000.0 mg/L. The reference, malachite green, was fungicidal at 8.0 mg/L regardless of exposure time. Crystal violet (10.0 mg/L) controlled fungus growth on natural substrate comparably to malchite green after 15 min or 60 min exposures. Although longer exposures (60 min) improved the activity of Polyphase 17WD (10X), Amical 48 (10X), Dodine (4X), and Du-Ter (1.5X), the effectiveness of the remaining compounds was not time-dependent.

A rating system (Table 4) was developed to compare the levels of antifungal activity and to rank the potential of the 22 top candidate chemicals to replace malachite green. Based on the evaluation of antifungal activity, minimum inhibitory concentration, availability, registrability, solubility, and toxicity (Human), these 22 compounds were prioritized. The ratings were totaled for each chemical, and ranking was determined numerically with the highest ranking corresponding to the highest priority. Ranking levels ranged from 11 to 32 with 36 as the highest ranking possible.

Eight of the 22 candidate compounds have been tested against fungus on living eggs, and others are scheduled for use in in vivo trials with rainbow trout eggs. Amical 48, copper-8-quinolinolate, Du-Ter Phaltan,Polyphase 17WD, Polyphase P-100, Thiabendazole, and TFM were all toxic to rainbow trout eggs at treatment levels (Table 5); these compounds are no longer considered viable candidates. After 15 min treatments with 30.0 mg/L 8-quinolinol three times weekly, fungus was observed on 38.1% of the eggs compared to 30.7% for eggs treated with 5.0 mg/L malachite green. Hatching success for malachite green and 8-quinolinol treated eggs was 60.6% and 55.3% respectively. Despite their high numerical ranking, crystal violet and ethyl violet were given lower priority because they have the same basic chemical structure as malachite green and their registrability is uncertain. Furthermore additional samples of Blasticidin S (Kaken Chemical Company, Tokyo) and Salicylanilide I (currently no sponsor) are difficult to procure for future experiments. Although the remaining compounds, Busan 30, Actidione, Dithianon, Dodine, 5-hydroxy-1, 4 napthoquinone, Thiram, and p-benzoquinone, are among the top candidates , their fates depend on in vivo test results. Presently 8-quinolinol is the leading candidate for replacing malachite green.

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Golden, J.J. and K.A. Oster. 1947. Evaluation of a fungicidal laboratory test method. Journal of the American Pharamaceutical Association 36:350-362.

Lio-Po, G.D., M.C.L. Baticados, C.R. Lavilla, and M.E.G. Sanvictores. 1985. In vitro effects of fungicides on Haliphthoros phillippinensis. Journal of Fish Diseases 8:359-365.

Pickering, A.D. and L.G. Willoughby. 1982. Saprolegnia infections of salmonid fish. Pages 271-297. In R.J. Roberts, ed. Microbial Diseases of Fish. Published for the Society for General Microbiology by Academic Press, San Diego, California.

Table 1. Minimal inhibitory concentration (mg/L) required to control growth of *Achlya flagellata* and *Saprolegnia hypogyna* after 15- and 60-min exposure. Measurements were made of fungal growth after 48 hours incubation at 20°C.

Chemicals	Minimal inhibitory concentration (mg/L)			
	A. flagellata		*S. hypogyna*	
	15 min	60 min	15 min	60 min
Malachite green	1.0	1.0	0.5	0.5
Copper-8-quinolinolate	1.0	1.0	1.0	1.0
Crystal violet	1.0	0.5	0.75	0.5
Phaltan	1.0	1.0	1.0	1.0
8-Quinolinol	1.0	7.0	1.0	1.0
Du-ter	3.0	4.0	1.0	1.0
Amical 48	5.0	3.0	3.0	0.75
Busan 30	5.0	3.0	5.0	3.0
Polyphase P-100	5.0	5.0	3.0	1.0
Polyphase 17WD	4.0	3.0	3.0	1.0
5-Hydroxy-1,4,-naphthoquinone	10.0	6.0	6.0	6.0
p-Benzoquinone	30.0	30.0	10.0	10.0
Dodine	30.0	30.0	75.0	75.0
Ethyl violet	30.0	7.5	10.0	10.0
TFM	30.0	30.0	30.0	30.0
8-Quinolinol sulfate	100.0	100.0	300.0	100.0
Thiram	100.0	75.0	30.0	30.0
Actidione	>100	>100	30.0	30.0
Salicylanilide I	>100	>100	>100	>100
Blasticidin S	500.0	500.0	30.0	3.0
Dithianon	700.0	75.0	300.0	100.0
Formalin-F	700.0	200.0	400.0	200.0
Thiabendazole	1,000.0	1,000.0	300.0	300.0

Table 2. Concentration ranges (mg/L) required to inhibit spore germination of *A. flagellata* and *S. hypogyna*.

Chemical	Effective concentrations (mg/L)	
	A. flagellata	*S. hypogyna*
Malachite green	>1<10	>1<10
8-Quinolinol	>1<10	>1<10
8-Quinolinol sulfate	>1<10	>1<10
Thiram	>1<10	>1<10
Dithianon	<1.0	>1<10
Busan 30	>1<10	>10<100
Phaltan	>1<10	>1<10
Amical 48	>10<100	>1<10
Copper-8-quinolinolate	>10<100	>10<100
Polyphase P-100	>100	>100
Polyphase 17WD	>100	>100
Thiabendazole	>100	>100

Table 3. Minimal concentrations (mg/L) required to control fungus growth on dead rainbow trout eggs for 48 h after 15- and 60-min exposures.

Chemical	Effective concentrations (mg/L)	
	15 min	60 min
Malachite green	8.0	8.0
Crystal violet	10.0	10.0
Busan 30	>50.0	50.0
Actidione	100.0	100.0
Blasticidin S	100.0	100.0
8-Quinolinol	100.0	100.0
Salicylanilide I	100.0	100.0
TFM	100.0	100.0
Polyphase 17WD	>100	10.0
Polyphase P-100	>100	>100
Du-ter	125.0	87.5
p-Benzoquinone	>150.0	>150.0
Amical 48	>250.0	25.0
Dodine	>300.0	75.0
Dithianon	>300.0	>300.0
Ethyl violet	1,000.0	1,000.0

Table 4. Ranking of top candidate fungicides based on ratings derived from six categories.

Chemicals	Anti-fungal index	MIC	Avail-ability	Registr ability	Solu-bility	Toxicity	Total	Comments
Polyphase 17WD	6	6	6	6	5	3	32	Toxic to rainbow trout eggs
Polyphase P-100	5	6	6	6	5	3	31	Toxic to rainbow trout eggs
Amical 48	6	6	6	6	5	1	30	Toxic to rainbow trout eggs
Busan 30	5	6	6	4	6	3	30	
Crystal violet	6	6	6	2	6	3	29	Potential health risk
Phaltan	5	6	6	6	2	4	29	Toxic to rainbow trout eggs
8-Quinolinol	4	6	6	6	5	2	29	
Copper-8-quinolinolate	5	6	6	6	4	1	28	Toxic to rainbow trout eggs
TFM	3	3	6	6	4	6	28	Toxic to rainbow trout eggs
Du-ter	6	6	6	6	0	3	27	Toxic to rainbow trout eggs
Ethyl violet	5	6	6	2	6	2	27	Potential health risk
Actidione	3	4	6	6	6	1	26	
Formalin F	3	2	6	6	6	3	26	
8-quinolinol sulfate	2	3	6	6	6	3	26	
Dithianon	3	2	6	6	4	4	25	
Dodine	3	2	6	6	5	3	25	
5-hydroxy-1,4-napthoquinone	5	6	6	6	1	1	25	
Thiram	5	3	6	6	1	4	25	
p-Benzoquinone	4	5	6	0	5	4	24	
Malachite green	6	6	6	0	6	0	24	
Thiabendazole	0	4	6	6	5	3	24	Toxic to rainbow trout eggs
Blasticidin S	2	2	4	6	6	3	23	
Salicylanilide I	1	2	0	0	5	3	11	Highly toxic to fish

[a]MIC = minimum inhibitory concentration on the minimum concentration level at which fungus growth was completed inhibited.

Table 5. Results of 15-min treatments of incubating rainbow trout eggs with eight candidate compounds and malachite green three times weekly.

Chemicals	Concentration (mg/L)	% infection	% hatch
Negative control	--	43.1	58.6
Postive control	--	42.6	60.1
Malachite green	5.0	30.7	60.6
8-Quinolinol	30.0	38.1	55.3
Polyphase 17WD	10.0	80.3	22.2
Du-ter	2.0	28.8	21.4
Phaltan	5.0	94.0	0.3
Thiabendazole	30.0	98.9	0
Copper-8-quinolinolate	20.0	50.1	0
Polyphase P-100	10.0	46.4	0
Amical 48	25.0	8.1	0

1. FISH PATHOLOGY

IHN vs WDG, Who's winning the battle?

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Abstract

Prior to 1981, Infectious Hematopoietic Necrosis (IHN) had not been documented at any Washington Department of Game (WDG) hatcheries or rearing ponds. Since 1981, IHN outbreaks have plagued operations at 10 WDG facilities (Beaver Creek, Chambers Creek, Chelan, Cowlitz, Lyons Ferry, Mossyrock, Skamania, South Tacoma, Turtle Rock and Tucannon). A variety of stocks of cutthroat, rainbow, summer and winter steelhead had been infected. Over 7.2 million fish have either died or were destroyed because of IHN. An additional 4.2 million eggs have also been destroyed because of IHN prevention i.e. broodstock selection. A history of the IHN outbreaks at the 10 WDG facilities was reviewed. Various IHN control and prevention measures have been employed and the success the of the measures were evaluated. Successful measures have included some or all or the following: 1.) destruction of fish and facilities sanitation, 2.) protection of water supplies, 3.) limitation of fish transfers, and 4.) broodstock selection (culling).

Introduction

Infectious Hematopoietic Necrosis, is a serious, contagious viral disease of salmonids which is endemic to the Pacific Northwest. Prior to 1981, IHN had not been documented in any WDG hatchery or rearing pond. The following is a history of IHN in WDG facilities and a review of the methods used to control or prevent IHN.

History of IHN outbreaks in WDG hatcheries and rearing Pond

1981

The first appearance of IHN was in summer steelhead fry at Skamania hatchery (Figure 1). IHN mortality was very high and all fish were destroyed and the hatchery was totally sanitized.

IHN also occurred at Cowlitz hatchery (Figure 1) in cutthroat rainbow, summer and winter steelhead. All fish undergoing IHN were destroyed and the ponds were sanitized.

Cowlitz stock winter steelhead fry being reared at Mossyrock hatchery (Figure 1) were found to have IHN. Cutthroat and rainbow were also became infected. All fish were destroyed and the hatchery was totally sanitized.

1982

In 1982, IHN reoccurred at Skamania hatchery in summer steelhead and the infected fish were destroyed. Broodstock selection with pooled sampling had been employed along with early fry rearing at Vancouver hatchery.

Cutthroat, summer and winter steelhead again died with IHN at the Cowlitz hatchery. Broodstock selection had been employed with individual sampling.

Beaver Creek hatchery (Figure 1) experienced IHN for the first time in spring, 1982. Losses were observed in cutthroat, summer and winter steelhead. Broodstock selection with pooled sampling had been employed.

1983

IHN outbreaks occurred in cutthroat and winter steelhead at Beaver Creek hatchery. Broodstock selection with individual sampling had been employed.

Cutthroat, summer and winter steelhead experienced IHN at the Cowlitz hatchery. No fish were destroyed. Broodstock selection with individual sampling had been employed.

Summer steelhead at Skamania hatchery were again infected with IHN. No fish were destroyed. Broodstock selection with individual sampling had been employed.

1984

No IHN outbreaks were encountered at any WDG hatchery or rearing pond.

1985

In 1985, IHN was seen in rainbow yearlings at Chelan hatchery (Figure 1). The diseased fish were destroyed and the ponds were sanitized.

IHN, was also seen in rainbow fingerlings at Lyons Ferry (Figure 1) and Tucannon hatchery (Figure 1). The infected fish were destroyed and ponds sanitized.

Two rainbow stocks were involved at the three hatcheries. The parent rainbow broodstocks had a long history of IHN free inspections.

1986

In the spring of 1986, a major IHN epizootic occurred at South Tacoma (Figure 1) and Chambers Creek hatchery (Figure 1). Cutthroat, rainbow, summer and winter steelhead were destroyed and ponds sanitized.

An IHN outbreak was also observed in summer steelhead smolts being reared at Turtle Rock rearing pond (Figure 1). The fish were released directly into the Columbia river.

Total eggs and fish destroyed because of IHN

A total of fish lost or destroyed because of IHN from 1981 to 1986 was 4.2 million. Eggs from IHN positive fish were also destroyed numbering 7.2 million. A summary of the total number of eggs or fish lost or destroyed because of IHN is shown in Table 1.

Table 1. Summary of eggs and fish lost and destroyed because of IHN, 1981 to 1986.

Hatchery	Eggs (x 1,000)	Fish (x 1,000)
Beaver Creek	538	968
Chamber Creek	0	2,033
Chelan	0	172
Cowlitz	1,359	678
Lyons Ferry	70	15
Mossyrock	0	982
Skamania	1,039	1,135
South Tacoma	1,200	1,142
Tucannon	0	36
Turtle Rock	0	9

IHN Control and Prevention

IHN control and prevention has included the following measures which have been employed in various ways at the problem hatcheries.

A. Destruction of fish and facility sanitation.
B. Protection of water supplies.
C. Limitation of fish transfers.
D. Broodstock selection (culling).

Destruction of fish and facility sanitation

Destruction of IHN infected fish and facility sanitation has been accomplished at 9 of 10 faciltities. Successful elimination of IHN (no IHN for 3 years) has resulted at Mossyrock, a spring water supply hatchery. However, were complete or partial destruction and sanitation has been done at surface water supply hatcheries; IHN has reoccurred.

Prompt destruction and sanitation has probably also aided in controlling the within hatchery spread of IHN, especially in closed water supply hatcheries.

Protection of water supplies

Limiting the use of surface water supplies has been the most important measure in IHN prevention. Successful IHN prevention at Chelan hatchery (no IHN for 1 year) has been accomplished because of the discontinuation of the use of Columbia river water for fish rearing. IHN control at Skamania has also come about by rearing the fish in a close water supply hatchery (Vancouver) follow by transfer to Skamania in the summer.

Limitation of fish transfers

Since IHN can be moved with it's host; limiting the transfer of fish has been very important in IHN prevention. Ideally, no fish transfers should be made. If fish transfers are made they should be limited to disinfected eggs from IHN free parents or fish from IHN free parents which have been reared in a closed water supply hatchery. Adult transfers should be totally prohibited.

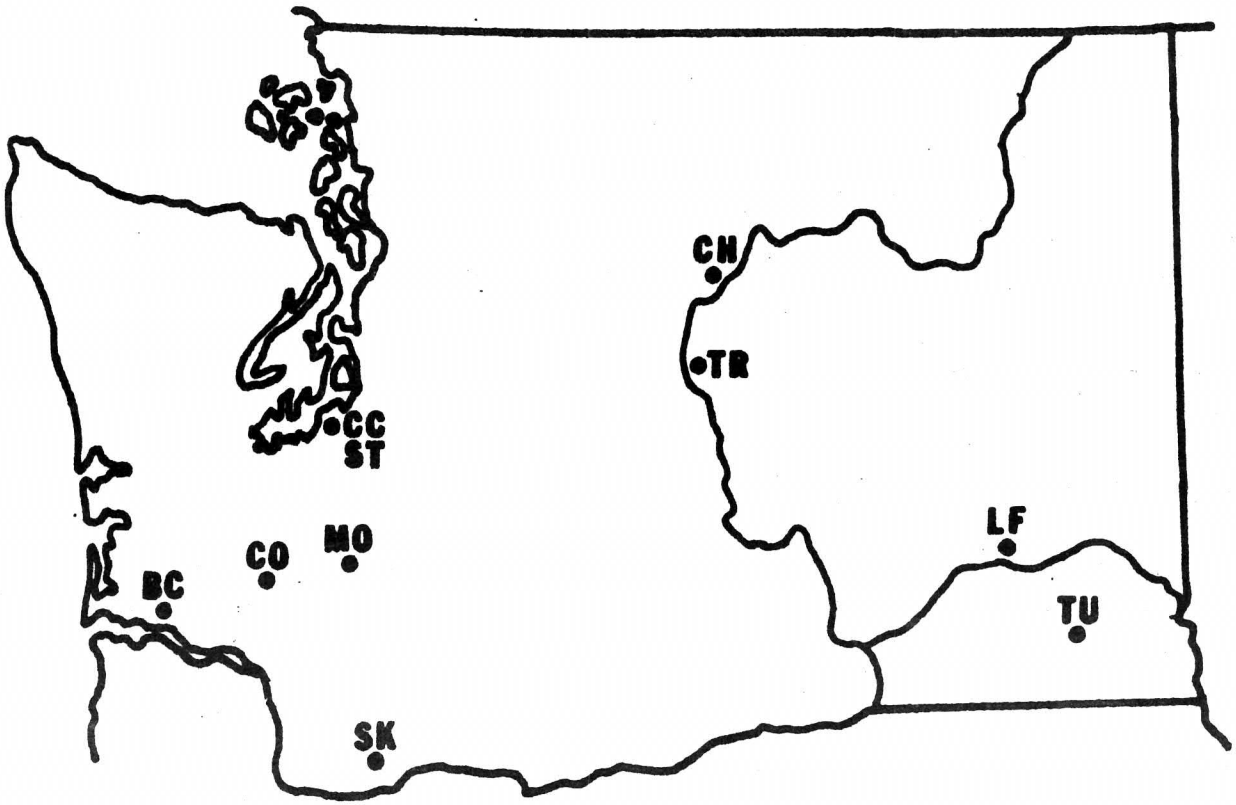
Broodstock selection (culling)

Of the measures to control and prevent IHN, broodstock selection is the most controversial. Broodstock selection is built on the premise that IHN is vertically transmitted. This premise is currently in serious question.

Broodstock selection has been employed at Beaver Creek, Cowlitz, and Skamania hatcheries. IHN outbreaks have occurred in fry from IHN negative parents. However, the outbreaks have occurred when the fish were being reared on surface waters. IHN has not occurred at the above lower Columbia river hatcheries for the last thee years. Is this a results of broodstock selection or just a natural low in the virus occurrence?

All the above measures have aided in the control and prevention of IHN. But the battle isn't over until all IHN outbreaks have been totally eliminated.

Figure 1. Location of IHN outbreaks in WDG hatcheries and rearing ponds, 1981 - 86.



BC = Beaver Creek
CC = Chambers Creek
CH = Chelan
CO = Cowlitz
LF = Lyons Ferry
MO = Mossyrock
SK = Skamania
ST = South Tacoma
TR = Turtle Rock
TU = Tucannon

The Frequency of Infectious Hematopoietic Necrosis Virus in Adult Steelhead (Salmo gairdneri) Held at Dworshak National Fish Hatchery

By Greg Pratschner

Introduction

During 1986, the incidence of the infectious hematopoietic necrosis (IHN) virus (IHNV) in returning adult steelhead remained at zero percent until April 1 (egg take 9). At that time, the virus, at low titre, was found in one adult male steelhead. The incidence remained low for the remainder of the spawning season, but was found in progressively more adults through May 7, the last spawning day (egg take 14). The incidence of IHNV increased from 0.77 percent to 12.0 percent from April 1 to May 7.

This year, as in recent years, adult steelhead in excess of our weekly spawning requirements were held in a holding pond on station pending an outplant program or other disposition. This year, because of the paucity of males, outplanting attempts were terminated on April 7, and all adults held in the pond were donated to the Idaho Department of Education for distribution to public food banks. Adults from egg takes 11 through 14 (April 15 through May 7), however, were held for a research project conducted by the University of Idaho.

For that research, 30 male and 50 female steelhead were sampled for the presence of IHNV and mated according to specific genetic phenotypes (glycl-leucine dipeptide) as determined by electrophoresis of muscle tissue. That analysis was performed by the University. The results of the IHNV sampling provided some interesting observations.

Results and Discussion

Table 1 summarizes the results of IHNV analysis of tissue samples conducted by the Dworshak Fish Health Center for egg takes 11 through 14. Additionally, the numbers of steelhead returned to the holding pond from each of these takes is shown in Table 2.

In the absence of significant horizontal transmission, the incidence of the virus in the University steelhead should have been approximately 10 percent. We observed nearly a six-fold increase in the incidence of the virus in the fish held for nearly four weeks (Fig 1). The virus titre was significantly higher in the fish held on station when compared to the titres measured on spawning day (Fig 2). There are several possible explanations for the increased frequency of the virus.

1. That the virus was in the water and infected the held steelhead. This is somewhat refuted by the observation that rainbow trout sentinel fish reared on station in two locations: the main pumphouse (hatchery intake) and in the Dworshak nursery did not contract the disease.

2. That the stress of handling induced virus shedding in the held steelhead.

3. That the deteriorating physical and physiological condition of the fish activated a carried virus. Items two and three may be interrelated in that handling contributed to the breakdown of the physical condition of the fish and activation of the virus.

4. That phenotypes of the enzyme glycl-leucine dipeptide are genetic markers of IHNV positive fish. The University actually performed these experiments twice, March 26 and May 9. In the first experiment, fish held for one week yielded no IHNV positive regardless of phenotypes.

It appears that holding sexually mature adult steelhead increased the overall frequency of IHNV. If these fish are held in a holding pond where the water is wasted to the river, such as Dworshak, there is a potential to infect resident, susceptible species and ultimately the hatchery water supply. Additionally, outplanting of these same fish upstream without IHNV sampling has the potential to infect wild, natural or uninfected resident trout populations.

Table 1. A summary of the IHN tissue sample results of steelhead adults spawned between April 15 and May 7, 1986 and of a pool of adults held for up to four weeks (i.e. excess adults from the same periods).

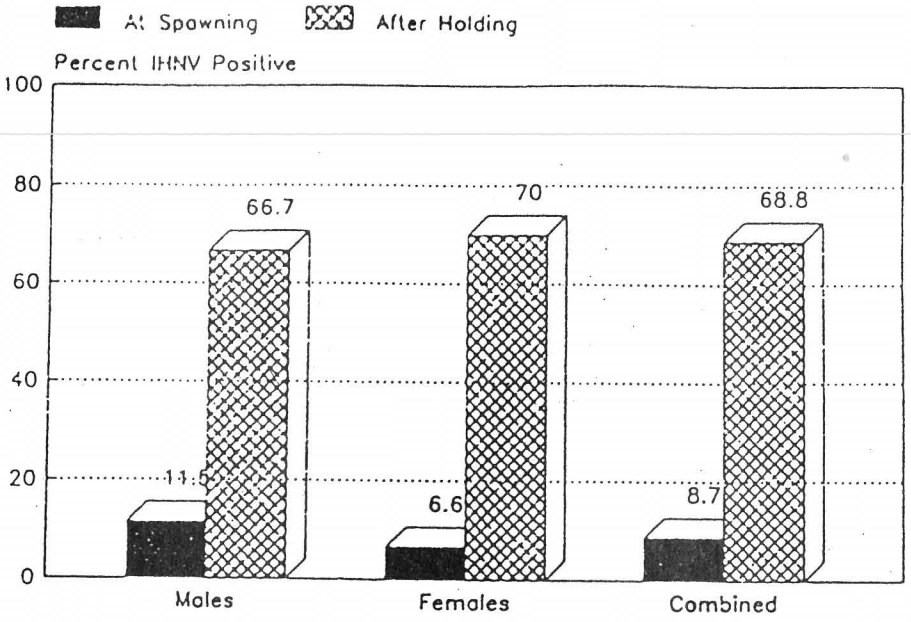
Egg Take	Date	No. Sampled		No. IHN +		Percent IHN +			Mean IHN Titre	
		Males	Females	Males	Females	Males	Females	Total	Males	Females
11	15-Apr-86	113	158	9	11	8.0	7.0	7.4	2.69E+02	1.86E+02
12	22-Apr-86	46	70	3	4	6.5	6.0	6.0	5.89E+03	1.95E+01
13	29-Apr-86	55	75	12	4	22.0	5.0	12.3	5.62E+02	2.82E+01
14	06-May-86	29	30	4	3	14.0	10.0	12.0	3.00E+03	2.10E+02
Totals/Averages		243	333	28	22	11.5	6.6	8.7	2.43E+03	1.11E+02
*UI	09-May-86	30	50	20	35	66.7	70.0	68.8	7.00E+03	2.10E+04

* Fish spawned were excess to spawning needs for takes 11, 12, 13, and 14 and held in Holding Pond 1 at Dworshak NFH. These fish were sorted on 5/7/86 and spawned on 5/9/86.

Table 2. The number of steelhead returned to Holding Pond 1 from each of egg takes 11, 12, 13, and 14 and subsequently spawned by the University of Idaho on 5/9/86.

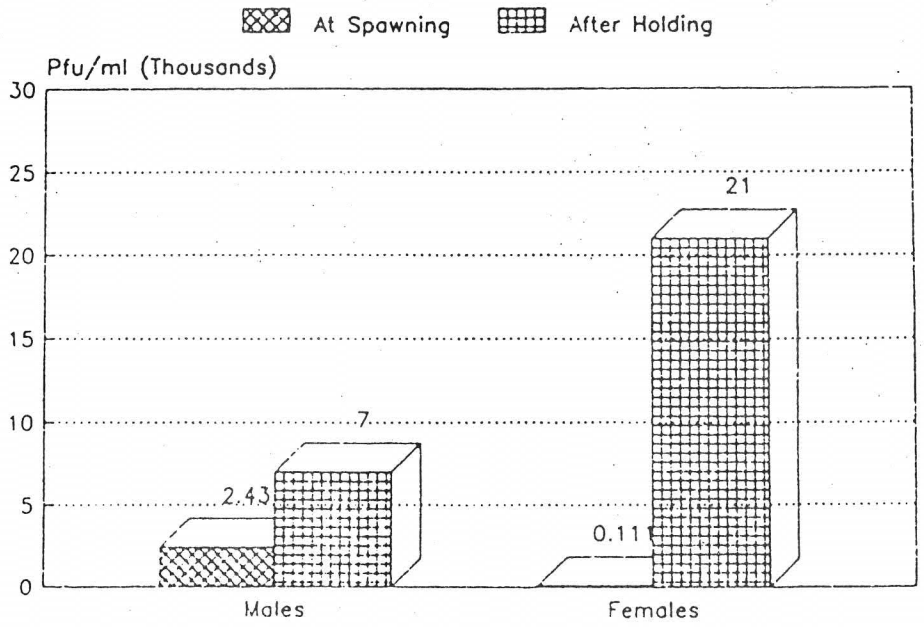
Egg Take	Date	Males	Females	Total	Percent of Total
11	15-Apr-86	24	97	121	31
12	22-Apr-86	40	2	42	11
13	29-Apr-86	52	129	181	47
14	06-May-86	1	40	41	11
Totals/Averages		117	268	385	
Mortality		24	31	55	
Available 5/9/86		93	237	330	

Figure 1. The Prevalence of IHNV
in Steelhead held at Dworshak NFH



April–May 1986

Figure 2. IHNV Titre in Adult Steelhead
Before and After Holding



April–May 1986

IODOPHOR WATER HARDENING OF STEELHEAD AND CUTTHROAT TROUT EGGS

by

Douglas R. Burton
Hatchery Superintendent, Oxbow Hatchery
Idaho Department of Fish & Game

ABSTRACT

Tests on the effects of water hardening eggs in Wescodyne and Argentyne were performed with steelhead trout and cutthroat trout, during the summers of 1982 and 1983. Active iodine concentrations of 0, 10, 20, 30, and 40 ppm were tested with both iodophors in 1982, but only Wescodyne at concentrations of 0, 25, and 50 ppm was tested in 1983. Incubation mortality rates were not increased by either iodophor at any concentration when the solution pH was at or near neutral, but incubation mortality was significantly greater in Wescodyne-treated lots than in Argentyne-treated lots when the pH was near 8.0 at iodine concentrations of up to 40 ppm. Water hardening treatments did not increase the number of deformed or "crippled" fry hatching from the treated eggs. Growth rates of fish hatched from treated eggs were not effected during early rearing. The experiments were inconclusive in determining the efficacy of iodophor water hardening to inhibit vertical transmission of IPN or IHN virus.

WATER SUPPLY DISEASE PROBLEMS AND OZONATION

Kathy Clemens, Fisheries Biologist
Coleman NFH

Battle Creek, the water supply of Coleman NFH, has historically been a viable carrier of disease organisms. As there are three private and one state hatchery upstream from Coleman, this is to be expected. Anything they get, we eventually get, whether it be ERM, Columnaris, 'Ich', IHN, or other external parasites. This has continued for so many years that hatchery people at Coleman knew what to expect and when and could prevent large losses of fish. This was an accepted (though not liked) fact of life until 1985 when one organism shipped down the creek presented a whole new set of problems. Myxosoma cerebralis (now known as Myxobolus cerebralis) was first diagnosed in juvenile STT in July 1985. As a result of Fish & Wildlife Service Policy, 1.2 million (80 ton) STT smolts were destroyed in Feb. 1986. Since Coleman production accounts for up to 80% of the STT run in the upper Sacramento River, this will have a devastating impact on this run of fish, which is already depressed.

United Anglers of California had been lobbying Congress for $2 million for improvements at Coleman. It was decided to use this money to build an ozone generating facility for treating Battle Creek water. The two generators purchased would treat up to 5,000 gpm, which would enable us to raise a small number of STT (approximately 150,000 smolts). To prevent contact with Myxobolus in the incoming water supply, the STT were kept on disease free water from eye-up on. Because construction on the ozone facility was not completed when the first of the fry were buttoned-up, they were ponded in the reuse system on Feb. 28, 1986. There they remained until April 8 when the ozonated water was turned in. At the time the STT were ponded, some of the reuse ponds were occupied by FCS fry, making sterilization of the system impossible.

Running the ozone system was difficult in that not much was known about ozone use on fish on a production scale, even though pilot studies had been done. Numerous mechanical problems added to the difficulties. We did not know what level of residual ozone to maintain, the effects of ozone on fish,and so on. We are still learning.

For the first month, we operated under the premise that any residual ozone meant total kill of organisms in the contact chamber. This is not the case. From the Cowlitz study, we found that a 0.3 ppm residual ozone must be maintained to insure a kill of Ceratomyxa. We applied this level to the Myxobolus organism. Because of mechanical breakdowns and operational ignorance, the generators were off or under producing almost as much as they were on. When the fish under ozonation were treated

for Columnaris within a month of turning on the ozonators, we weren't able to determine positively the source of the organism: bacteria already present in the system, birds bringing it in, or undertreating the incoming water.

From August 9 on, continuous operation of the generators at a constant level helped us have more control of our evaluation of the system. We found that from Total Bacterial Plate Counts, water with low turbidity (less than 5 NTU's) obtained a 98 to 99+% kill of bacteria going through the ozonation system. We know that more ozone is used as the water becomes more turbid. Based on preliminary data, the breakpoint appears to be somewhere between 4.5 and 8.5 NTU's. The breakpoint is where the demand exceeds the production. We also found that the amount of organic material in the water makes a difference in the amount of ozone consumed; it is not just a function of turbidity.

We are still in the preliminary evaluation phase of our ozone treatment. There is alot we do not know and may never know for sure. We are currently using ozonated water in our hatchery building, with the hopes of eliminating fungus and 'Ich' infections. We find that we have less fungus on our eggs this fall and fungus is normally a big problem. BY 85 FCS fry loss to 'Ich' was estimated to be 4 million; these were fish which came out of the incubators with adult 'Ich' on them. We have also found that the STT juveniles were practically free of external parasites when they are normally loaded with them. The STT contracted ERM within a week of being placed on untreated water prior to being released. We have found that a 0.17 ppm ozone level on the eggs is lethal; the younger the eggs, the more they are affected. All information we have received so far indicates that a level of 0.02ppm is the upper safe limit for fish. Perhaps the biggest indication that ozone works as a disinfectant is that the control STT on untreated water contracted whirling disease whereas the production STT did not.

We believe in the potential of ozone and are pleased with the results so far. There is a lot more we need to do and develop to improve our system but we can see ozonation as an asset to our production facility.

OZONATION OF HATCHERY WATER SUPPLY AT COLEMAN NATIONAL FISH HATCHERY

Bryan Baker
Biological Technician
U.S. Fish and Wildlife Service

Abstract

In April 1986, an ozone disinfection system was put on line at Coleman National Fish Hatchery. Primary objective is to control influx of the myxosporidian Myxosoma cerebralis present in the Battle Creek water supply. One process train was put into operation at the outset, with a second contact basin due on line in early December, 1986. A treatment capacity of 5000 GPM initially will be expanded to 10,000 GPM, with a final design capacity of 20,000 GPM built into the initial construction phase now completed. Two Emery Model EG-V125 Ozone Generator skids, each with a maximum production of 125 pounds ozone/day, were installed. Provisions for installation of additional units pending demand data taken through the winter when turbidity is high has been designed into the project.

Introduction

Myxosoma cerebralis (whirling disease) infection in the Coleman steelhead strain is the primary reason for installation of the ozone water treatment system. Service policy dictated the destruction of the Brood Year 1985 production, due to infection, with a potentially disastrous impact on the steelhead fishery for years to come. The system was put on line just in time for the hatch in the spring of the 1986 Brood Year STT. The nursery ponds are the only ponds on the hatchery that receive ozonated water, though the production flow has now been replumbed into the hatchery building for the sake of the Chinook salmon eggs that have been taken since October. The STT that were raised in the nursery ponds have been released. In December, a second process water line will go on stream to run through the biofilter bays and into the nursery ponds in a reuse mode. At that time, flow will be up to 10,000 GPM, 5000 GPM each into the hatchery and through the nursery ponds.

We are dealing with a number of unknown factors in this project that will come to bear on whether additional generation capacity will be required and how much. At this writing, there has yet to be a prolonged period of elevated levels of turbidity, which has a significant effect upon total ozone demand in the water. Water quality has been remarkably good and constant throughout spring, summer, and now into fall. And since the reuse system will be using recirculated, heated water, possibly with a higher concentration of ammonia, we expect the demand for ozone in that water to be different than the raw water now being treated for the hatchery building. Whether demand in the reuse will be higher or lower we do not yet know. Our first year in ozone production, through which we are half-way, is basically one of experimentation and data collection.

The purpose of this paper is to outline the production system and the assorted hardwares, and to briefly describe the process flow, related instrumentation and support technology.

Ozone

Ozone is triatomic oxygen. It is highly unstable and produced in low concentrations. It cannot be stored and hence must be generated at the location at which it is to be utilized. Molecular weight is 48. The oxygen-to-oxygen bonds are of equal length; bond angle is 116 degrees, 49 minutes. The instability of the bond is the source of the very powerful oxidizing capacity of ozone, second only to fluorine.

Ozone kills. Smaller organisms are more easily killed than larger ones, and at lower concentrations and exposure times. At Coleman, the process of water disinfection is remarkably simple and straightforward in concept: we generate ozone, put it into the incoming water for a given amount of time and at a set concentration, take the ozone out of the water, send the clean water to eggs and fish. It is in process control and maintenance that one can encounter difficulties, though by no means insurmountable ones. What follows is a description of the essential components of the ozone generation project at Coleman National Fish Hatchery. Using the attached flow sheet as a guide, a component-by-component account of the process will give the reader an understanding of the system and will acquaint him or her with the associated technology and the workings thereof.

The Process

The process design and application can best be understood in terms of its major component groupings. These are: 1. Air Preparation; 2. Ozonation; 3. Contaction; 4. Ozone Destruction.

1. Air Preparation

The air preparation system functions in terms of its constituent components; the ozonation process begins here. Ambient air is compressed by two Ingersoll-Rand ESV-1P Non-Lubricated cylinder **compressors**. The hot, compressed air is cooled by a water-jacket heat exchanger, or **aftercooler** located immediately downstream of the compressor. The air flow then passes through a moisture **separator** to remove condensation prior to the introduction of the air into the **receiver**. Air is compressed at 80-100psig; the receiver serves as a storage vessel for the process air. Downstream of the receiver, the airflow passes through a **prefilter** where the filter element coalesces entrained mists and traps particulates that have escaped the airfilter on the compressor. The prefilter is so called due to its relation to the **desiccant dryer**. The prefiltered air enters a Deltech Heatless Duplex Dryer. Air is dried continuously by the automatic cycling of each of the two desiccant beds. While one bed is adsorbing entrained humidity, the other is regenerated by a portion of the air being dried by the tower that is currently on line. Dew points of -70 to -80 degrees C. are provided continuously. Downstream of the dryer, the process air passes an **afterfilter**. The filter element traps desiccant dust from the dryer. The final component of the air preparation system is a **pressure reducer**. The process stream at 80-100psig is reduced to 10-15psig prior to its introduction into the air lines immediately preceding the **ozone generators**. Notice on the flow sheet that there are two air preparation systems which join a common line which then feeds two ozone generators. This is to enable either compressor to run either ozone generator or both generators in the case of compressor problems or scheduled maintenance. Each air preparation skid and ozone generator skid can be fully entrained or fully isolated from the process flow.

2. Ozonation

Compressed, clean, dry air from the air preparation system enters one or both ozone generators. Each Emery EG-V125 ozone generator is of the horizontal tube, voltage-controlled, water-cooled type. All parts that contact ozone are made of stainless steel, glass, or other ozone resistant materials. Generation of ozone occurs as follows: Inside the stainless shell are arranged 72 pyrex glass tubes about 9 feet long and 3 inches in diameter. These are called **dielectrics**. The dielectrics are centered inside stainless steel tubes which serve as ground electrodes. Inside each dielectric, running the length thereof, is found stainless steel mesh or screen which is the voltage electrode. A high voltage alternating current is applied to the voltage electrode. An electric discharge occurs across the gap between the dielectric and the ground electrode. This **corona effect** energizes the oxygen atoms in the process stream and converts them to ozone according to the reaction $3O_2 \longrightarrow 2O_3$. The rate of reaction can be controlled either by varying the air flow or the applied voltage. At Coleman, we keep air flow constant and control our ozone process with **electronic controllers**. A variable voltage signal is transmitted to the **transformer** for each generator according to a reference signal received by the controller from a source further downstream in the process (discussed later). The controller increases or decreases the power output of the transformer thereby varying the internal energy available for ozonation within each generator. In this manner we are able to adjust ozone production continuously as required by conditions outside in the water flow.

3. Contaction

Once ozone is generated into the process stream, it must be delivered to the hatchery water for disinfection. Out of each generator comes a 2-inch stainless line carrying the ozone-enriched air stream. The two lines come together and run as one 2-inch line to the outside basins called **contact chambers** or **contactors**. Each basin (there are four total) is a cement structure 25'x25', with a depth of 14', enclosed but for channels through which the water enters at bottom and exits at bottom into a sump from which a 40-horsepower pump delivers the ozonated water at 5000 GPM. The stainless line carrying the process enters the contactor and splits into two 1-1/2-inch lines, one for each half of the basin which is divided down the middle by a wall running from floor to near the ceiling. This causes the water to flow up and over and back down to the bottom of the second half of the basin from where it is drawn to the pump.. Flow time is thereby increased by the roundabout path which the water must take. Each 1-1/2-inch line runs to the floor where it traverses the length of the structure. On the horizontal run, along the floor, are spaced ceramic, fine-pore **diffusers**, airstones 24" long and 2" in diameter, 46 total in each contactor. The process gas bubbles up through the water, through a 12-foot water column thereby dissolving the ozone. The ozone kills the bugs in the water during the course of its flow through the contactor, designed to provide a 10-minute retention time within. The water is disinfected after this time and is nearly ready to be supplied for hatchery use.

An important feedback parameter takes its source at the contactor. At the point of pumping, there is a device which samples the water. It is a **dissolved ozone probe**, a semi-permeable membrane and analyzer device that measures and displays the actual dissolved ozone concentration in the water, read in parts per million. This device transmits a reference signal back inside to the control panels on which are located the controllers mentioned previously. As the concentration

varies in the water, the change in the reference signal causes the controller to increase or decrease high voltage input to the dielectrics, thereby maintaining constancy of concentration in the process water flow. In concert with the probe signal is another important monitoring device. At a point just downstream of the Tee where the two stainless generator lines come together, a 1/4-inch sample line carries a portion of the process to the **high concentration monitor**. This device, about the size of a VCR, displays a digital readout of "percent by weight" of the process stream that is ozone. By monitoring the readout, we can determine the relative demand for ozone in the water supply. As the dissolved ozone concentration changes according to water conditions, the probe signal causes the controllers to vary the power input to the dielectrics. This variation causes the percentage of the process that is ozone to change as well, and the difference is reflected on the high concentration monitor. For example: Should the water become quite turbid, it will require much more ozone to maintain a constant dissolved **residual**. The probe senses a drop in the residual as the turbidity rises and sends a weakening signal to the controllers. Each controller jacks up the power, more ozone is produced per net volume of air flow through the dielectrics, and the high concentration increases. A higher readout then appears on the monitor, while the residual outside is restored. We know, then, that demand has risen in the water. At Coleman, we maintain a residual of .300ppm. The corresponding process concentration ranges between .3% to 2.0% by weight ozone.

4. Destruction

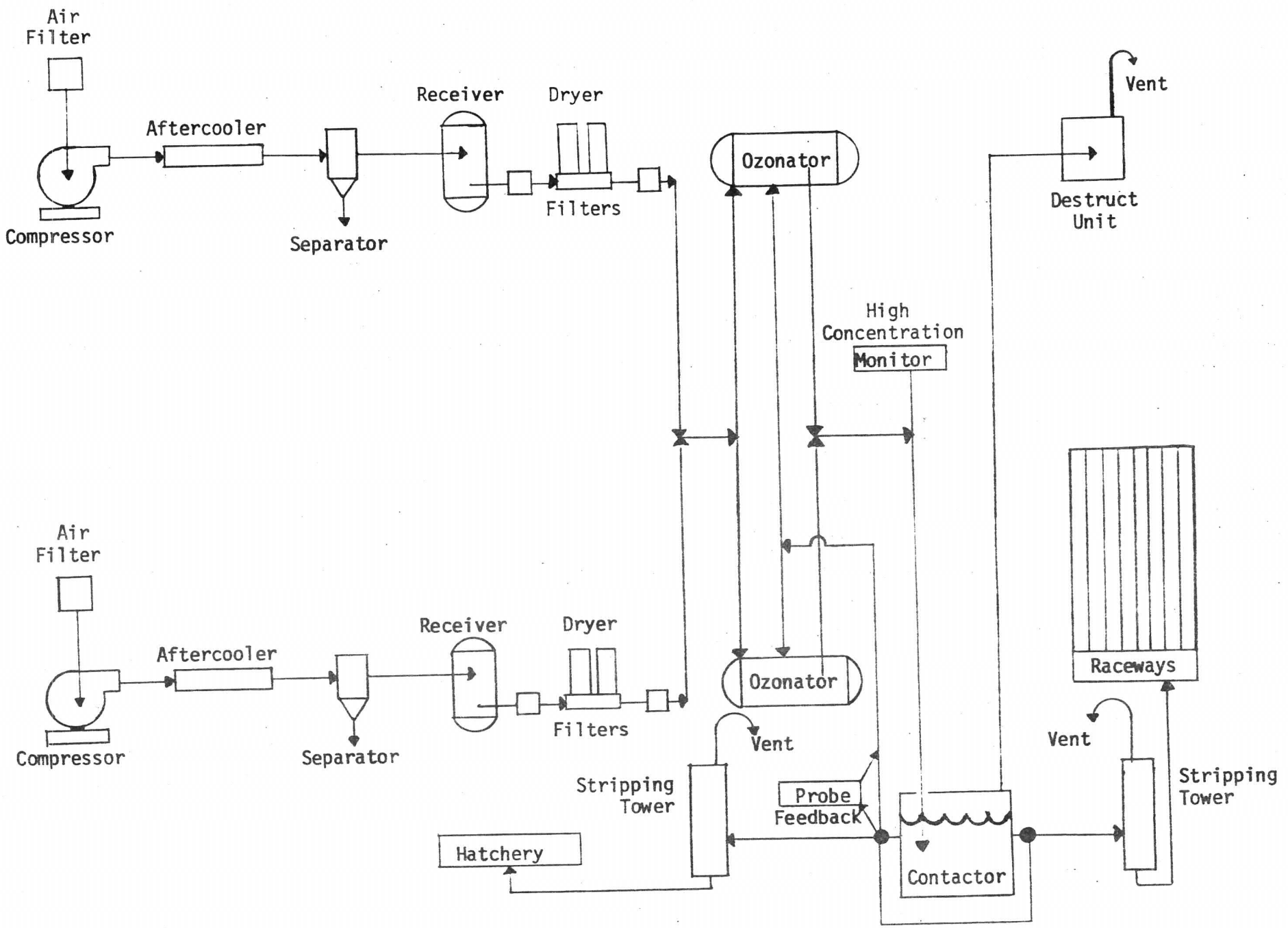
Once the water is ozonated, it is toxic not only to protozoans but to fish as well. The ozone must be removed from the water. As mentioned, 5000 GPM is pumped out of the contactor sump. The water courses through an 18-inch line to a structure called a **stripping tower**. It is nothing more than a 10-foot length of 30-inch diameter steel pipe, supported over a basin, and stuffed with plastic bio-filter (Koch) rings. The water is pumped in the top and it cascades down over the rings thereby freeing the ozone to the atmosphere as it readily goes out of solution. The deozonized water is then pumped out of the catch basin to the raceways. In the case of the hatchery building water, however, we built a **detention basin**, a big concrete pool 128'x32', and 5' deep into which the stripped water flows by gravity. The water flows through the detention basin for about 45 minutes. During this time, any remaining ozone will decay naturally back to oxygen. The water is then pumped to the hatchery building. The added flow time is to ensure that no ozone gets onto the eggs or into the air inside where the hatchery crew might be in danger of exposure to airborne ozone.

At one other point in the process is deozonation or destruction important. In the contactors, not all of the process ozone will dissolve into the water column. We find about 90% dissolution. The remaining ozone collects in the air space above the water and beneath the cap of the contactor. Penetrating the cap is a 4-inch stainless pipe which takes off this gas. The pressure of the process flow into the contactor forces this **off-gas** to flow through the line into the **destruct unit**. This is a combination heater-catalyst device that destroys the off-gas. The heater reduces some of the ozone back to oxygen. The manganese-dioxide catalyst reduces the remainder. High concentration gas is thereby removed from the contactor, though not vented into the atmosphere.

Summation

Ozonating hatchery water is a conceptually simple, straightforward approach to water disinfection. The technology involved is readily available, has few working, moving parts, is simple in design and easy to operate. From our experience thus far, it has proven successful in ridding raw creek water of most viruses, bacteria, and protozoans. After completion of a year's cycle of operation and seasonal changes in the water supply, we should be better able to evaluate the overall success of the process operation.

Ozonation Process Flow Sheet
Coleman National Fish Hatchery



2. INCUBATION

A SMALL-SCALE HEATED WATER INCUBATION SYSTEM

Howard J. Fuss, Daniel Witzcak[1/] and Paul Seidel
Washington Department of Fisheries
115 General Administration Building
Olympia, Washington 98504

Occasionally, fish culturists need to accelerate the development of embryo's. This often occurs when incubation temperatures are low and/or the hatchery must spawn fish later than normal. In the latter case, these spawnings usually consist of a low number of eggs per spawning.

At the Washington Department of Fisheries' Lewis River Hatchery, a combination of cold water temperatures and small egg takes occurs with the run of fall chinook. Fish are spawned at the hatchery from mid-October through mid-November. Water temperatures are high (52°-63° F) in October and the first two weeks of November and then rapidly drop after mid-November. Water temperatures remain cold (38°-43° F) until the first of April when they begin a slow warming for the next two months.

Because the run of chinook to the hatchery is small, most spawnings are small and tend to be spread over a long time period. Because of the water temperature regime, a two-week difference in spawning often results in a four to five-week difference in ponding. The small egg numbers per spawning, the low overall numbers of eggs, and the rearing space limitations in the hatchery has resulted in the mixing of progeny at different stages of development in a common rearing vessel. This practice contributed to large size variations between fish and contributed to high numbers of pinheads and dropouts.

In an attempt to remedy this situation, several options were explored: (1) new rearing containers could be built; (2) cuts in coho or spring chinook production could be made to free up rearing space; (3) the fall chinook program could be moved to another hatchery or eliminated; or (4) a low-cost, small-scale heated water incubation system could be built to speed up development of later egg takes and produce a more developmentally homogenous group of fry.

[1/] Present Address: Nooksack State Salmon Hatchery
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The latter option was chosen with the understanding that the system use small volumes of water and both capitol and user costs be kept at a minimum. Because of these constraints, some of the more traditional heating units, such as large electrical boilers, were not considered. Also, a system using recirculated water was ruled out because of cost and physical space limitations. Therefore, a system had to be developed that did not use a large-sized, expensive heat source, and did not have large space requirements. The system, as built, had to be flexible enough to allow the operator to choose different temperatures for each stack of incubators. But, most importantly, the system had to be built such that damage to eggs or alevins would not occur due to malfunction.

The most feasible method of accomplishing these mandates was to use a heat exchange system. The system that was built at Lewis River Hatchery consists of three electrical heating units, four head boxes which feed incubation water to each of four stacks of Heath trays, a small, cartridge circulating pump (1/20 hp), 3/8-inch OD aluminum tubing, which serve as heat exchange coils, and 1-inch galvanized pipe to carry the heated water to and from the heating elements.

System Specifics

The heat exchange system operates as a closed circulating system. Heated water passes through the heat exchange coils and returns to the heating elements. Heated water is never introduced to ambient water; this reduces the possibility of metal toxicity that can occur with direct heating element contact with the water.

The system is shown in Figure 2. Water is heated by two Heatrae (TM) tankless water heaters connected in parallel. The 7 and 9 KW heaters (20 and 30 amps, respectively) supply approximately 55,000 BTU/hr. heat input to the system. Additionally, a standard 3.5 KW, 52-gallon water heater increases the heat capacity by another 12,000 BTU's/hr. The system was designed to increase water temperatures 3°, 6°, 8° and 10° F in each of four Heath stacks. The total heat input required to accomplish this objective was approximately 41,000 BTU/hr. We felt that exceeding the system input requirements would allow for more flexibiity in regulating temperature in each stack. The water tank heater is plumbed in parallel with the tankless heaters and serves several functions: (1) storage of heated water (approximate retention time of 20 minutes; (2) provides a pressure relief valve; and (3) a 10-foot, 3/4-inch galvanized pipe is plumbed to the water tank and serves as a vertical pressure maintenance column and a convenient inlet to add make-up water. A spur runs from this juncture to the pressure relief valve of the hot water tank. A sight tube is attached to the column to allow visual inspection of the system water level.

The heated water is moved through the circuit by a 1/20 hp Taco(Tm) in-line low pressure circulating pump. The pump delivers 4 gpm at 20 psi and is plumbed to the outlet of the hot water tank. Water is circulated through 1.0-inch galvanized pipe. At each juncture of a Heath stack, a 'T' joint

is installed which feeds water to the heat exchange coils located in the head boxes on top of the Heath cabinet. A short length of pipe runs from the joint to a 1.0-inch gate valve which regulates flow to the aluminum heat exchange coils. A 0.75-inch polyethylene male elbow reducer is connected to the gate valve and attaches to the 0.375-in OD aluminum tubing with a 0.375-inch ID nylon tubing sleeve, secured by hose clamps.

The heat exchange coils run counter to the flow of incubation water, which optimizes heat transfer. The coils join the return or cold water line of the circuit via the polyethylene male elbow reducer which is attached to a 1.0-inch check valve. The check valve is joined to the return line by a 'T' joint. The hot water line continues past the last Heath stck in the system where two additional gate valves are located. One valve is located on a spur that allows draining of the system to check temperature; the other valve is located in-line and can be shut off to force all water through the heat exchange coils. The 1.0-inch return line (cold water) must be reduced to 0.50 inches to plumb into the Hetrae heaters. This is accomplished by a female reducer. The two heaters are connected in parallel and to the hot water tank by 0.50-inch copper flex tubing.

The head boxes were constructed of 0.75-inch marine grade plywood. Dimensions of the boxes are: 23.75 x 20.5 x 12.75 inches (ID). Water levels are maintained at about 9 inches, giving a total volume of 18.7 gallons and retention time of approximately six minutes. The inside portion of the boxes were fiberglassed to ensure water-proofing. Two baffle plates were installed to direct water flow in a counter-current direction to the heated water flow.

The boxes rest on top of the Heath tray cabinets and are partially supported by two lengths of 24 x 4 x 0.375-inch steel. These strips are fastened to the rear portion of the Heath cabinet with existing bolts. Water is introduced to the box via a length of 1.0-inch PVC pipe which extends from the head trough to the front portion of the box. A gate valve regulates water flow to the head box. Water is supplied to the incubators via a 1.0-inch PVC pipe which extends through the box at about the water line (9-inch vertical height). A 90° angle is attached to the inside portion of the outflow and can be turned 360° to regulate water flow. Water levels in the head box are partially maintained by a 2-inch OD standpipe located at the front portion of the box. The standpipe fits in a sleeve in the bottom of the box which prevents it from being accidentally knocked over. Removal of the standpipe also allows draining of the box.

System Effectiveness

The original design of the system used 0.375-inch ID nylon tubing as the heat exchange coils. Several tests were run to determine the total length of nylon tubing required to give maximum heat exchange. Also, tests were run varying the amount of flow to the coils. A third test varied the amount of flow to the head box. The final test substituted 50 feet of aluminum coils in 1 box for the nylon tubing.

Results of the tests are shown in Table 1. Temperatures were increased in each box as a function of: (1) the length of the heat exchange coils in the box; (2) the reduction of flow to each box from 5 gpm to 3.5 gpm; and (3) the replacement of nylon tubing with aluminum tubing. Regulation of flow through the coils had only a minor affect on temperature exchange. We believe this was due to inefficiency in flow regulation by the gate valves. A more precise type of valve may have been more effective.

Effect on Fish Size Variability

Direct comparison of fish size between brood years was not possible. However, several comparisons were made with similar sized fish in populations from similar numbers of spawnings (Table 2). In each comparison, the size variability (measured by the coefficient of variation) was less in groups incubated in heated water. There were no unusual or increased mortalities in groups incubated in the hot water system.

System Precautions

Mortality due to the heated water system was low except in one instance. An air lock developed in one gate valve that fed water from the head trough to the head box. As a result, flow was shut off to the head box and the remaining water heated to lethal levels prior to entering the incubators. This accident could have been eliminated by excluding the gate valve and using a different metering system or by having a thermostatic control that would shut off the hot water system or sound an alarm if incubation temperatures were too high.

System Cost

The entire system was built for under $2,000. Electricity costs were about $500 a month.

Acknowledgments

The authors would like to thank the crew at the Lewis River Hatchery for their help in constructing and evaluating the system.

TABLE 1. Test and result data for heated water incubation system at Lewis River Hatchery during 1985-1986.

Test	Incubator flow rate (gpm)	Ambient temperature (°F)	Achieved temperature (°F)	Net result
1. Fifty feet of nylon tubing, return valve open, heat exchange valves open. All boxes.	5	41	46	+5°
2. Fifty feet of nylon tubing, return valve closed, heat exchange valves open.	5	41	48-49	+7-8°
3. Box A 50 ft nylon tubing	5	41	45	+4
Box B 100 ft nylon tubing			47	+6
Box C 110 ft nylon tubing			47	+6
Box D 120 ft nylon tubing			49	+8
Return valve closed, heat exchange valves full open.				
4. Box A heat exchange valve 1/2 turn	5	41	47	+6
Box B heat exchange valve 3/4 turn			51	+10
Box C heat exchange valve full open			47	+8
Box D heat exchange valve full open			48	+7
5. Boxes A-D as in Test 3	3.5	41	49	+8
Boxes A-C as in Test 3	3.5	42	48-50	+6-8
Box D with aluminum tubing			52	+10
Box D only	3.5	44	57	+13

TABLE 2. Comparison of fry size variability in populations incubated with or without heated water.

Treatment	Spawning dates	Brood year	No. of spawnings	Mean length (mm)	SD	Coefficient of variation(%)
Non-heated	10/30-11/18	1983	5	41	3.3	8.2
Heated	10/10-10/28	1985	4	39	2.0	5.0
Heated	11/01-11/26	1985	5	36	1.1	2.9
Non-heated	10/11-11/14	1984	6	59	8.1	13.7
Heated	11/01-11/26	1985	5	56	4.6	8.3

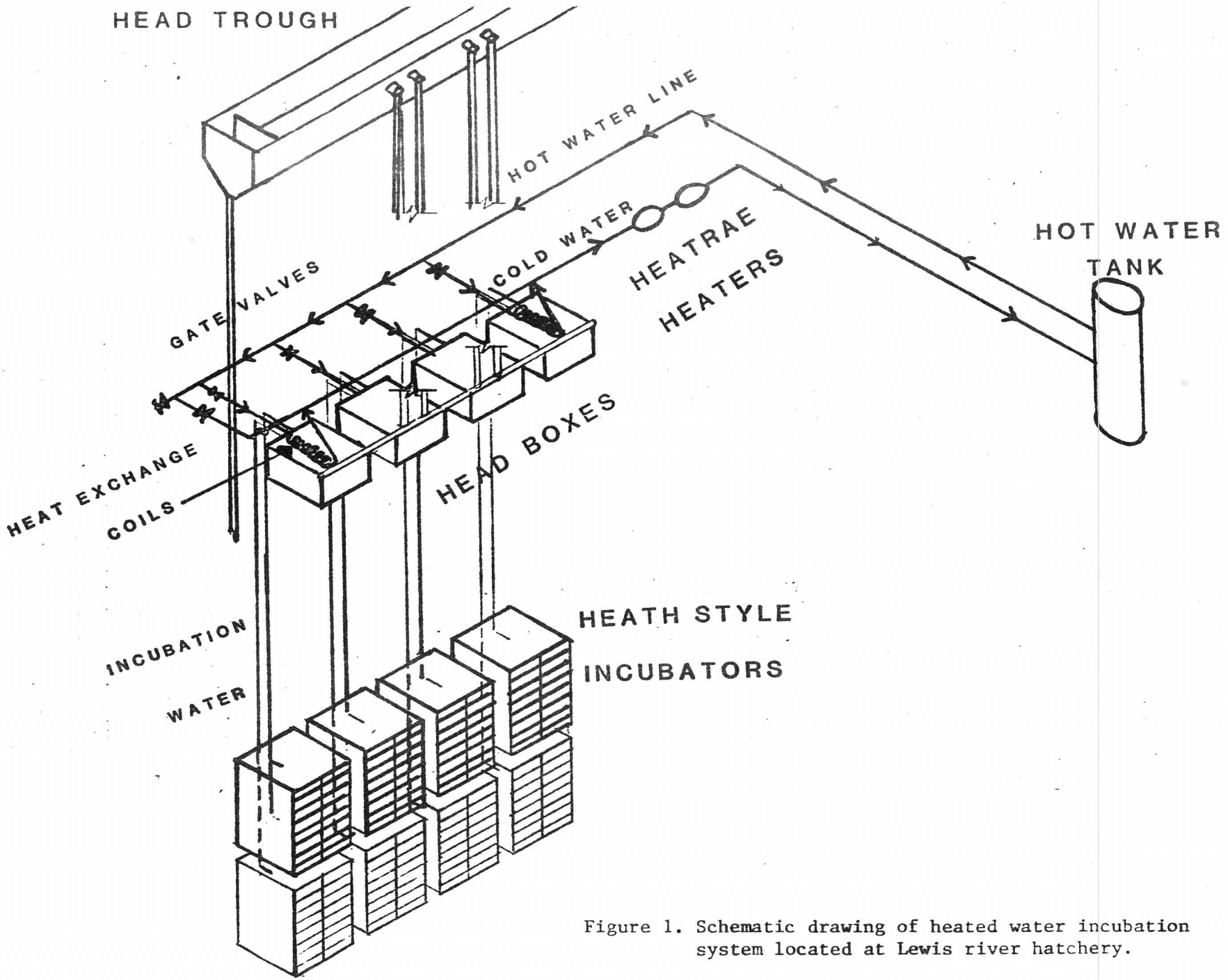

Figure 1. Schematic drawing of heated water incubation system located at Lewis river hatchery.

OREGON ISOLATION INCUBATOR

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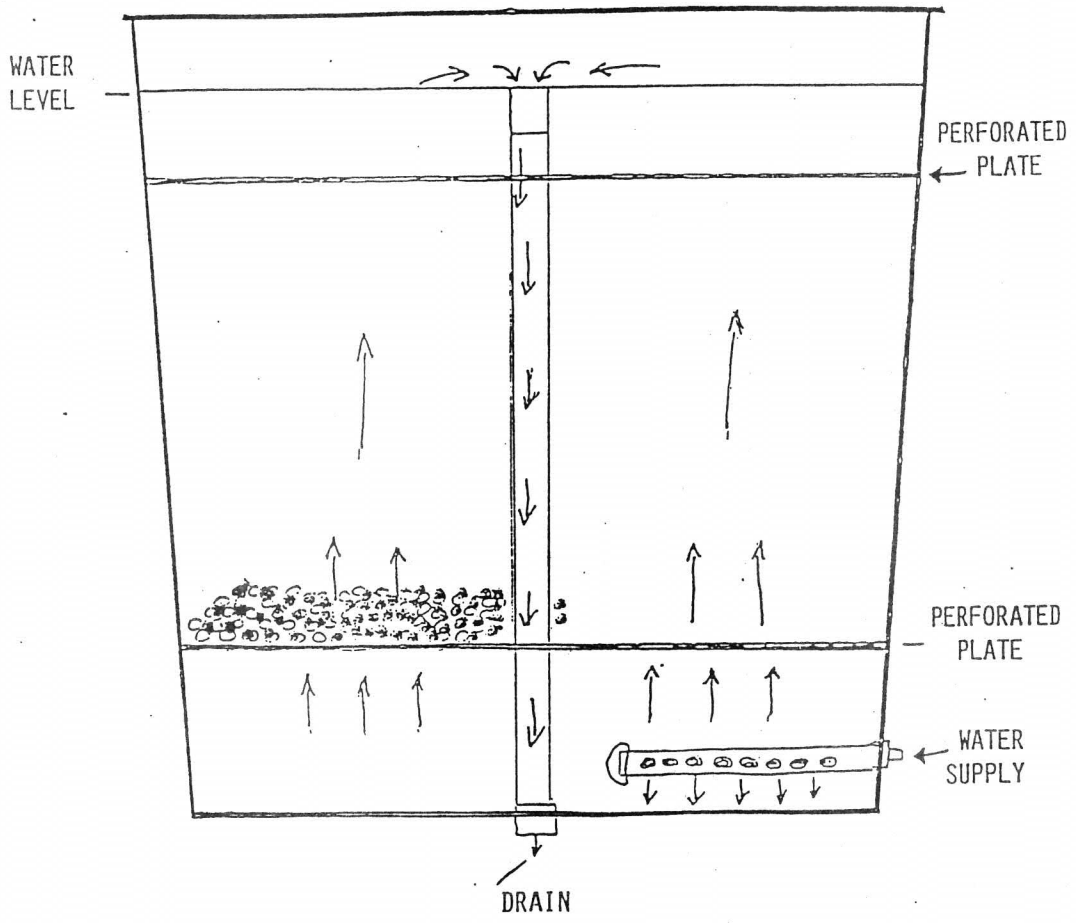
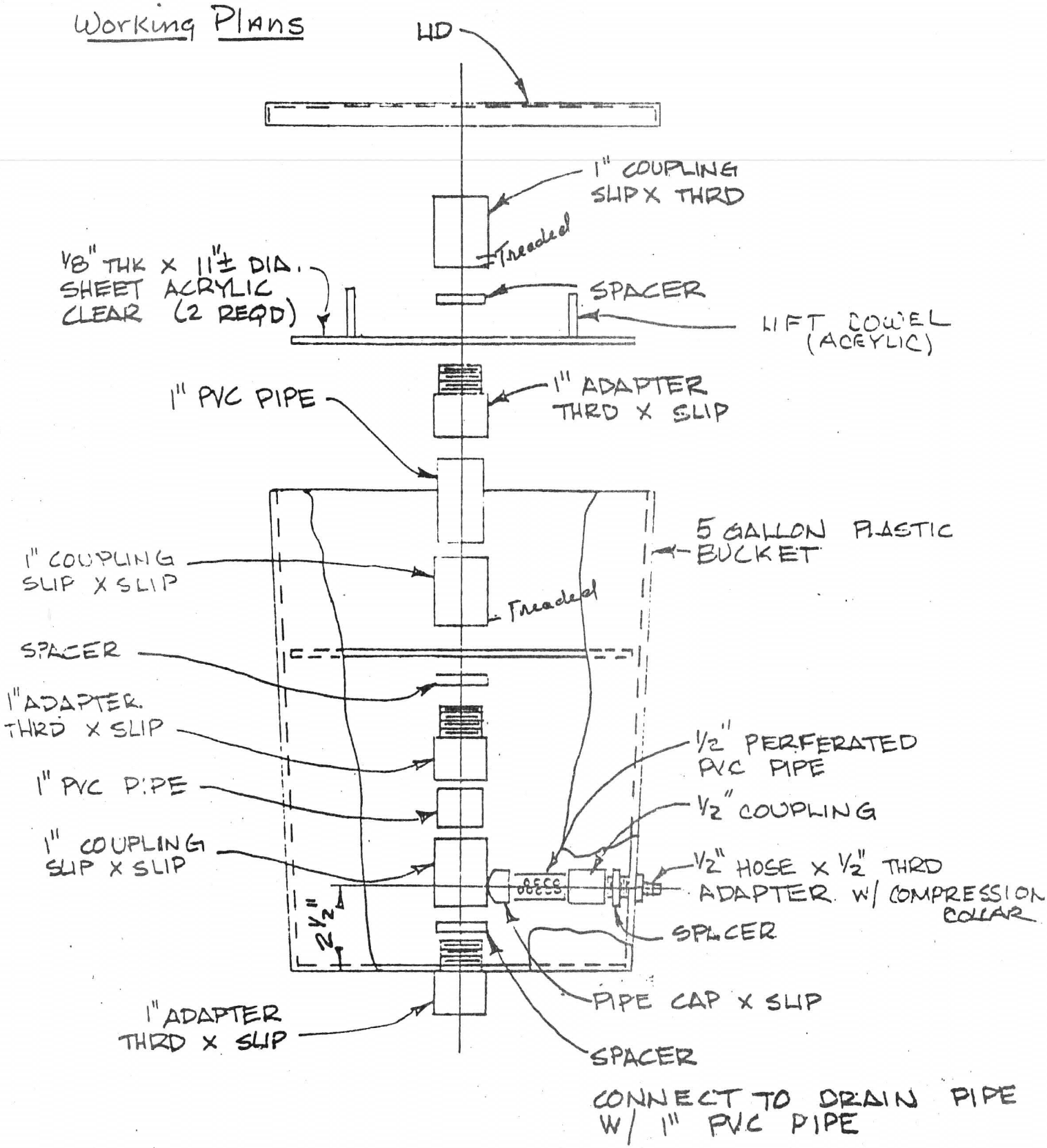
In the summer of 1984 an isolation incubator was needed for individual chinook salmon. The request was for a design to place one female per unit with a water intake of around three gallons per minute. This unit would be used in a research project to control IHN virus on Oregon's south coast, Lone Ranch Creek Project.

With the above criteria, the crew at Roaring River Fish Hatchery came up with a "First" Oregon Isolation Incubator. The unit is functional and was made from readily available material. The materials used was a 5 gallon plastic bucket, various PVC fittings, plexiglass and some "Yankee Ingenuity."



Working Plans



OREGON ISOLATION INCUBATER

SCALE NONE

DESIGNED BY DAN BARRETT / DEVAN GARLOCK

COWLITZ DOWN-WELL BUCKET INCUBATORS

Michael Baxter

Cowlitz Salmon Hatchery
Washington Department of Fisheries

INTRODUCTION

The Cowlitz down-well bucket incubators were developed to isolate successive takes of salmon eggs from possible horizontal transmission of infectious hematopoietic necrosis virus (IHN). This modified version of a low flow isolation system for salmonid egg incubation was adapted for use with existing Heath incubators (A. J. Novotny et. al., N.M.F.S., 35th Annual Fish Culture Conference).

METHODS

A four gallon plastic square bucket, with the bottom cut out and replaced with 1/8" mesh vexar screen, is placed inside another four gallon plastic square bucket. The outside bucket has sixteen 1/2" holes drilled at the top for water drainage. The water supply is introduced from 3/4" PVC pipe that is plumbed into the Heath incubators. A 3/4" PVC gate valve is used to set water flows at 1/2 gpm per bucket.

Water flows down onto a floating foam pad which dissipates energy, then down-wells through the eggs and exits the inner bucket through the screen at the bottom. The water rises between the inner and outer bucket and exits from holes at the top of the outer bucket.

16,000 - 20,000 spring and fall chinook eggs are incubated to approximately 500 - 600 temperature units, picked and then placed in Heath trays to hatch.

Females from the 1985 brood spring and fall chinook were spawned in five fish pools and ovarian fluid samples were taken. Viles of ovarian fluid samples were numbered and cross referenced to specific buckets. If a sample was determined to be IHN positive, the corresponding bucket of eggs would have been destroyed. Malachite was used for control of fungus. The season egg mortality averaged 7%.

COMMENTS

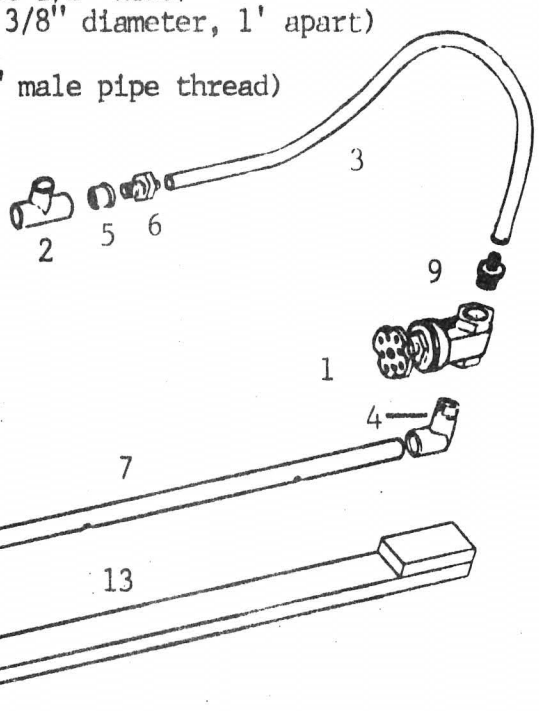
For convience the bucket incubation system was used for the 1986 brood spring and fall chinook. The season egg mortality for the spring chinook was 9%, which was within normal limits.

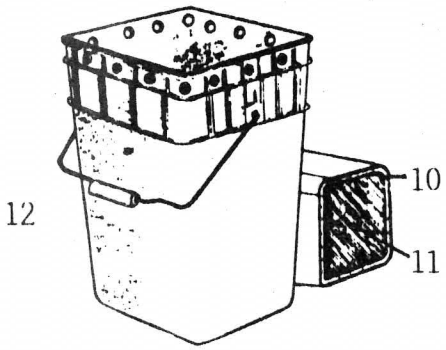
This system facilitated the effective isolation of groups of salmon eggs and eliminated extensive loss due to IHN. It simplified loading eggs into incubators, disinfecting eggs, and subsequent egg shocking, picking, transferring and incubator clean-up.

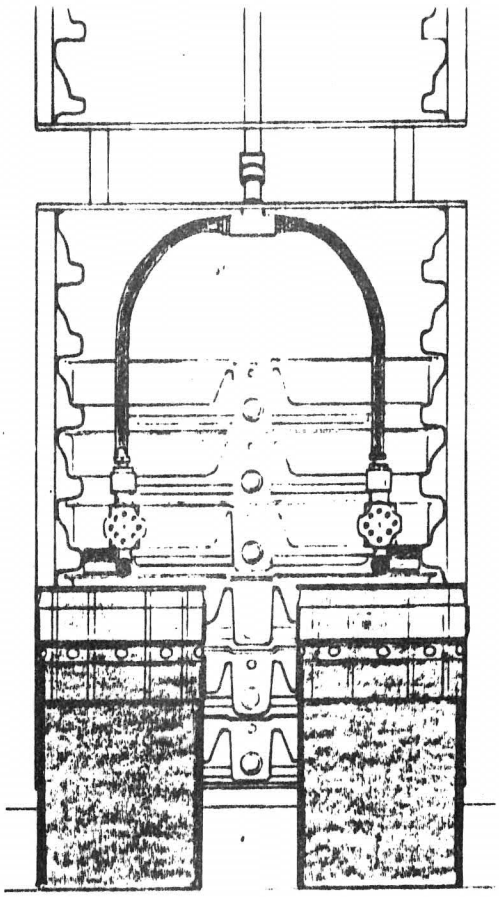
The bucket incubators were only subjected to mild sediment loads. Extreme caution should be exercised, while in the vicinity of buckets, to avoid bumping and prematurely shocking tender eggs.

MATERIALS

1. 3/4" PVC gate valve
2. 3/4" PVC tee
3. 1/2" I.D. clear milk tubing
4. 3/4" PVC 90° street ell (male end threaded)
5. PVC 3/4" x 1/2" bushing NPT (inside thread)
6. male adapter (1/2" male pipe thread to 1/2" hose)
7. 3/4" schedule 40 PVC x 32" (3 holes, 3/8" diameter, 1' apart)
8. rubber stopper, size #3
9. adapter coupling (3/4" female to 3/4" male pipe thread)
10. 1/8" plastic rivets
11. 1/8" Vexar screen
12. 4 gal. square plastic bucket
13. 1" x 2" x 48" wood







FRONT VIEW

THE ABC'S OF INDUCED SPAWNING

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There are numerous reasons why culturists may want to induce spawning in their brood stocks. Hormone therapy can be a cost-effective means to either cause fish to spawn or shorten the holding time until spawning. Last year we discussed recent advances and findings regarding this technique in salmonid fishes (see Fitzpatrick and Schreck. 1985. The use of homones in salmonid broodstock management. Proc. 36th Ann. N.W. Fish Cult. Conf. p. 36-37). The objective of the present paper is to outline the methods used for hormonal treatment and discuss areas about which the culturist needs to be concerned when considering this technique.

There are numerous substances or preparations that can be used to successfully induce spawning in both females and males. For salmonids, a synthetic compound, Luteinizing Hormone Releasing Hormone analog (LH-RHa or des-Gly^{10}[D-Ala^{6}]-LH-RH-ethylamide) is very effective and is available from companies such as Argent and Sigma (no endorsement implied). We find that 5µg LH-RHa/1-2 lbs of fish dissolved in 0.5 ml saline (available from pharmacies) injected into the body cavity is adequate. Care needs to be taken to avoid leakage or injection into viscera. The injection using a 21-ga 1" hypodermic needle via syringe or ovinjector should be repeated in 2-3 days. Care to disinfect the needle between fish needs to be exercised.

The closer the treatment is before normal spawning, the more successful it will be. Salmonids may be effectively treated with hormone 4-6 weeks before normal spawning would occur; other species will ovulate only if treated when fully ripe. Treated fish need to be checked more frequently than normal broodfish. If done properly, eggs resulting from hormonally-induced parents should have no significant loss of viability.

PRODUCTION OF MONOSEX STOCKS OF CHINOOK SALMON (*Oncorhynchus tshawytscha*) AT COMMERCIAL MARICULTURE FACILITIES IN BRITISH COLUMBIA

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The control of sex differentiation in salmonids, with the purpose of producing sterile or all-female stocks, is one of the major goals in the commercial mariculture of Pacific salmon. Experimental batches of milt, containing only female spermatozoa obtained by hormonal masculinization of genotypic chinook salmon females, have been made available to the mariculture industry in British Columbia since 1983.

Twenty-one phenotypic males were used in the experiment in the fall of 1985. The sperm, collected by repeated manual stripping over a period of 25 days, was used to fertilize normal ova from sea-run and captive chinook broodstock at 7 salmon farms and at the Capilano River Hatchery.

Quantitative and statistical analysis of sperm production included frequency of milt collection, volume of milt produced, periodic determination of spermatocrit and subjective evaluation of sperm motility. The fertility of the sperm was determined by survival of eggs to the eyed stage.

Fertilization rates were variable, ranging from 16 to 75% at the fish farms to 81% at the Capilano Hatchery.

Close to 550 thousand monosex female chinook alevins were produced of which about 90% will be reared at the commercial facilities. The remainder are part of the production of the Capilano River Federal Salmon Hatchery and will be released as part of an ongoing research program on the enhancement of depleted chinook stocks.

3. LIBERATIONS

HISTORY OF LIBERATION IN OREGON

Terry Dufour

With the beginning of trout production in fish hatcheries transportation immediately became a problem. Fish were hauled from the hatcheries first by horse and wagon and later by the old railroad pullman "The Rainbow". "The Rainbow" fish distribution car was purchased in 1913 for $6,700 from O.W.R. & N. Railroad. The car was equipped with milk cans and an aviation system. The car could be attached to any train traveling throughout the state. The train would be met at various stations, which still left the fish far from their destination. Either pack strings horse and wagon or early vintage automobiles would be waiting at the stations to immediately pick up the fish and move them on to their destination. The Rainbow was used to haul fish by rail until 1922. The Rainbow was last seen rotting away in the Eugene area.

The horse and wagon was replaced by truck. Early fish liberation trucks were loaded with milk cans in which the fish were carried. Around 1927-28 early fish tank trucks came into used which gradually replaced the milk can method. Nothing much in the way of liberation truck development was done until the early 1940's. It was then that a change in production policies started to come about and a emphasis was placed on quality rather quantity in fish. Hatcheries began holding fish until they reached a larger size. There was a need then for more liberation equipment. Three wooden tankers were built out of 2 inch tongue and grove Port Orford cedar. These were 425 gallon units with no insulation. 1½ inch circulation pumps driven by the power take off from the truck engine. A single suction and discharge pipes with a 4 inch discharge outlet. Ice was used to chill the water when it was thought to be necessary. In 1947 the old Game Commission had four 425 gallon liberation units state wide.

One of the liberation units was used to haul fish to the head of pack trails where the fish were held in a live box until a pack train could haul them on into their destination. It was this same year that the airplane made its appearance and began to be proven a feasible and economical method to liberate fish. The fish were being carried in a specially constructed belly tank that was suspended between the wheels of the plane. Releasing the fish at an altitude of approximately four hundred feet above the lake had proven successful. This tank was equipped with an aereating device and a flap-type hinged door that was sealed on a water light gasket. In the actual liberation the pilot would pass over the edge of the lake, trip the door and pull the plane up sharply. This resulted in less forward progress of the fish as well as helping to empty the tank. Also during this same period of time the planting boat came into use. These early planting boats were towed behind another boat and when the liberation site was reached the fish were either dipped out with a long handle dip net, or the boat was over turned and the fish released. Actually the planting boat was merely a floating live box. By 1950 horse packing liberation operations were curtailed partly because of excessive cost and partly because airplane stocking has been able to accomplish comparable results. There were two airplanes in use for the high lake stocking. In this same time period larger liberation units were put into service. There were 725 gallon units mounted on two-ton trucks. The tanks were made from plywood and fiber glass and were insulated to maintain low water temperatures. They were also equipped with an aeration system, which included a 2 inch pump with one ventrie on the discharge side of the pump. The pump was driven by a power take from the truck. Also more planting boats were being put into use.

By the mid 1950's they had discovered that if fish were hauled in water temperatures ranging in the low to mid 40's the delayed mortality went way down. So they began to explore and evaluate mechanical refrigeration as a practical means of controlling water temperatures in transporting tanks. Also during this same time they were improving on the venturie system and overhead spray units. The development of mechanical refrigeration was frustrating and costly. Finally by 1959 two new refrigerated tankers were put into service. After the first mechanical difficulties that were encountered had been over come these units were able to haul up to 50% more than the conventional units of that day. By 1960 another large refrigerated 1000 gal tanker had been put in service making it three refrigerated tankers and a total fleet of 23 units. Also in 1960 a new technique of transporting small amounts of fish successfully in plastic bags using water and oxygen came into use.

As hatchery fish production increased through out the 60's liberation equipment had to meet the demand. So more equipment was added to the fleet. Portable slip tanks were built they were 150 gal units with Briggs and Straton engines able to fit in the back of a 3/4 ton pick-up. Also in the late 1960's two 1600 gal units were put into service. These units had diesel powered reefer units, up until now reefers had been powered by gasoline engines which seemed to create a continual problem. These new diesel units proved to be much better unit. In addition these new units also had a single cylinder diesel unit for a back up circulation system which also proved to be an effective back up system. Prior to this a circulation system driven by the trucks power take off was in use. By the early 1970's the diesel powered reefer units were replacing the gasoline powered reefer units. Also power take off driven back up

circulation systems were being replaced by a diesel driven system. Two units commonly refered to as the "Blue Goose" came into use in the early 1970's. They were 3,500 gal unit with a 6 inch circulation pump driven by a four cylinder Wisconsin engine. With oxygen being bubbled through carborundun stones. These two units are not equiped with refrigeration systems. Changes were taking place in the aerial stocking of the high lake system. Airplanes were being equiped with larger tanks that were divided into compartments thus allowing them to stock several lakes in a single trip. Some of the problem with this aerial stocking by airplane was the accuracy of the pilot to get the fish into the water, and if he was able to in fact locate the lake. Because of his load size he was unable to take a navigator along with him so it was just up to him to locate the liberation sites. So in 1980 a new method of fish liberation for use in the high lake country came on the scene thanks to an arrangement made with the Forest Service to use their stand-by heli-tack crew we began to experiment with the possibilities of stocking fish with a helicopter. This method of aerial fish liberation proved to be successful and economically feasible in fact it was so much so that last year (1983) we went to all helicopter aerial stocking 480 lakes in all. The one problem with this is the fact that we could loose the use of the helicopter in the event of a forest fire. We have come a long way in our 70 plus years of being in the fish hauling business from those milk cans in the back of a horse drawn wagon to dropping fish into a lake from a hovering helicopter. Those early day fish liberation truck drivers would wonder what the world has come to, if they spent a day with a liberator of the 1980's hauling fish in his diesel powered truck with power steering and brakes that really work with the sweet sound of music in the back ground.

DESIGN AND OPERATION OF A HELICOPTER FISH LIBERATION DEVICE

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Vancouver Island Hatchery
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Vancouver Island Hatchery and other provincial government trout hatcheries in British Columbia have been involved with stocking steelhead fry in remote streams for a number of years. The fish are scatter planted over as large an area as possible as the fry will still be spending a further one to three years of rearing in that river before smolting and migrating downstream. They require low instream densities as competition for food is fierce in these relatively unproductive coastal rivers. On Vancouver Island, steelhead fry are usually stocked at between 0.25 - 0.5 fish per square metre stream surface area.

In order for the steelhead fry to get from the hatchery or liberation staging site to their instream release locations, we required an easier, quicker and at times safer method of releasing fish than trucking to rivers and planting by hand.

Prior to 1983, fish were often transported in plastic garbage buckets in the backseat of Bell 206B helicopters after first removing both doors. This method worked fairly effectively with the helicopter lowering itself down to the stream surface and a fish culturist leaning out (with seat belt on!) and dumping the fish into the water. While effective, it was felt that one day a more serious mishap than just clipping a few branches from streamside trees would occur.

In 1983, a new machine was developed and built by a local helicopter company with input from ourselves. This fry release device was designed to be suspended from a helicopter using a thirty metre power-braid polyester longline. The fry mover itself consists of ten separate thirty litre aluminum containers each hinged individually to the machine frame. All containers or buckets are covered with a flip-up plexiglass lid to prevent fish from being swept from the bucket when in flight. Each bucket is also individually supplied with compressed oxygen through perforated plastic tubing from a 3.38 cubic metre oxygen cylinder clamped to the aluminum frame. The power is supplied by two - twelve volt heavy duty automotive batteries. The buckets are each held upright by a steel rod welded to an electric solenoid. When the pilot or passenger in the helicopter activates a switch on a handheld control box from within the helicopter, the solenoid pulls the steel rod inward allowing the bucket to drop downward on its hinge releasing water and fish.

Over the last four years, we have found the maximum load per bucket is about 6 kilograms of fish per 13 litres water when using a Bell 206B helicopter. The corresponding fish density is about 460 grams of fish per litre. With one gram fish, each bucket can safely carry 6,000 fish or a total of 60,000 fish per trip using all ten buckets. With two gram fish, the total fish liberation would be 30,000 fish at 3,000 fish per bucket. Each trip normally averages 20 - 30 minutes in duration although occasionally the total trip time might reach 45 minutes.

Fish are first weighed in plastic garbage buckets and one bucket is then dumped into a corresponding container on the fry mover. When all buckets are loaded, the helicopter lifts the unit and flies to the stream site where one bucket is released. If the stream and forest canopy are open enough, the pilot does not have to continuously raise and lower the helicopter but can move slowly upstream releasing each bucket in a suitable site. This continues until all buckets are released and the pilot returns for another load. While the helicopter has been away releasing the fish, the ground crew have since weighed out a further ten buckets in preparation for loading on the pilot's return. Once the liberation is completed, the fry mover can be lowered into the back of a standard pickup truck and returned to the hatchery.

While this fry mover has worked out very well in its first four years, several minor weaknesses have been found. This machine was a prototype pieced together by helicopter mechanics, aluminum fabricators and fish culturists. Bracing had to be added to all legs and even then frequent cracks in welds have required rewelding. After listing all new changes and options we would like to see added, an engineering company has designed and drafted up a new ten compartment fry mover that should be lighter, stronger and with proposed options included, more efficient than the prototype we have been using. Some of the new design features include:

1. sturdier shock absorbing legs,
2. different design of bucket release mechanism,
3. oxygen cylinder placement change,
4. automatic oxygen shut off valves per bucket,
5. selector type switch box for mounting on helicopter control lever,
6. more streamlined and smaller frame,
7. a power supply running directly from the helicopter.

At least two helicopter fry release devices have been developed and marketed by companies in British Columbia as well as one built by a federal government salmon hatchery on Vancouver Island. They all achieve the same end result as ours but all to date are only designed to carry four separate containers of fish. Because of the nature of our steelhead fry stocking program, we require a minimum of eight compartments and preferably ten or twelve to maximize distribution of fish in each river.

Following four years of operation of this helicopter fry mover, we have found we are able to release greater numbers of fish in a shorter period of time while operating in a much safer working environment. With a new and improved model to be constructed in the near future, we should be able to improve our fish liberation efficiency even more.

LOGISTICS OF LARGE SCALE CHUM FRY TRANSPORT TO A REMOTE RELEASE SITE

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Northern Southeast Regional
Aquaculture Association

ABSTRACT

Northern Southeast Regional Aquaculture Association (NSRAA) began its chum program in Sitka in 1981. NSRAA operates the Medvejie Hatchery with a chum capacity of 28 million green eggs. The goal of the program is to provide the maximum number of chum to commercial fishermen at the least cost. All but 2 million chum fry are released at a remote release site called Deep Inlet, 11 water miles from the hatchery. The 2 million fry released at the hatchery return as broodstock for both releases. This separation of release sites resolves the problem of trying to protect broodstock while trying to maximize fishing opportunity as is the case when all fish return to the same site.

Medvejie Hatchery is designed to facilitate efficient handling of eggs and fry. Two styles of incubators are used. Chem-Proof R-48 incubators are used to eye eggs. Of the 3 million placed in each incubator 98% survive to the eyed stage. R-48s are used because of the ease at which green eggs can be added to the incubator. Favorable survival allows use of hatch screens in NOPAD incubators instead of the time consuming process of egg-picking. NOPAD incubators were chosen for development from the eyed stage due to the ability to use hatch screens and to their water efficiency over R-48's (15-20 GPM vs. 40-50 GPM per million eggs, respectively). NOPAD incubators hold 190,000 eggs each and are stacked five high.

NOPAD incubators are mechanically unloaded at a rate of 1 million fry per 30 minutes. Fry are unloaded in a water medium and collected in a holding raceway where they overnight prior to transport. A net liner is used in a tanked fishing boat to move fry at a rate of 1.6 million fry per trip (1.0 lbs./gal. (net volume)). Loading, transport, unloading and the return trip takes four hours dock-to-dock. The boat can haul 3.2 million fry per day which costs $600/day in charter fees. Four people are used in the loading operation and two for unloading. Fish are never out of the water or dipnetted.

Sealed polyethylene pipe is used for floatation of net pens. The floatation and walkway system for the eight 40' x 40' x 15' (deep) pens cost $40,000. Three million fry are placed in each net pen and the target is 2 g (227/lb) so that grow-out density if 0.57 lb/cu.ft. Net pen mesh is 5/32 in.

The first four-year-old return to Deep Inlet occurred in 1986 and showed a marine survival of 7%. About 125,000 adults returned from a release of 1.78 million fry.

The remote release of 24 million chum involves additinal costs over on-site releases of approximately $7,500, most of which are charter costs. Other costs include food for personal and additional personnel time.

Deciding whether to relese all fry onsite or split the relese between the hatchery and a remote site is a pay-me-now or pay-me-later consideration. Remote release involves up front costs, but provides opportunity for effectively utilizing the returns for their intended purpose. Releasing all fish at the hatchery site is cheaper at the outset, but operators will have difficulty trying to maximize harvest and protect broodstock at the same time. There are solutions to this problem,but they do involve costs, compromises and a certain amount of risk. Off-site releases are not always the solution either, but ought to be considered where appropriate.

SUCCESSFUL REHABILITATION OF A SOCKEYE SALMON STOCK UTILIZING AN EGG PLANTING DEVICE

by

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ABSTRACT

This report describes the sockeye salmon (Oncorhynchus nerka) rehabilitation work at Karluk Lake, Kodiak Island, Alaska during 1978 to 1986. The primary objective of this project is the rehabilitation of the early run Upper Thumb River stock of Karluk by massive eyed egg plants. A total of 85 million eggs were planted during this period. Pre-emergent fry survival results, from brood year 1979-1985, indicate survival of 42.5% from eyed eggs planted to pre-emergent fry. The return of 20,000, 22,000, 29,000, and 34,000 sockeye spawners to the systems in 1983 to 1986 respectively were the best recorded to the system since the 1920's and coincides with the returns from the egg plant effort.

KEY WORDS: Karluk Lake, sockeye salmon, (Oncorhynchus nerka), rehabilitation, eyed egg plants, tagging.

INTRODUCTION

Karluk Lake, on the south end of Kodiak Island (Figure 1), at one time supported a sockeye salmon run of greater magnitude, in relation to lake size, than any other sockeye salmon producing system in the world. In the early years of overexploitation the runs ranged from 1 million to 5 million fish. The recent (1978 to 1984) escapements have averaged only 323,000 sockeye salmon with the catch mainly incidental to the westside pink sockeye salmon fishery. In 1985 and 1986 there were 1.1 and 1.6 million sockeye salmon in the escapement and catch, a record going back to the 1930's (Table 1).

There are many theories advanced for the decline of the Karluk sockeye salmon. Most stem from the belief that over fishing occurred and resulted in an upset of the life cycle of the fish. The US Fish and Wildlife Service has been recently studying the predators and competitors. The Department of Fish and Game has been conducting pre-fertilization studies since 1978, and has been actively planting sockeye salmon eggs since the 1978 broodyear.

A stream side egg eyeing facility was constructed in the spring of 1980 on Upper Thumb River, Karluk Lake. This site was selected because historical records indicated Upper Thumb River, which was formerly a major producer, had become a minor producer of sockeye relative to the other subpopulations of Karluk Lake.

The approach used to rehabilitate the Upper Thumb River component of the Karluk sockeye population is to artificially incubate the eggs to get the increased green to eyed egg survival that this technique provides, in excess of 80% compared to 13.6% for eggs spawned naturally (Drucker 1970).

At Karluk Lake in the fall of 1977 and spring of 1978, a new salmon egg planting device (SEPD) was tested and compared with the conventional shovel method of planting eggs. Bothe methods were tested in natural streambeds with 465,000 eyed sockeye salmon eggs. The egg planting device was 3.5 times faster and easier to use than the shovel method. Eyed egg to fry survival was 11.0% for the conventional method and 50.8% for the new egg planter (White 1980).

After the initial test, massive egg plants were undertaken from 1978 to 1986. Since the project's commencement, it has become the largest rehabilitation effort in the State of Alaska. It is also the largest egg plant operation to be conducted anywhere in the North Pacific.

REHABILITATION EGG TAKE, INCUBATION AND EYED EGG PLANT 1978 to 1986

Methods

Supplemental production of sockeye salmon to Upper Thumb River was accomplished primarily by taking eggs and milt from sockeye salmon returning to Upper and Lower Thumb Rivers. Eggs were taken by incision and fertilized

Table 1. Karluk River ten year average sockeye salmon run 1882-1980, 1981, 1982, 1983, 1984, 1985, and 1986.

Year	Average Escapement	Average Catch	% of Average Run Caught	Total Average Run
1882 - 1890 a/	-	1,326,397	-	-
1891 - 1900	-	2,503,987	-	-
1901 - 1910	-	2,205,012	-	-
1911 - 1920	-	1,342,637	-	-
1921 - 1930	1,182,125	974,198	45.6	2,136,323
1931 - 1940	972,238	799,054	45.1	1,771,292
1941 - 1950	656,200	487,351	42.6	1,143,551
1951 - 1960	403,150	146,135	26.6	549,285
1961 - 1970	389,445	219,939	36.1	609,384
1971 - 1980	338,662	107,030	24.0	445,692
1981	222,706	95,143	29.9	317,849
1982	164,407	146,755	47.2	311,162
1983	436,145	140,950	24.4	577,095
1984	420,268	258,375	38.1	678,643
1985	995,948	145,443	12.9	1,141,393
1986	887,171	762,717	46.2	1,649,888

a/ Nine year average

Source: Barnaby, 1921-1936; U.S. Fish and Wildlife Service, weir reports and agent's reports, 1937-1956; ADF&G, Comm. Fish. Div., Area Annual Reports, 1957-1986.

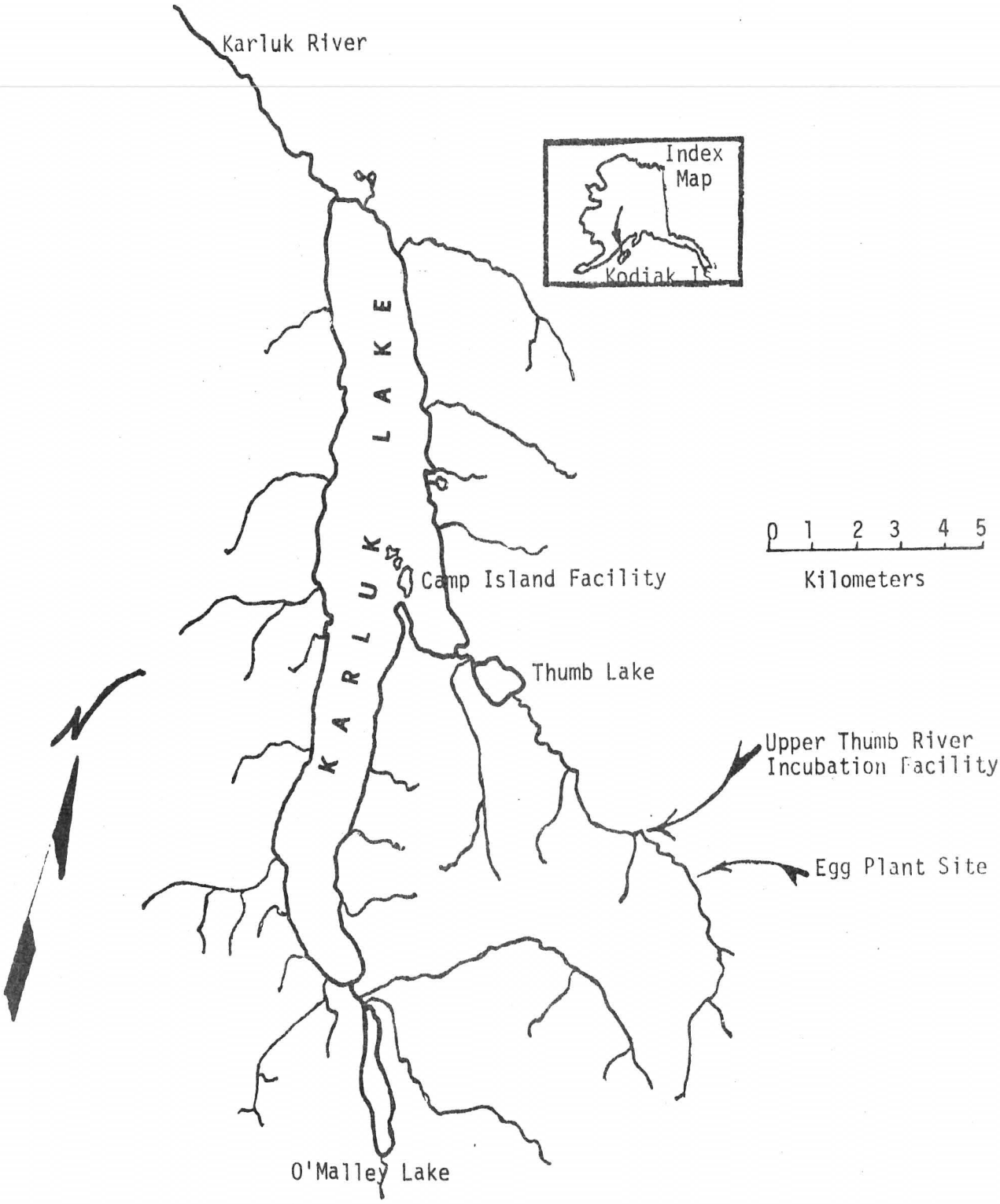

Figure 1. Karluk Lake, Alaska, showing major tributaries important for sockeye salmon spawning and rehabilitation facilities.

in the spawning bucket or plastic container. During the years 1978 to 1980, six females and two to three males were used per bucket and from 1981 to 1984 the gametes from each female and two to three males were stripped into individual containers. During the latter period each container of fertilized eggs was isolated until eggs were water hardened and disinfected with a Betadine solution for ten minutes. Water hardened and disinfected eggs were then consolidated and transported 2.75 km to the incubation facility. In 1978 and 1979 eggs were incubated at Devil's Creek on the United States Coast Guard base in Kodiak and at the Kitoi Bay Hatchery on Afognak Island. In 1980, a new incubation facility was constructed on the East Fork of Upper Thumb River (Figure 2) and from that period on, all eggs were incubated at this site. Eggs were primarily incubated in 74 cm diameter incubators. Flows were maintained at approximately 30 liters per minute. Eggs were treated with Formalin at 1:1000 to 1:600 concentration for 15 minutes every third day during the entire green to eyed egg incubation stage. The eyed eggs were shocked and culled with a photoelectric egg picker, and counted, primarily by volumetric displacement.

Eyed eggs were backpacked (0.5 km to 6.0 km) from the incubation facility to the planting sites above the first and second falls on the East and North Fork of Upper Thumb River (Figure 1) in areas barren of natural spawners.

With the aid of an egg planting device (Figure 3) described by White (1980) most eggs were planted in areas where past pre-emergent sampling indicated the highest survivals could be expected. The probe end of the device was driven approximately 30 cm into the streambed and eggs were hydraulically planted at the rate of 455 eggs per probe plant at a distance of 15 cm or more between each plant.

Results

The 1978 to 1986 early run egg take results are shown in Table 2. The egg takes at Thumb River have resulted in 85,041,000 eyed eggs from early run fish. Green to eyed egg survival has averaged 84.0%. The nine year egg planting summary is shown in Table 3. The egg plant density has averaged 1,377 eggs/m^2 during this period.

Discussion

In the initial years, 1978 to 1981, the egg takes averaged only 5.6 million eggs annually. This was a result of weak natural returns to Upper Thumb River (10,000 fish or less) and project plans which called for using not more than 50% of the natural stock for egg take purposes. In contrast to this, the annual egg takes from 1982 to 1986 have averaged 17.3 million eggs. This is a direct result of strong returns of fish to Upper Thumb River, coinciding with the first returns from the initial rehabilitation effort in 1978-1980.

The average green to eyed egg survival of 84.0% (range 73.8 to 88.8), is below the desired 90% survival level. Mortality can be attributed to the additional handling associated with the half-hour backpack from the egg take site to the incubation facility in the latter years and hour-long charter flights in the former years.

Figure 2. Upper Thumb River, Karluk Lake streamside incubation facility.

Figure 3. Eyed sockeye salmon eggs being planted in Upper Thumb River, Karluk Lake with aid of a salmon egg planting device.

Table 2. Summary of the egg take records for the early run[1/] rehabilitation effort at Upper Thumb River, Karluk Lake 1978 - 1986.

Brood Year	Brood Source	Number of Eggs Taken	Females Spawned	Males Spawned	Egg Take Fecundity	% Survival Eyed Eggs	Number Live Eggs	Incubation Location
1978	Upper Thumb	3,071,000	1,030	525	2,982	84.1	2,583,000	Devil's Creek
1979	Upper Thumb	4,816,000	1,491	489	3,298	81.9	3,945,000	Devil's Creek
1980	Lower Thumb	4,115,000	1,563	925	2,679	73.8	3,038,000	Upper Thumb
1981	Lower Thumb	2,902,000	1,241	701	2,338	81.0	2,343,000	Upper Thumb
1982	Upper Thumb	11,190,000	4,888	1,404	2,282	82.0	9,206,000	Upper Thumb
1983	Lower Thumb	15,256,000	6,353	2,138	2,401	80.0	12,284,000	Upper Thumb
1984	Upper Thumb	15,475,000	6,452	3,324	2,399	85.8	13,207,000	Upper Thumb
1985	Upper Thumb	20,949,000	8,471	3,057	2,473	89.4	18,612,000	Upper Thumb
1986	Upper Thumb	23,443,000	9,259	3,804	2,532	84.6	19,823,000	Upper Thumb
Total or Average:		101,217,000	40,748	16,367	2,484	84.0	85,041,000	

1/ Early run fish are those spawned in July to mid-August and late run are those fish spawned from mid-August to October.

Table 3. Summary of early run egg plants in Upper Thumb River, Karluk Lake from 1978 to 1986.

Brood Year	Number of Eggs Planted	Area Planted (M^2)	Mean Density (eggs/M^2)	Rate of Planting 1/ Eggs/Man Hour
1978	2,583,000	1,779	1,452	--
1979	1,449,000	680	2,121	--
1980	3,038,000	1,566	1,940	10,060
1981	2,344,000	1,037	2,260	13,000
1982	9,206,000	2,489	3,691	38,206
1983	12,284,000	5,017	2,448	18,869
1984	13,207,000	14,359	919	26,796
1985	18,612,000	27,850	668	46,488
1986	19,823,000	5,148	3,851	49,067
Total or Average:	82,546,000	59,925	1,377	28,926 2/

1/ Man hours does not include packing time.

2/ Annual average.

A total of 82.5 million eggs have been planted over the nine year period. I know of no other egg plant operation of this magnitude in the North Pacific. In 1983 to 1986 there were so many eggs to plant that new planting areas had to be explored and evaluated. The major area of expansion took place in the upper stream area of Upper Thumb River. This area is so remote, 5 km to 6 km from the incubation site, that it required up to one and a half hours to back-pack uphill to the site.

EGG PLANT TO FRY SURVIVAL

Background

Eyed egg plant survivals were estimated by mark-recapture and pre-emergent fry sampling. The two methods insure an overall estimate should one method or the other fail to provide reliable data because of early spring floods.

Methods

Mark-recapture Fry Sampling:

Survival estimates by the mark-recapture method were based on hand counts of fry caught in an index fan trap, described by Ginetz (1977). Fry were marked with Bismark brown Y solution in a method described by Ward and Verhoeven (1963) and released approximately 100 m upstream from the trap. The daily fry population estimate was based upon the ratio of marked to unmarked fish which were hand counted.

The mark-recapture population estimate is expressed mathematically in terms of:

N = total number of fish in the population
D = total number of marked fish in the population
n = number of fish sampled
d = number of marked fish recaptured in the sample
$\hat{N}$ = estimate of N

The estimate is computed according to the following formula (Rawson 1984):

$$\hat{N} = \frac{nD}{d}\left[1 + \frac{D-d}{Dd}\right],$$

and its confidence interval is obtained using the following formula for estimating the variance of $\hat{N}$ (Rawson 1984).

$$\text{Var}(N) = (n+d)\ D\ (D-d)\ /d^3$$

Pre-emergent fry sampling:

In the spring of 1980 to 1986, fry were pumped out of the gravel at randomly selected and marked areas in the egg plant site. Fry were collected in a cylindrical shaped net of 0.1 m^2, circumference 1.12 m, and then hand counted. The method used is similar to that described by McNeil (1964).

Results

Mark-recapture fry population estimate:

The average estimated survival from eyed egg to emergent fry at Upper Thumb River during the 1979 to 1985 brood year period (Table 4) was 40.3% (range 1.4% to 70.0%) using this method.

Pre-emergent fry sampling:

Pre-emergent fry sampling over the 1979-1985 brood year period, (Table 5) resulted in an average survival estimate of 42.5% (range 1.4% to 61.3%).

Discussion

During the period of estimating the population by mark-recapture, from 1979 to 1983, fishing time was lost each year due to high water conditions. There were 5,1,2,3, and 1 days of fishing time lost in 1979, 1980, 1981, 1982, and 1983 respectively. The fry population was unknown during these high water periods. Fry trapping in 1984 to 1986 was exceptional in that no fishing time was lost during high water periods.

When comparing the pre-emergent and mark-recapture estimates (Table 6) over the years, the pre-emergent estimates exceeded the mark-recapture by only 1,014,000 more fry. Overall, the pre-emergent estimate appears to be more reliable because flooding has not affected the results.

The pre-emergent data has also been useful in identifying survivals by specific planting areas. Many streambed areas that have been avoided after the sampling indicated low survival because of apparent streambed instability. The highest mortality (or disappearance of eggs and fry) appears to be caused by flooding which shifts streambed gravel. Longer and more severe floods create greater mortality. Water discharge records, kept by the United States Geological Survey (USGS) over an eight year period at Upper Thumb River (USGS 1976 to 1983), indicated a mean discharge of 2.068 m^3/s was recorded for a 17 day period in October and a 10 day period in November. The pre-emergent index after this flood was 5.5 fry/dig, which was the worst pre-emergent survival data recorded.

In 1980 a flood period of six days in October resulted in an index of 120 fry/dig, which is slightly below the five year average of 136 fry/dig. In 1981

Table 4. Mark-recapture fry population estimate of early run eyed egg plant fry from Upper Thumb River, 1978 to 1985 brood years.

Brood year	Sample year	Number of eyed eggs planted	Number fry estimated	95% C.I. Upper	95% C.I. Lower	Mean % survival
1978	1979	2,583,000	724,000	-	-	28.0
1979	1980	1,449,000	21,000	24,000	20,000	1.4 1/
1980	1981	3,038,000	663,000	705,000	622,000	21.8
1981	1982	2,344,000	1,643,000	1,689,000	1,597,000	70.0
1982	1983	9,206,000	2,715,000	3,164,000	2,055,000	29.5
1983	1984	12,284,000	4,811,000	5,154,000	4,469,000	39.1
1984	1985	13,207,000	5,704,000	5,559,000	5,849,000	43.0
1985	1986	18,612,000	8,970,000	8,882,000	9,066,000	48.2
Total or Average		62,723,000	25,251,000	-	-	40.3

1/ Low survival due to planting technique and floods in October and November, 1979.

Table 5. Pre-emergent fry population estimate of eyed egg plants from Upper Thumb River, 1979 to 1985 broodyear.

Brood year	Sample year	Number of eyed eggs planted	Number of pre-emergent fry estimated	Sample size	No. of fry/dig	Mean % survival
1979	1980	1,449,000	20,000	80	5	1.4[1/]
1980	1981	3,038,000	1,013,000	47	120	33.3
1981	1982	2,344,000	1,437,000	43	279	61.3
1982	1983	9,206,000	4,483,000	123	221	48.7
1983	1984	12,307,000	4,797,000	73	177	39.0
1984	1985	13,207,000	6,728,000	125	215	51.0
1985	1986	18,612,000	7,063,000	124	184	38.0
Total/Average		60,140,000	25,541,000	615	136	42.5

1/ Low survival due to floods in October and November, 1979.

Table 6. Pre-emergent and mark-recapture population estimates of fry projected from eyed egg plants at Upper Thumb River, Karluk Lake, 1978 to 1985 brood years.

Brood year	Sample year	Mark-recapture population estimate	Pre-emergent population estimate	Pre-emergent minus the mark-recapture difference
1978	1979	724,000	-	-
1979	1980	21,000	20,000	-1,000
1980	1981	663,000	1,013,000	+350,000
1981	1982	1,643,000	1,437,000	-206,000
1982	1983	2,715,000	4,483,000	+1,768,000
1983	1984	4,811,000	4,797,000	-14,000
1984	1985	5,704,000	6,728,000	+1,024,000
1985	1986	8,970,000	7,063,000	-1,907,000
Total Difference:				+1,014,000

there were only three flood days between October and November. This probably greatly contributed to the index count of 279 fry/dig for 1981, which was the highest pre-emergent density recorded in the study period. In 1979, the worst year, the flood damage was apparent in a lack of not only live fry but also a lack of dead fry and eggs as well. There was physical evidence of streambed erosion, a portion of the egg plant area was covered with gravel and became part of a new stream bank. The disappearance of fry is assumed to be mortality. However, it is quite conceivable that some of the eggs or fry which were washed out of the egg plant area may settle in low velocity areas and survive unrecorded, in areas downstream from the evaluation project.

The annual egg to fry survival of naturally spawned sockeye salmon at Karluk, based on the actual egg deposition, was 29.4% (range 19.0% to 42.8%) in the period from 1964 to 1967 (Drucker 1970). In our study the eyed egg to fry survival was 42.5% (range 1.4% to 61.3%; Table 5). Canadian spawning channels egg-to-fry survivals for sockeye salmon in 1983 averaged 46.3% (range 32.6% to 80.4%) at Upper Pitt, Weaver Creek, Gates Creek and Nadina River (INPFC 1984). At Jones Creek, annual egg-to-fry survival of pink salmon, (O. gorbuscha) was 37.7% (range 8.5% to 79.1%) over a 15 year study period (Frazer and Fedorenko 1983).

In comparision, the egg-to-fry survivals of the Karluk egg plant operation are within the range of survivals experienced by the Canadians in their spawning channels. The survivals for the egg plant are also higher than those reported for both potential and actual egg deposition from natural spawners as reported by Drucker (1970) in his eight year study at Grassy Point Creek, Karluk Lake.

The pattern of fry emergence was similar to that recorded previously by biologists at Karluk Lake (Drucker 1970). Migration was nocturnal. As the season progressed and daylight increased, the period of fry emergence shifted to later in the evening. The emergence period lasted from mid-March until mid-June with the peak periods from the first week of April to the last week of May, depending upon floods or freshets which apparently trigger bursts of emergence.

FRY MARKING INVESTIGATIONS

Background

In the spring of 1979, 1981, 1984, and 1985 early run sockeye salmon fry were marked for identification of adult returns to the rehabilitation effort. In the 1979 and 1981 period sockeye salmon fry were marked by the removal of an adipose (AD) and the left ventral fin. In 1984 and 1985 fish were marked with a "half length" 0.5 mm coded wire tag (HLCWT).

Fry that were used for the marking project were from eggs planted above a falls, an area barren to natural spawning sockeye salmon.

Methods

Fry from the egg plant were marked by the removal of a fin in a manner described by Bams (1972) and Moberly, et al. (1977). The HLCWT program was conducted in a manner described by Rawson, et al. (1986) except the adipose fin was not removed in our study. A quality control program was conducted during the entire project to insure that only valid marks were recorded for each marked group. Marked fry were released in the evening or at night when the natural migration occurred.

Returning adult sockeye broodfish were inspected for missing fins in July at Upper Thumb River, in conjunction with the egg take in 1983 - 1986.

Because there are multiple age groups of sockeye salmon with the same mark, each sockeye salmon inspected has to be aged to determine brood year of the marked and unmarked fish. The age of broodfish was determined from otolith samples.

Results

Fry marking from 1978 to 1985 is summarized in Table 7.

A total of 43,827 adult sockeye salmon broodfish were inspected for marks in 1983 - 1985 (Table 8). This sample contained 591 valid marked fish with missing fins. There are still 3.3 age fish for the 1980 brood year to return in 1987.

Discussion

The 1978 broodyear marked returns were substantially less than the 1980 broodyear. The 1980 broodyear has contributed to over half of the 2.7 million Karluk sockeye salmon returns in 1985 and 1986. So it is not surprising that the survival of 1980 brood year marked fish was greater than the 1978 group. The overall 1.3% survival of marked fish to returning adult is close to the 1 to 2% survivals expected.

The HLCWT of young sockeye in 1984 and 1985 was an effort to solve the problem of fin regeneration and obtain a life-long tag that would possibly aid in following the fish from juvenile to smolt and finally to adult return. This is the first time that sockeye salmon fry have been tagged without the removal of an adipose fin for external identification. Adults will have to be inspected with a quality control device for tag detection from 1987 to 1991.

ADULT RETURNS

Background

Escapement records have been kept since 1921 at the Karluk River weir to

FIGURE 4. Early run peak survey counts of sockeye adults at Karluk Lake 1971–1986

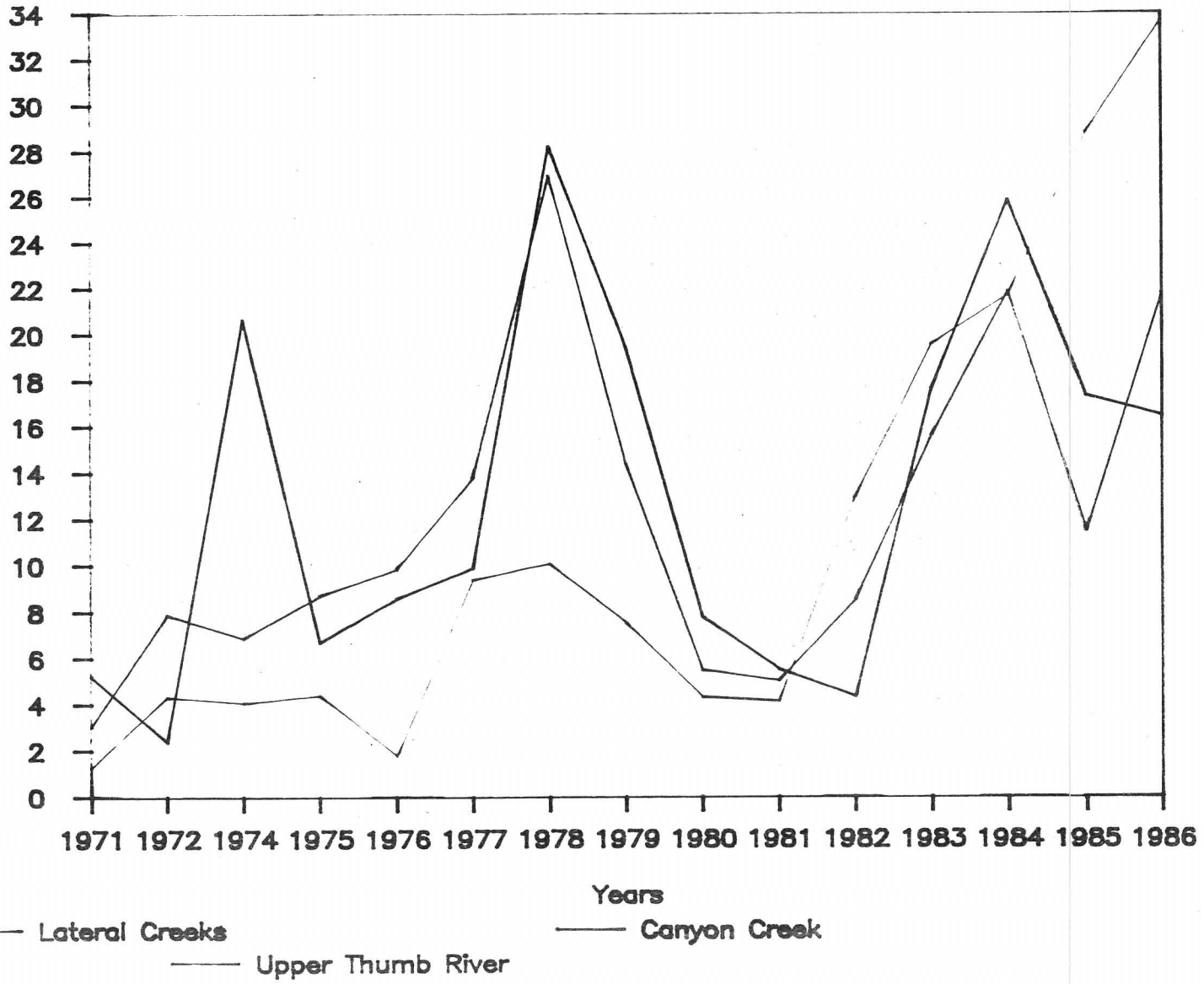

FIGURE 4. Early run peak survey counts of sockeye adults at Karluk Lake 1971–1986

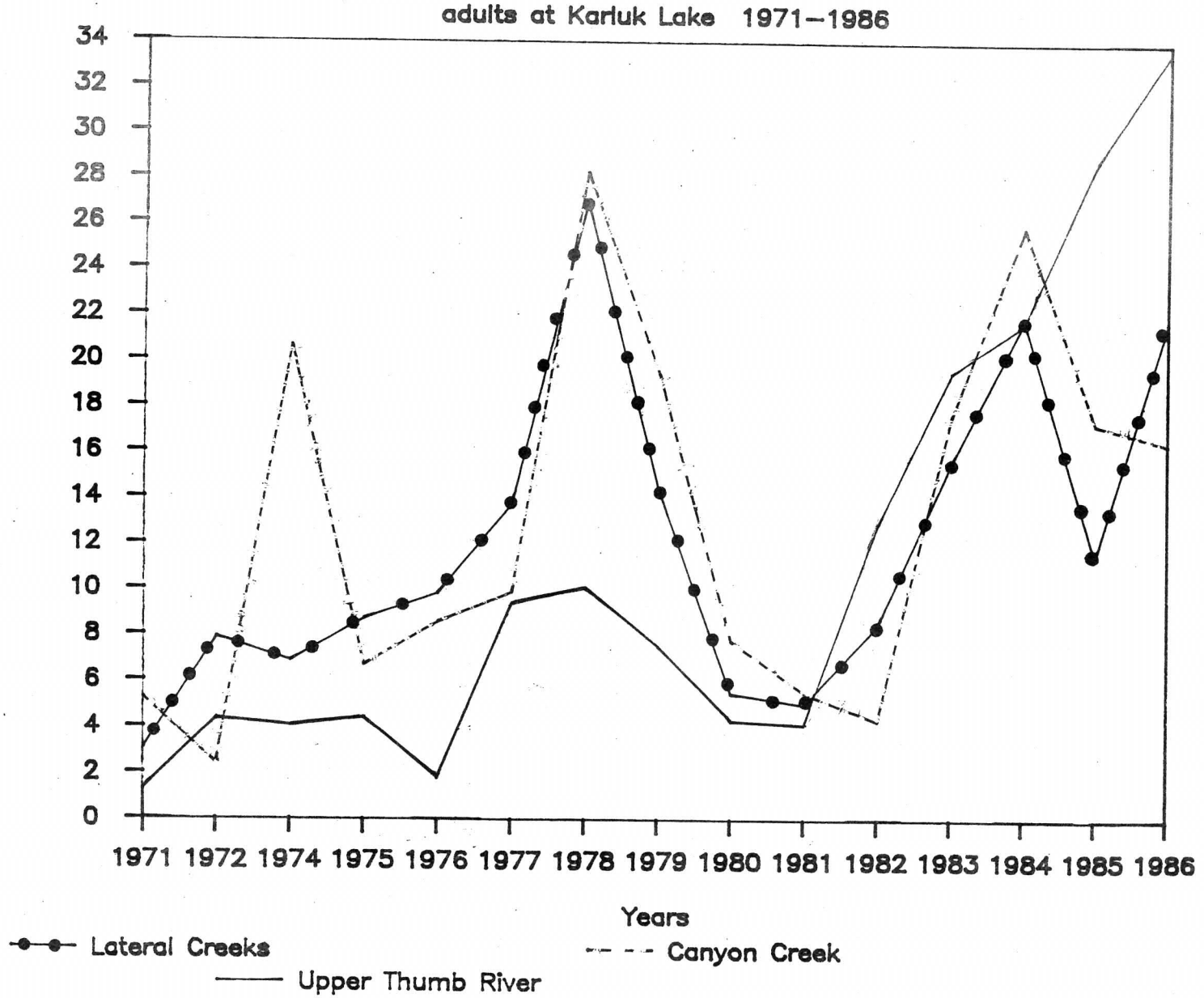

Table 7. Summary of early run fry marked at Upper Thumb River, Karluk Lake, 1979 to 1985.

Brood stock	Brood year	Origin	Mark type	Number fry marked	Number unmarked fry released
Upper Thumb	1978	Egg Plant	AdLV	27,700	691,000
Upper Thumb	1980	Egg Plant	AdLV	70,600	942,400
Upper Thumb	1983	Egg Plant	HLCWT	117,000	4,683,000
Upper Thumb	1984	Egg Plant	HLCWT	141,000	5,562,000

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Adult Returns from Releases of Three Sizes of Skamania Summer Steelhead Smolts

Mark Wade

Oregon Department of Fish & Wildlife

We hand sorted Skamania summer steelhead reared at the South Santiam Hatchery into three size groups; small-- 18 cm, medium--18 to $<$20 cm and large--$\geq$20 cm. There was no difference between the groups of medium and large size smolts in survival to our traps located 26 and 212 kilometers downstream in 1980 or 1982, however the capture rate of the small size smolts was significantly less.

There were differences in adult returns of the medium and large size smolt groups. For example, as 2-salt adults returning to South Santiam Hatchery, the large size group averaged 68.7 cm for females and 71.2 cm for males, whereas the medium size group averaged 67.3 cm for females and 69.7 for males. The medium size group was 60% females and the large size group was 44% females. Total 1-salt, 2-salt and 3-salt returns were 0.69% for the small smolts, 2.4% for the medium smolts and 4.3% for the large smolts.

Our results cannot be extrapolated to production groups of smolts. The test groups were produced by grading, so that the smolt _ 20 cm were the fastest growing fish. We do not know the relationship between the growth rate of smolts and survival to adult. We need to evaluate the effect of size of steelhead smolt at release with test groups produced by programming the feed so that there are fast growing and slow growing fish in each size group.

4. REARING: LIFE STAGES

EFFECTS OF DELAYED INITIAL FEEDING

OF SUMMER CHINOOK SALMON FRY

ABSTRACT

At the McCall hatchery a unique strain of chinook salmon is reared. These fish are long running, summer spawning, chinook salmon. A study examining the affects of delaying the initial feeding of summer chinook salmon, under conditions at the McCall hatchery, was conducted in the spring of 1986.

Four groups of sacfry, divided into three subgroups, were started on feed at different times, ranging from 1,638 daily temperature units to 1,904 daily temperature units. Necropsies were performed to monitor yolk sac absorption, amount of feed in the gut, and growth.

The amount of yolk sac dropped to near zero shortly after 1,874 daily temperature units were achieved, corresponding to a sharp increase in length and weight. The amount of feed in the gut did not appear to influence the rate of yolk sac absorption.

Although feed was ingested soon after it was presented, little growth occurred until most of the yolk sac was absorbed, suggesting that feed is not needed until yolk sac absorption is nearly complete.

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Reducing Pinhead Mortality in Steelhead Trout

Tom Shaw
Hagerman National Fish Hatchery

Introduction

Pinhead mortality causes a 10-15% loss of feeding fry in summer steelhead at Hagerman National Fish Hatchery when fed the traditional Silver Cup Salmon dry diet. Most of this loss occurs within the first 25 days of feeding when the fish are between 3700 and 550 per pound. The cause of pinhead development is unknown. It appears that some pinheads eat but cannot utilize the diet and some reject the diet.

Because of the high pinhead mortality associated with the dry diet it was surmised that a soft diet may reduce pinhead development. Rangen Soft Moist and Bio-Diet's were selected because freezing was not necessary and handling was easier.

The three diets were fed to test fish for 25 days at the recommended sizes. Daily mortality counts were made to determine the loss associated with each diet.

Materials and Methods

Approximately 152,000 eyed summer steelhead eggs were incubated in egg hatching jars for each diet tested. Each test group consisted of four concrete hatchery tanks and four egg hatching jars containing 38,000 eggs. All eggs were from the same egg take. The treatment of each test group was identical and the water temperature was a constant 59° F.

After the eggs had hatched the fry and dead eggs were separated by use of a minnow grader placed in the tank. The fry were allowed to develop to the swimup stage in the tanks and all mortality was removed, counted and subtracted from the number of eggs to establish the numbers at initial feeding. When an estimated 75% of the fry reached swimup, feeding was started. All tanks were started on feed the same day. The fry were fed by eye eight times a day and all fish were overfed, which was obvious by the excess feed on the bottom of the tanks. The tanks were cleaned and the mortality recorded daily for 25 days.

Results

The eyed eggs hatched and reached initial feeding in 18 days. The survival to initial feeding was very similar for each diet: 97.1% (147,541) for Silver Cup, 96.4% (146,519) for Rangen and 96.7% (146,990) for Bio-Diet.

After initial feeding the daily mortalities for each diet were relatively low for the first 7 days, ranging from 34 to 161 per day. On the 8th day the pinhead mortality associated with Silver Cup feed began to climb rapidly and peaked at 5302 on the 14th day. From the 12th day on mortality associated with the soft diets remained less than 100 per day. By the 24th day the mortality for all diets was less than 100 per day, which is considered normal. (See figure 1.)

The cumulative mortality for 25 days reveals the substantial pinhead loss which can occur with the dry diet. At the end of the 25 day feeding period the loss was as follows: Silver Cup Salmon diet 14.71% (21,701), Bio-Diet 1.37% (2,012) and Rangen Soft Moist 1.09% (1,596). (See figure 2.)

After the initial 25 day feeding period the traditional Silver Cup Salmon diet performs extremely well. This is well documented by the F.Y. 1986 production of 364,000 pounds of summer steelhead smolts at a 1.19 feed conversion.

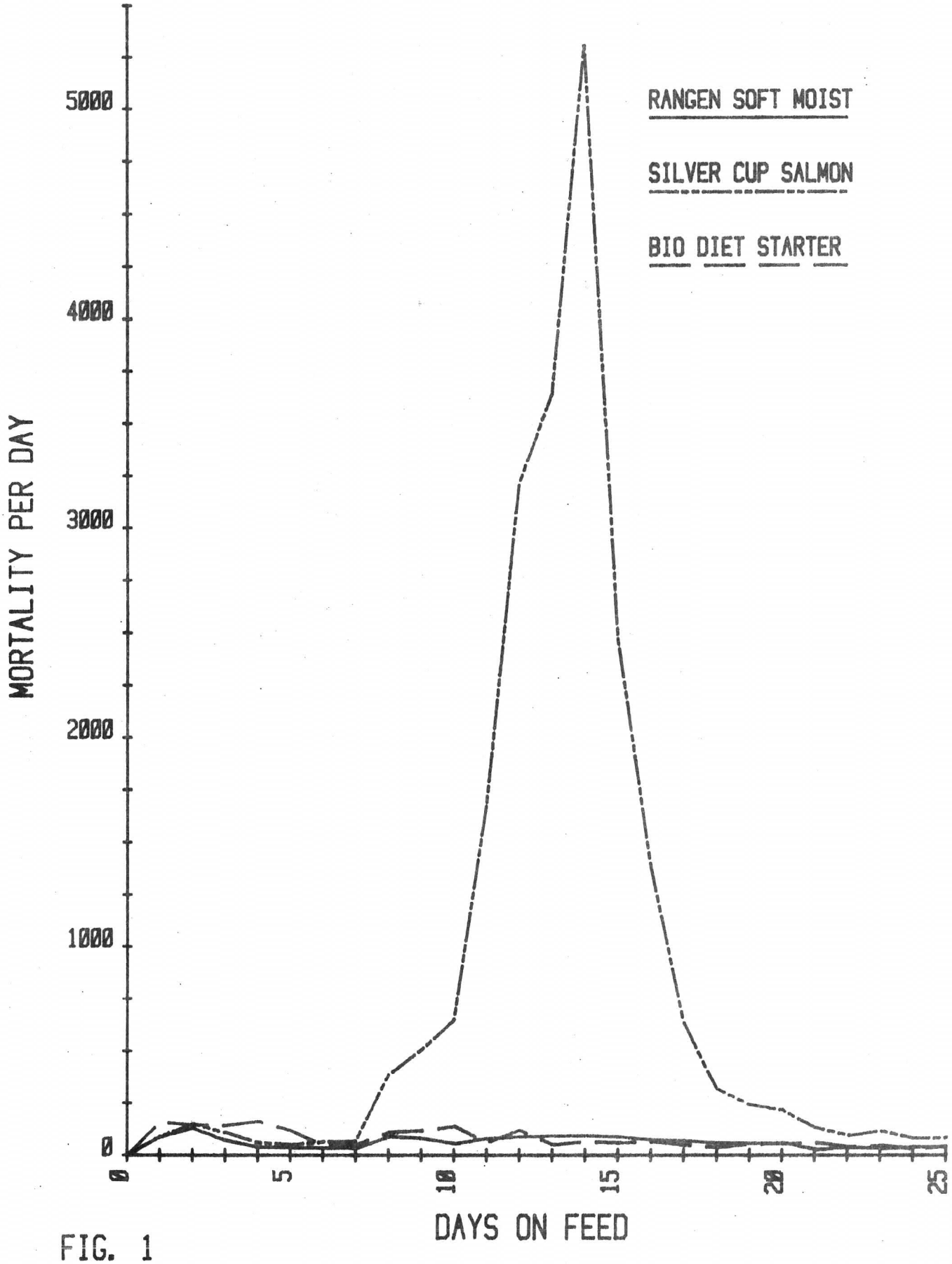
RANGEN SOFT MOIST
SILVER CUP SALMON
BIO DIET STARTER
MORTALITY PER DAY
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
DAYS ON FEED

FIG. 1

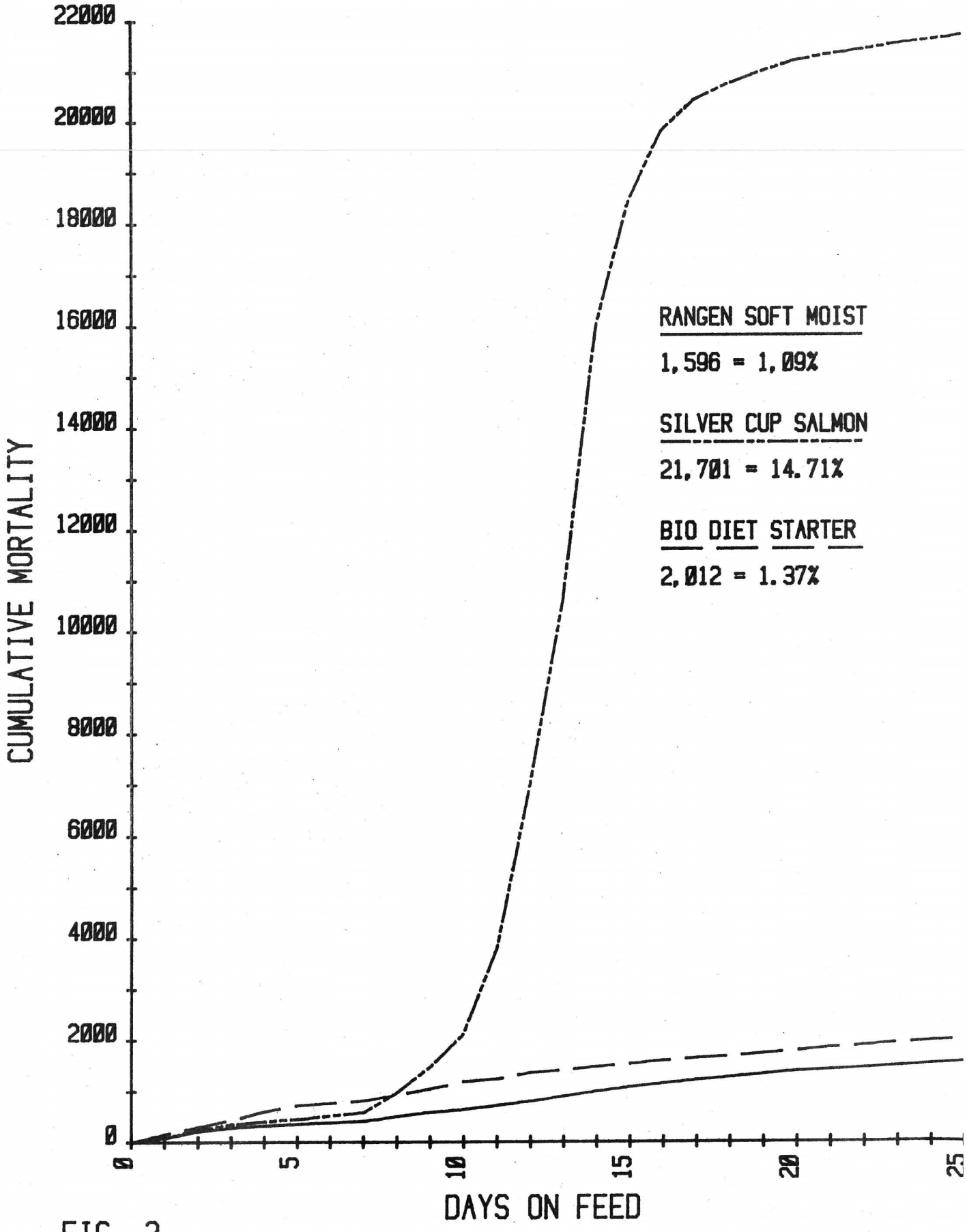
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
CUMULATIVE MORTALITY
0
5
10
15
20
25
DAYS ON FEED
RANGEN SOFT MOIST
1,596 = 1,09%
SILVER CUP SALMON
21,701 = 14.71%
BIO DIET STARTER
2,012 = 1.37%

FIG. 2

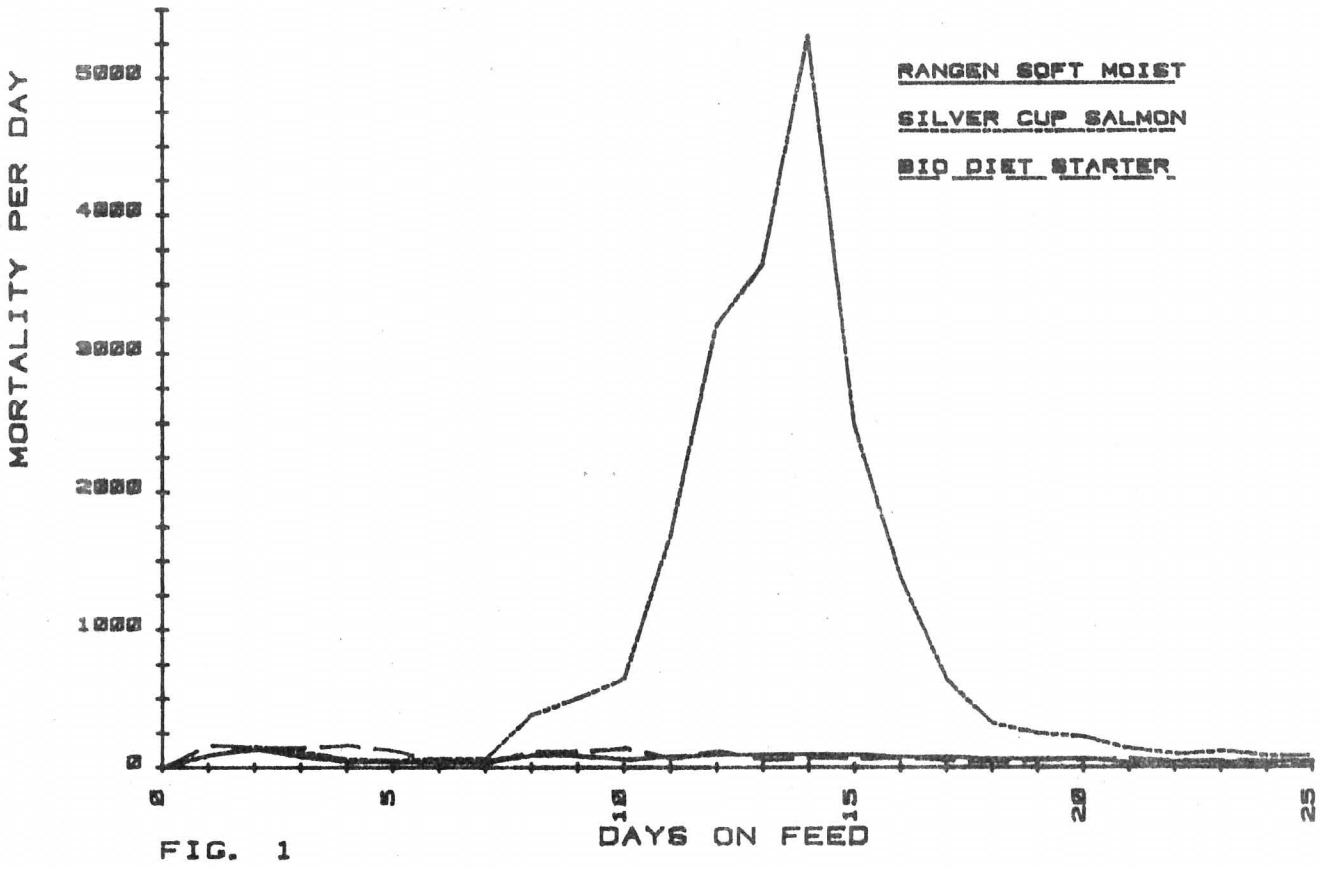
MORTALITY PER DAY
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
DAYS ON FEED
RANGEN SOFT MOIST
SILVER CUP SALMON
BIO DIET STARTER

FIG. 1

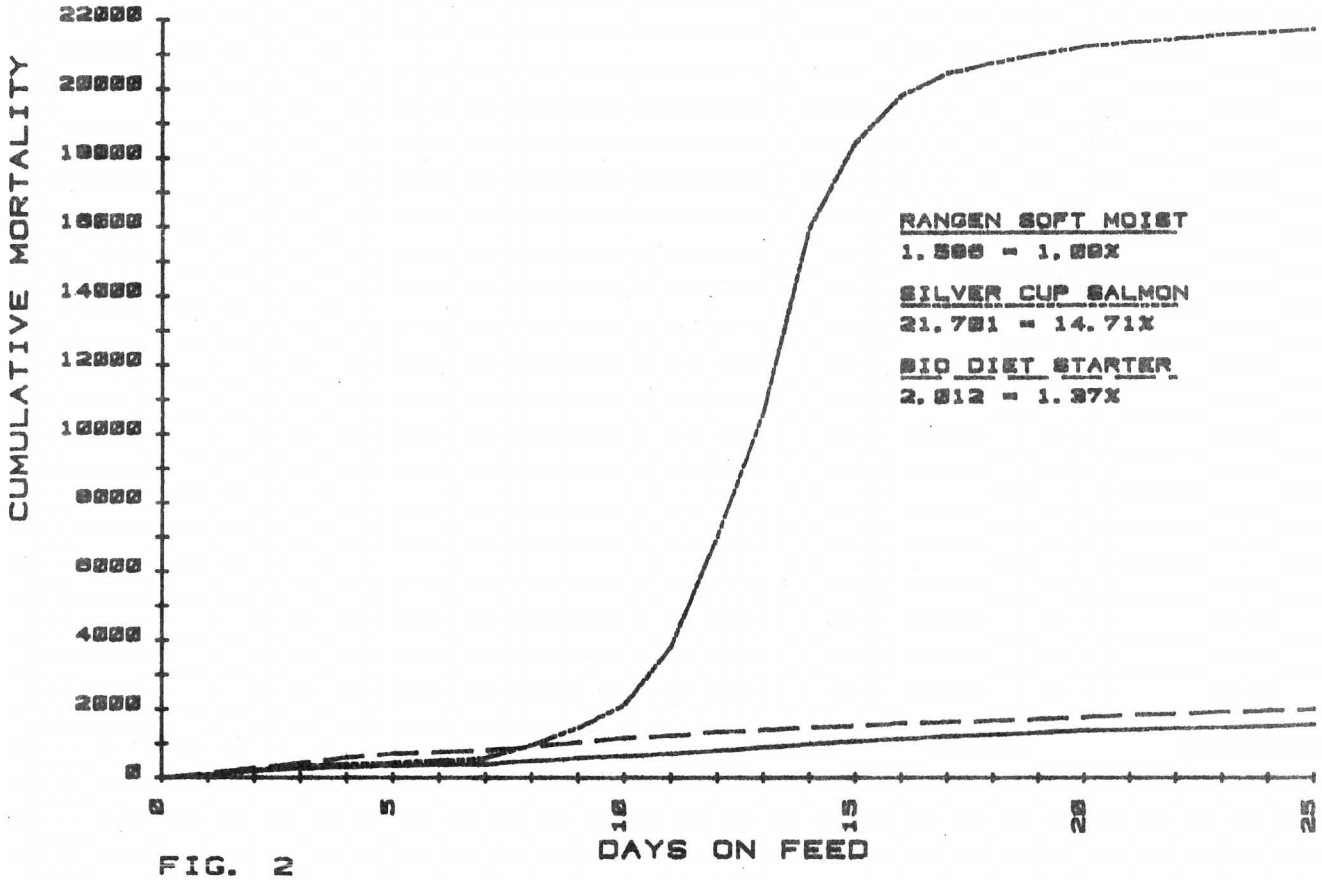
CUMULATIVE MORTALITY
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
DAYS ON FEED
RANGEN SOFT MOIST
1.500 - 1.00%
SILVER CUP SALMON
21.781 - 14.71%
BIO DIET STARTER
2.812 - 1.87%

FIG. 2

CHEHALIS SYNDROME

Presented by Dave Harding

Since the opening in 1982, Chehalis Hatchery has been plagued with heavy losses of fall white chinook alevins. These losses have ranged from 21 to 85 percent and usually occur between 650 and 750 ATU 'C. This presentation reviews the general history of the syndrome and the findings of several experiments conducted during the incubation of the 1985 brood.

The first obvious symptoms are the pale color and general lethargy of the alevins in a tray. Heavy die-off occurs 5 or 6 days later followed rapidly by heavy fungus growth. Many red blood cells either lack a nucleus or it is deformed and there are few immature cells. The gills exhibit hyperplasia but there is no major organ damage. Tissue chemistry reveals a decrease in sodium.

The condition appears at random within the Heath stack and then spreads downward to the lower trays. Lowering temperature, changing from well to river water, reducing density, adding substrate or dispersing the fry had no effect. Various treatments and changes of regimen had no discernable effects.

No pathogens have been found nor any direct connection to parental health. Pesticide and herbicide residues are well below critical levels, as are heavy metals. Chehalis water is very soft, slightly acidic and low in ionic strength. Large numbers of eggs incubated at locations with greater hardness have not developed symptoms.

Experiments on the 1985 brood produced the following results:

1. contagion is involved;
2. UV with filtering stops tansmission;
3. the infectious agent is not on the egg or in the water supply;
4. susceptibility is inherited mainly from the male parent;
5. increasing Ca, Na and K may help to control the losses.

Experiments on the 1986 brood are designed to confirm the findings on contagion and to test the hypothesis in 5. above. Electron microscopy will continue in the search for the agent of contagion.

WATER TEMPERATURE AND DOWNSTREAM MIGRATION BEHAVIOR OF COHO AND STEELHEAD SMOLTS

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City of Arcata, California, 95521

ABSTRACT

Downstream migration (DSM) behavior of smolts of the same genetic stock of 1985-brood coho salmon was studied in three separate environments: a brackish-water rearing pond and two small urban streams. DSM of pond-reared coho smolts was also compared with that of steelhead smolts reared in an adjacent brackish-water pond. An atypical warm-weather pattern in March 1986 produced two periods of rapidly rising water temperatures in ponds, but did not elevate cool stream temperatures. Coho smolts in creeks moved downstream at a relatively uniform rate under a water temperature that rose from 10°C to 16°C over a 43-day period. Peak period of coho migration from the pond correlated with rising water temperatures (12°C to 17°C over a three-day period). Rise in water temperature in March initiated a minor peak in any steelhead outmigration. Peak out-migration of steelhead occurred on May 4 when water temperature increased from 13.5°C to near 17°C in two days. Coho out-migration in ponds ceased when daily mean water temperatures exceeded 17°C in salinities of 10 ppt during smolting and out-migration.

INTRODUCTION

Elevated water temperatures have been shown to produce three effects in the smoltification process of juvenile coho salmon as measured by patterns of gill Na+,-K+ ATPase activity: (1) sharper rates of increase, (2) reduced periods of elevated activity, and (3) sharper rates of decrease (Wedemeyer et al. 1980). These enzyme activities correlate with the extensive literature reporting the control of water temperature on smolt behavior (Folmar and Dickhoff 1980). An opportunity to study temperature and DSM behavior in smolts under field conditions arose in the spring of 1986 in northern California when a weather pattern produced cold air temperatures in early March, followed by a period of above-normal warm weather, followed in turn by a uniform period of relatively cool weather. Smolt out-migration studies have been routinely conducted at the Arcata ponds (Del Sarto 1980, Leonhardt 1984) but only occasionally have studies been made on smolt behavior in small urban streams flowing through Arcata (Allen 1983). In the spring of 1986, however, downstream migration (DSM) studies had been planned for two systems (Janes Creek and Jolly Giant Creek). Thus we were able to compare the DSM migration behavior of coho (Oncorhynchus kisutch) and steelhead (Salmo gairdneri) smolts in brackish-water pond with the DSM of coho smolts in streams under temperature regimes produced by the unusual spring weather pattern of 1986.

WASTEWATER-SEAWATER AQUACULTURE

Specific environmental requirements of a cultured stock of anadromous salmon or trout set the broad limits within which aquaculturists must manage their facilities. Historically anadromous salmonid culture stations were able to exploit large volumes of high quality water delivered by gravity to a site with adequate flat land for fish cultural facilities. Suitable acreage adjacent to large volumes of high quality water are now both scarce and expensive, forcing aquaculturists to seek unconventional water supplies or to reuse existing available water supplies (Allen 1985, Klontz 1984). In 1963 the City of Arcata and the Fisheries Department at Humboldt State University began a cooperative program to investigate the potential of an unconventional water source for salmonid aquaculture (adequately treated domestic wastewaters, Allen 1983, 1985). Initial rearing experiments occurred in the summer of 1971 (Allen et al. 1972). With the construction and testing of a two-celled production unit (Leonhardt 1984), the project has now advanced to a demonstration stage. In the winter of 1985, a second two-celled production unit was placed into operation.

Testing pilot and demonstration facilities was conducted with coho and chinook salmon (O. tshawytscha) and steelhead and anadromous cutthroat trout (S. clarki). Egg incubation and early fry culture employ standard techniques (Heath incubator; 1,000 gallon tanks fitted with pea-gravel bottom and air-lift recirculation). Fry, after one to two months feeding in tanks, are transferred to shaded wastewater-seawater ponds that maintain maximum summer temperatures below 19°C ("summer" ponds, Allen 1983, Plate A). Fish in summer ponds are fed commercial pellets. Pond banks of broken concrete rip-rap are colonized by benthic invertebrate providing an unknown amount of natural food. With occurrence of cool pond temperatures in late October and November, fingerling are removed from summer ponds, identified with fin marks and/or coded-wire tags (CWT) and released into unshaded "winter" ponds (0.15-0.20 ha) operated as static systems. At the beginning of rearing in the fall wastewater and seawater are mixed to produce an initial salinity of about 20-22 ppt. In order to enhance natural food production, winter ponds are filled with underwater reefs, primarily brush bundles (Hull 1983). At stocking densities of less than 30,000 fingerlings per winter pond, juveniles feeding only on natural foods grow at rates slightly better than wild stocks in local streams. Smolts produced in winter ponds are harvested by seining, trapping (voluntary migration), and pond draining. Voluntary migration depends on artificially creating water flows to induce smolt out-migration. Water currents are directed into smolt traps by electric out-board trolling motors (Hume 1976; Del Sarto 1980) or by pumping (Allen 1983). Harvesting by voluntary migration is our preferred method of removing smolts from ponds because there is less handling than smolts harvested by seining or pond draining. Coho smolts harvested by trapping show elevated gill ATPase levels, migrate quickly to Humboldt Bay on release (Del Sarto 1980), and thus meet the criteria of a quality smolt (Royal 1972; Whale and Zaugg 1982).

Although voluntary migration is generally effective (50-76 percent of total smolts produced taken by traps), there are years when smolts have not entered traps (smolt removal by trapping only 10 percent). Present rates of smolt removal by trapping are not maximal since inhibition of DSM behavior occurs when warm spring weather elevates pond water temperatures beyond 17°C in late April or early May during periods of peak migration.

Initial coho smolt migration in March is associated with the general physiological conditioning related to photoperiodism and increasing day length (Hoar 1976; Wagner 1974). We have studied factors associated with peak out-migration into traps but have not been able to find factors that produce consistent correlations between years (moon phase, barometric pressure changes, daytime light patterns, rainfall, wind patterns, or water temperature other than the fact that elevated values stop DSM as noted). McVicker (1985) analyzed by correlation and multiple regression, the influence of barometric pressure, sunshine, photoperiod, and moon phase or trap capture of coho smolts. The study included five pond-out-migrations covering four brood years. Moonphase and advancing photoperiod were the most closely correlated with DSM behavior but still could only account for 17 percent of the variation observed. Insufficient daily temperature and salinity records precluded use of these variable in her analysis. In the spring of 1982, a special study of pond temperatures and coho migration was completed (James, Lee 1985. Unpublished master of science thesis data. Fisheries Department, Humboldt State University, G. Allen, Supervisor). James data are presented as part of this report.

TERMINOLOGY

In this paper the term "smolt" is employed as a noun. It is applied to trapped coho and steelhead juveniles possessing either presmolt or smolt external morphological features as used by Allen (1976):

Parr: Skin color yellowish, fins yellowish; strongly developed parr marks.

Presmolt: Skin color only faintly yellow; fins clear with slight touches of black along distal edges; parr marks present but not bold.

Smolt: No yellow tinge to skin color; fins clear, with dorsal and anal fins with a very dark distal edge; parr marks faint to absent; scales with silvery sheen; dorsal portion of body often quite dark.

Coho juveniles in samples of non-trapped fish (seining, pond draining) were not difficult to assign to a morphological stage. For non-trapped juveniles of steelhead/rainbow trout assignment to categories was much more difficult. Trapped steelhead smolts exhibited considerable variability in external morphology (faint parr marks still visible, highly colored ventral fins, silvering not intense, highly evident black spots). Non-trapped steelhead rainbow trout of larger size (generally greater than 20 cm) possessing some body silvering, slight darkening of distal edge of fins, faint but readily visible lateral red bands, and robust general body shape, were classified as "large trout".

EXPERIMENTAL OPPORTUNITY

In addition to the previously noted unique weather pattern of spring 1986 during our pond and stream DSM studies, a second experimental opportunity arose by having coho parr of the same parental stock in the three environments (Winter Pond No. 1, Janes Creek, Jolly Giant Creek). The opportunity

developed as follows. Coho smolts (1981 brood, Iron Gate Hatchery stock) were identified by coded-wired tags (CWT), released to enter ocean fisheries, and returned to at least four streams in Arcata Bay (north arm of Humboldt Bay) (Allen 1985). Most marked adults were taken from Jolly Giant Creek where smolts were released. Half the females were allowed to spawn in small artificial spawning grounds constructed in the creek, while the other half were taken for artificial propagation. Marked coho salmon strayed into Janes Creek and spawned (one CWT carcass recovered in fall of 1984 and coho fry recovered from the creek in June of 1985). Native coho salmon adults have been absent from both Jolly Giant and Janes creeks for decades, and adult salmon recovered from the creeks have resulted from plantings of artificially propagated smolts. Thus differences in DSM behavior of coho smolts in the three habitats we studied in 1986 would not be confounded by differences in genetic backgrounds.

A third study opportunity in spring 1986 developed from the initially testing of our second winter pond using steelhead/rainbow trout. We placed 2,195 yearlings (12.3-24.8 mean fk length) into the pond on 3 March 1986 primarily to test a new smolt-trap design that had been intalled in the pond. Since the two winter ponds shared a common bank, we routinely counted smolts and took water surface temperatures at the same time for both ponds, providing for a field comparison of DSM behavior as measured by trapping in two similarly-operated ponds (coho, Winter Pond No. 1, and steelhead/rainbow trout, Winter Pond No. 2).

METHODS

Trap used to remove coho smolts from Winter Pond No. 1 originally had only a single submerged pipe as an entrance (Allen 1983, Plate B) (Table 1). In 1986, a second entrance through a surface channel was added (Figure 1). Steelhead smolts in Winter Pond No. 2 were trapped in a redwood box located immediately adjacent to the pond bank (Figure 2). Water flowed into the box through a funnel entrance located flush with the floor of the box, drawn by an air-lift located at the opposite end of the box.

DSM migration behavior of coho smolts in streams (Jolly Giant and Janes Creek, Table 1) was monitored by catches in two McBane traps located in parallel. Trap site on Janes Creek was located about two km from Humboldt Bay and trap site on Jolly Giant Creek was about one km inland. Janes Creek traps could not filter the entire flow of the creek (estimated 80-90 percent under non-freshet flows), while the entire non-freshet flow could be filtered by traps in Jolly Giant Creek.

Smolts were removed from pond traps by fisheries technicians at least twice daily (mid-morning and early-evening periods), and more frequently during days of heavy smolt catches. Traps in streams were visited at least once a day, with time of checking traps variable depending on schedules of fisheries students conducting the studies.

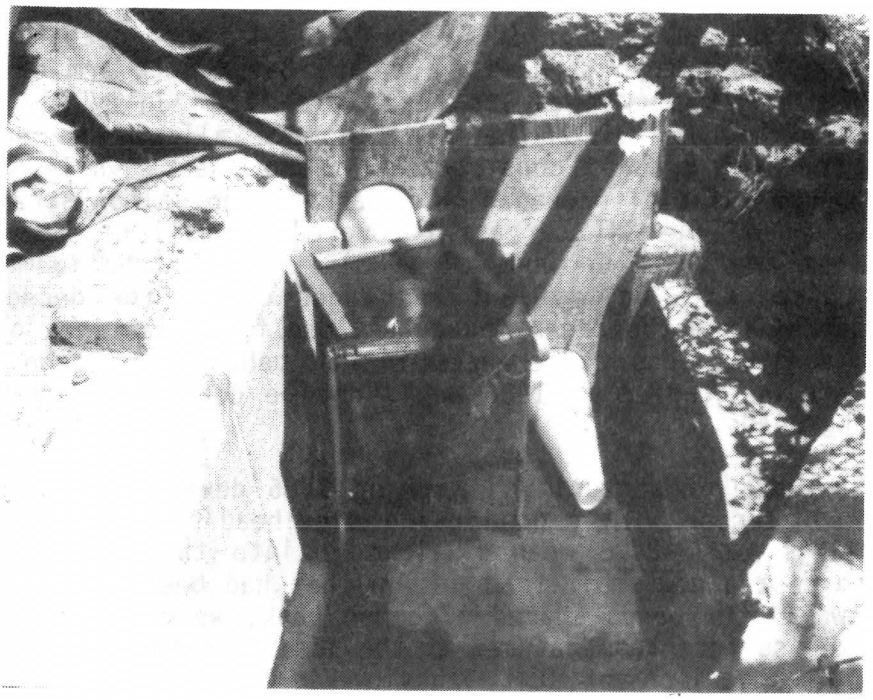

Figure 1. Smolt trap entrances, Winter Pond No. 1, City of Arcata wastewater aquaculture system, spring 1986 (Funnel from surface channel on left, funnel frum submerged pipe on right).

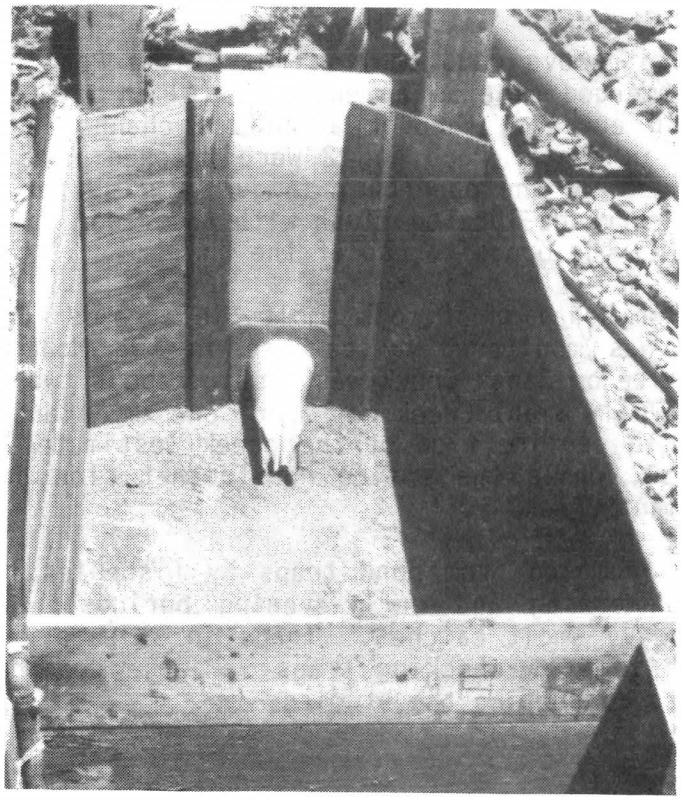

Figure 2. Smolt trap entrance, Winter Pond No. 2, City of Arcata wastewater aquaculture system, spring 1986 (Airlift located at base of board in immediate foreground).

Table 1. Rearing environments and 1985-brood smolts available for DSM studies, spring 1986, City of Arcata, California.

Environment	Species	Description
Winter Pond No. 1	Coho	AD-CWT juveniles from eggs of artificially spawned adults of 1982 brood returning to Jolly Giant Creek and Freshwater Creek, north arm Humboldt Bay.
Winter Pond No. 2	Steelhead	Unmarked juveniles of Mad River stock and from rainbow brood stock at HSU HSU hatchery originally steelhead stock from Mad River.
Janes Creek	Coho	Unmarked juveniles from natural spawning in 1985 of 1982 brood adults straying to Janes Creek.
		Ad-CWT smolts trapped from Winter Pond No. 1 and released into Janes Creek at three sites (Table 2).
Jolly Giant Creek	Coho	Unmarked juveniles from natural spawning in 1985 of 1982 brood smolts released into the creek spring of 1983.
		Ad-CWT smolts trapped from Winter Pond No. 1 and released into Alliance Road sediment basin (Table 2).

All smolts captured were measured for fork length, examined for finmarks and for their general physical condition. Stream water temperatures were recorded with hand mercury thermometers accurate to 0.5 C. Pond temperatures in 1986 were taken with a probe accurate to 0.1 C and a hand thermometer accurate to 0.25 C. Pond temperatures in 1982 were taken by probes attached to recording thermographs. Loss of hand thermometer in mid-April resulted in a gap in our temperature record for Janes Creek, but fortunately there was no change in the general weather pattern to influence stream water temperatures until a small storm system produced a freshet in early May.

In order to estimate the number of 1985-brood smolts produced by the natural spawning in 1982 in Janes and Jolly Giant creeks, we planted ad-marked Ad-CWT tagged coho seined from Winter Pond No. 1 (Table 2). Ad-CWT coho were released into Janes Creek at three sites extending from 0.7 to 3.1 km above the DSM trap site. These marked smolts could be identified as to release site by size. Marked coho were only released at one site in Jolly Giant creek and were of random size. These marked pond-reared coho produced comparative data on DSM behavior of coho smolts.

Table 2. Number and size of CWT-tagged coho seined from Winter Pond No. 1 and released into Janes Creek and Jolly Giant Creek, 15 April 1986.

Size (cm)	Number Released	Location of Release	Distance above trap site (km)	Remarks
<14.5	35	Janes Creek, Foster Avenue	0.7	Stream passes through dairy farm pastures.
15.0-16.0	26	Janes Creek, Hwy 101 overpass	2.2	Area where coho fry sampled in 1985.
>16.0	28	Janes Creek, West End road	3.1	North fork of Janes Creek flows through an industrial area. Heavy aquatic vegetation in creek.
All sizes	15	Jolly Giant Creek (Alliance Road sediment basin)	0.9	Known area of maximum density of naturally-produced coho parr during summer months.

RESULTS

DSM migrant behavior in Jolly Giant Creek could not be monitored because of lethal water quality arising from unidentified sources of non-point pollution that occurred both above and below the trap site. In a sediment basin located above pollution source (Alliance Road) a healthy population of unmarked coho underwent normal smolting morphology (Table 3). A total of only four coho smolts were trapped, all dead or moribund (Table 4). Three smolts originated from natural spawning and one was from the 15 Ad-CWT smolts planted into the Alliance Road sediment basin (Table 2). Three of the four recoveries were recorded in late April which has traditionally been the period of peak outmigration of coho from our ponds (Del Sarto 1980, Leonhardt 1984) and in adjacent streams (Jacoby Creek, Harper 1980).

First DSM coho was trapped in Janes Creek on 8 April at water temperatures of 12^{o}C (Figure 3). Intensity of out-migration remained relatively constant. Of seven Ad-CWT marked coho released into Janes Creek, six were from fish released 0.7 km above the trap (Foster Avenue, Table 2). Recoveries from 17 April to 13 May did not produce a catch pattern suggesting that a period of peak migration had occurred. Average size of native (unmarked) smolts changed with time of capture, with earlier-arriving smolts larger on the average than later arrivals (Figure 3). Since marked fish recaptured came mainly from fish released at one site and these fish varied only about one cm in fork length at planting, a uniform size with time of capture of Ad-CWT could only occur. A small freshet inundated traps near mid-May so there was a possibility that a peak of DSM behavior might have gone unrecorded.

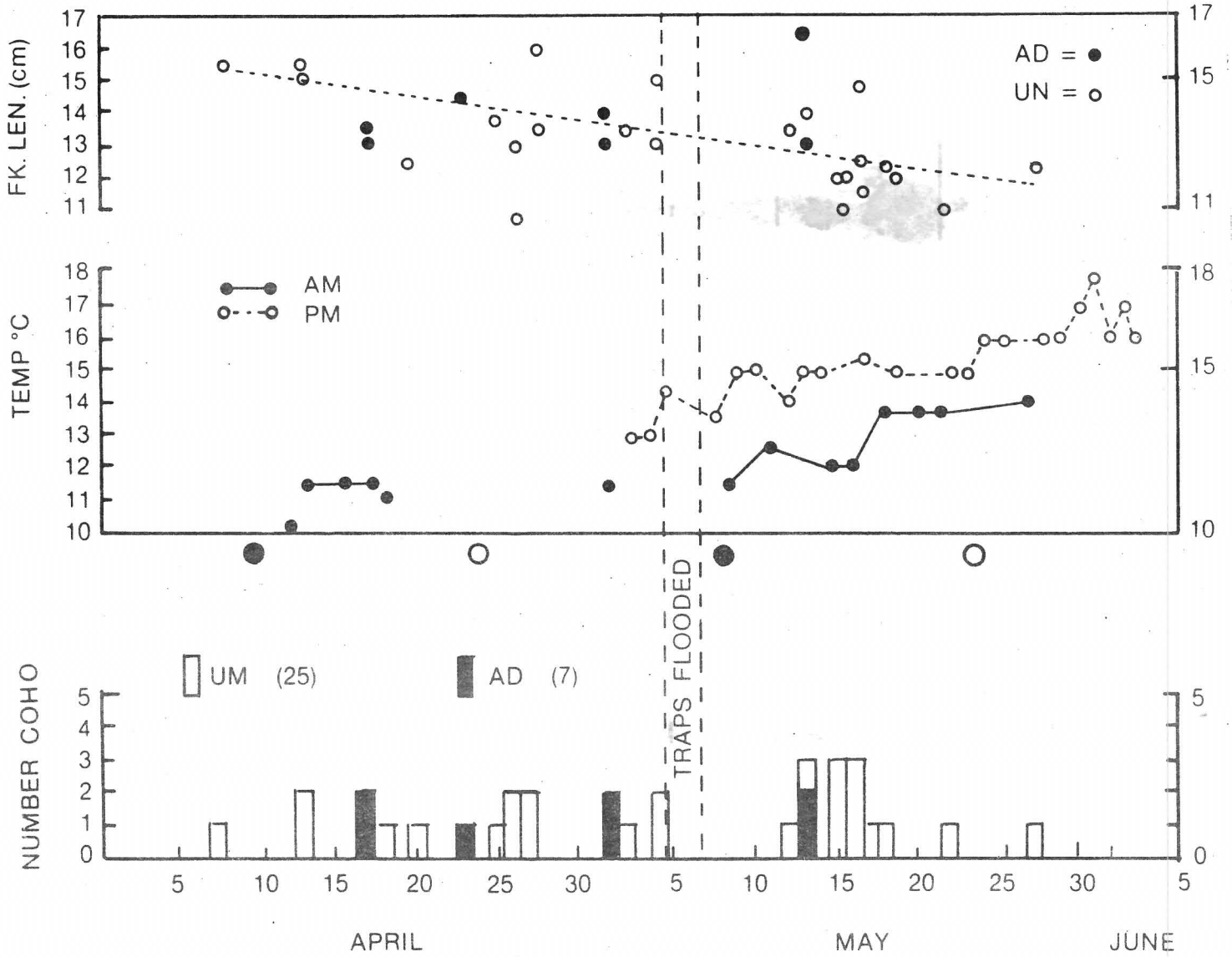

Figure 3. Size and time of appearance of unmarked (UM, naturally-spawned and stream-reared) coho smolts and Ad-CWT marked (Ad, artificially-spawned and pond-reared) coho smolts in DSM traps, Janes Creek, April-June, 1986.

Table 3. Number, size, and morphological stage of naturally spawned juvenile coho salmon sampled by three 20-foot minnow seine sweeps through Alliance Road sediment basin, Jolly Giant Creek, City of Arcata, February and April 1986.

Date sampled	Number Coho	Fork length (cm)			Stage		
		Min	Mean	Max	Parr	Presmolt	Smolt
25 Feb 86	26	9.4	11.5	12.9	25	1	0
3 Apr 86	15	11.0	12.2	15.5	0	15	0

Table 4. Number, size, and condition of pond reared (Ad-CWT) and naturally spawned (unmarked) coho smolts recovered in Jolly Giant Creek downstream-migrant traps, 25 March - 5 June 1986.[1]

Date Trapped	Mark	Fork length	Remarks
27 April	Ad-CWT	16.5	Second day of major pollution event.
	UM	13.5	Both smolts dead.
28 April	UM	13.0	Smolt dead.
3 May	UM	12.0	Smolt dead. Solvent smell and film on water still present.

[1]April 16-17 trap inundated from rise in creek water from unknown cause (possibly draining of city water storage tank for yearly cleaning). May 4-7 trap was inundated by freshet.

In 1982, intensity of DSM migration of coho smolts in Winter Pond No. 1 was measured by converting actual number of smolts trapped to the catch per hour of actual trapping (Leonhardt 1984). James compared these data to the average daily surface and bottom temperatures of Winter Pond No. 1 (Figure 4). The major peak of out-migration correlated with rising water temperature (20 April), but another major pulse of out-migration was associated with uniform temperature (15 April).

In 1986 coho out-migration in Winter Pond No. 1 began in mid-March and continued until early May when the pond was drained (Figure 5). Coho smolts trapped in 1986 from Winter Pond No. 1 contributed 51 percent of all juveniles produced (24 percent by seining, and 25 percent at pond draining; total production 2,936). In a sample of coho removed at pond draining on 13 May 1986, only three parr were recorded (9.9-11.9 cm range). Most coho (95

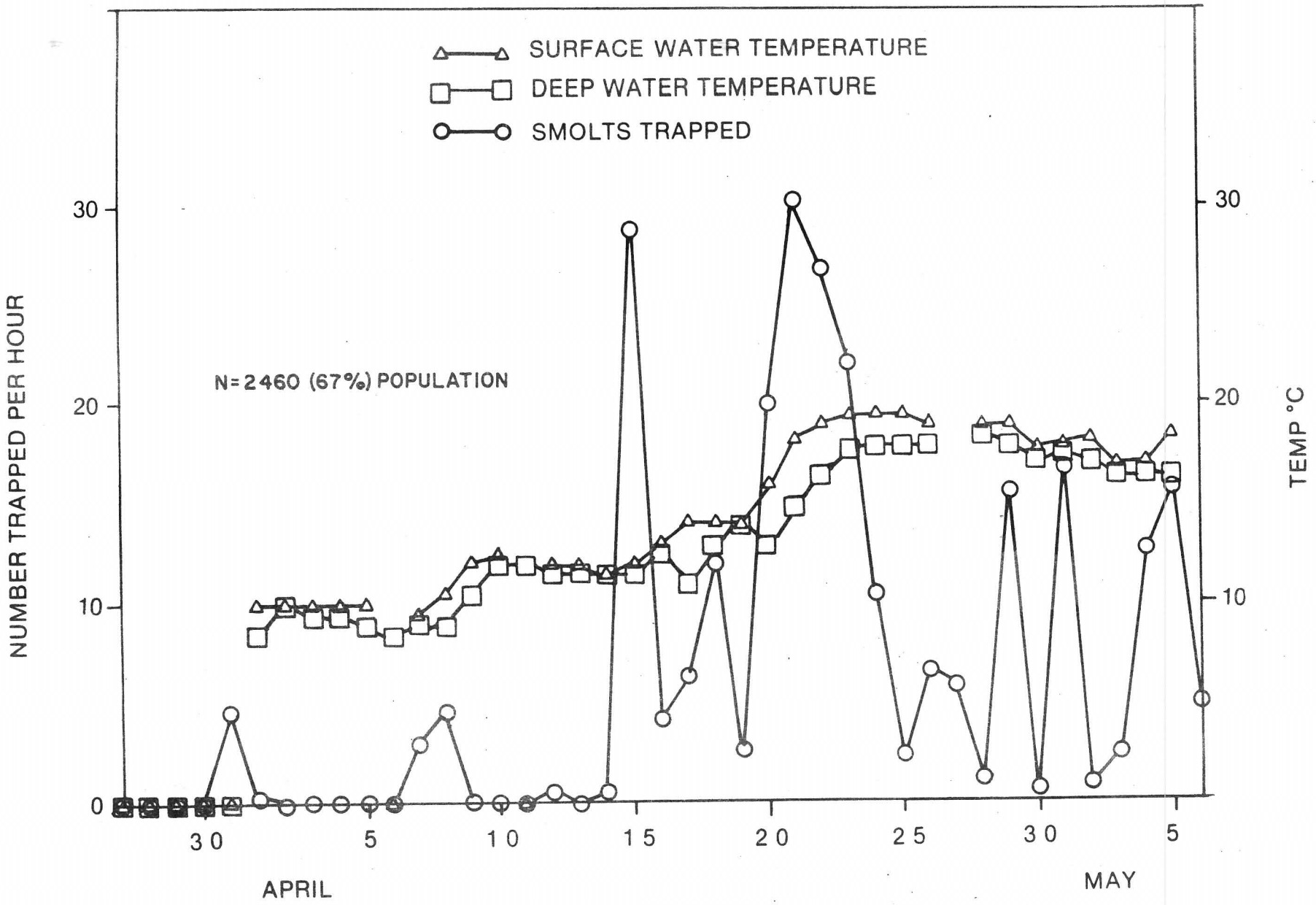

Figure 4. Catch of coho smolts in trap compared with surface and bottom water temperatures, Winter Pond No. 1, City of Arcata wastewater-seawater aquaculture project, March-May, 1982.

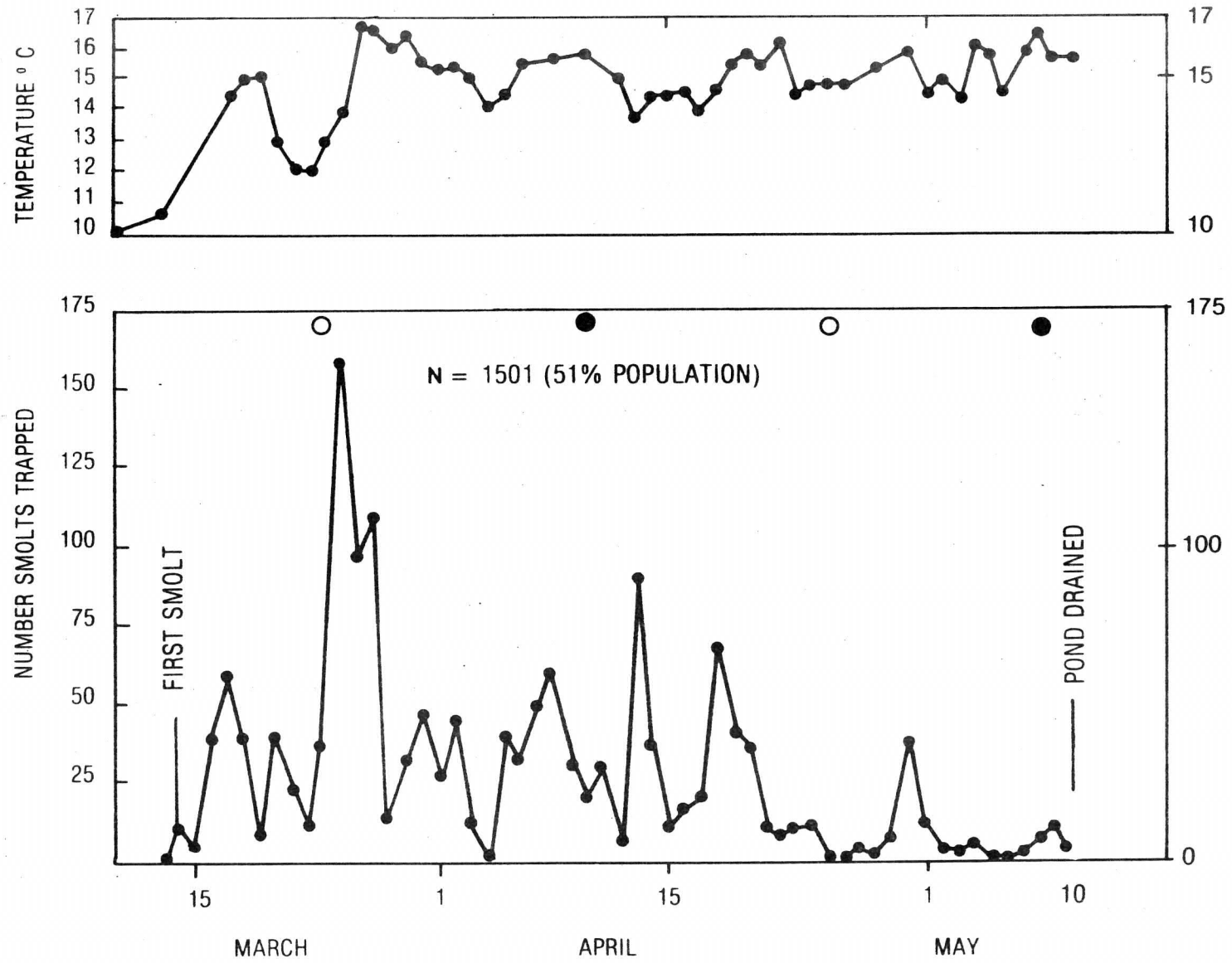

Figure 5. Catch of coho smolts (Ad-CWT tagged fish from artificial spawning) in trap compared with moon-phase and surface water temperature, Winter Pond No. 1, City of Arcata wastewater-seawater aquaculture project, March-May, 1986.

percent) averaged 14.3 cm and were all in presmolt and smolt morphological stage. Migration started and peaked in mid-March following two rapid increases in pond water temperature ($5^{o}C$ rises over 2-3 day periods). Following peak migration when water temperature reached a maximum of $17^{o}C$ an extended period of relatively cool, stable water temperatures ($15\text{-}16.5^{o}C$) occurred. Coho entered the trap in small pulses during this cool-water regime. No obvious environmental factors could be associated with these pulses (Figure 5).

Of steelhead/rainbow trout yearlings released into the Winter Pond No. 2, only 211 were trapped as smolts (10 percent) (Table 5). Trap catches included 61 parr. Two peaks of smolt migration were recorded. The first in late March correlated with a rapidly rising water temperature. A second in early May correlated with a passing storm front (Figure 6) and included in a three day period 35 percent of all steelhead smolts trapped (May 4-6, Figure 6). Trap catches ceased when pond temperatures exceeded $17^{o}C$. Trapped smolts originated from progeny of HSU hatchery trout brood stock (Mad River steelhead origin), and from winter-run steelhead taken from Jolly Giant Creek. Smolts from both stocks were of a consistent average size (18-20 cm) (Table 6). In

Table 5. Number by life-history stage of rainbow/steelhead trout removed from Winter Pond No. 2, City of Arcata Wastewater Aquaculture System, Spring 1986.

Method of Removal	Life history stage				Total
	Parr	Pre-smolt	Large trout	Smolt or Smolt-like	
Seining					
18 April (#1)	30	47	3	35	115
18 April (#2)[1]	-	-	11	-	11
22 May	16	9	20	27	72
Trapping	61	0	0	211	272
Draining					
Live	375	(-)[2]	109	189[2]	673
Mortalities	-		-	-	12
Total	482	56	143	462	1155

[1]Only large trout removed from pond. Other fish returned to pond unmeasured.

[2]Rapid processing of fish netted during pond draining required qualitative judgment by student workers. Pre-smolts were classified as smolts for immediate marking and release.

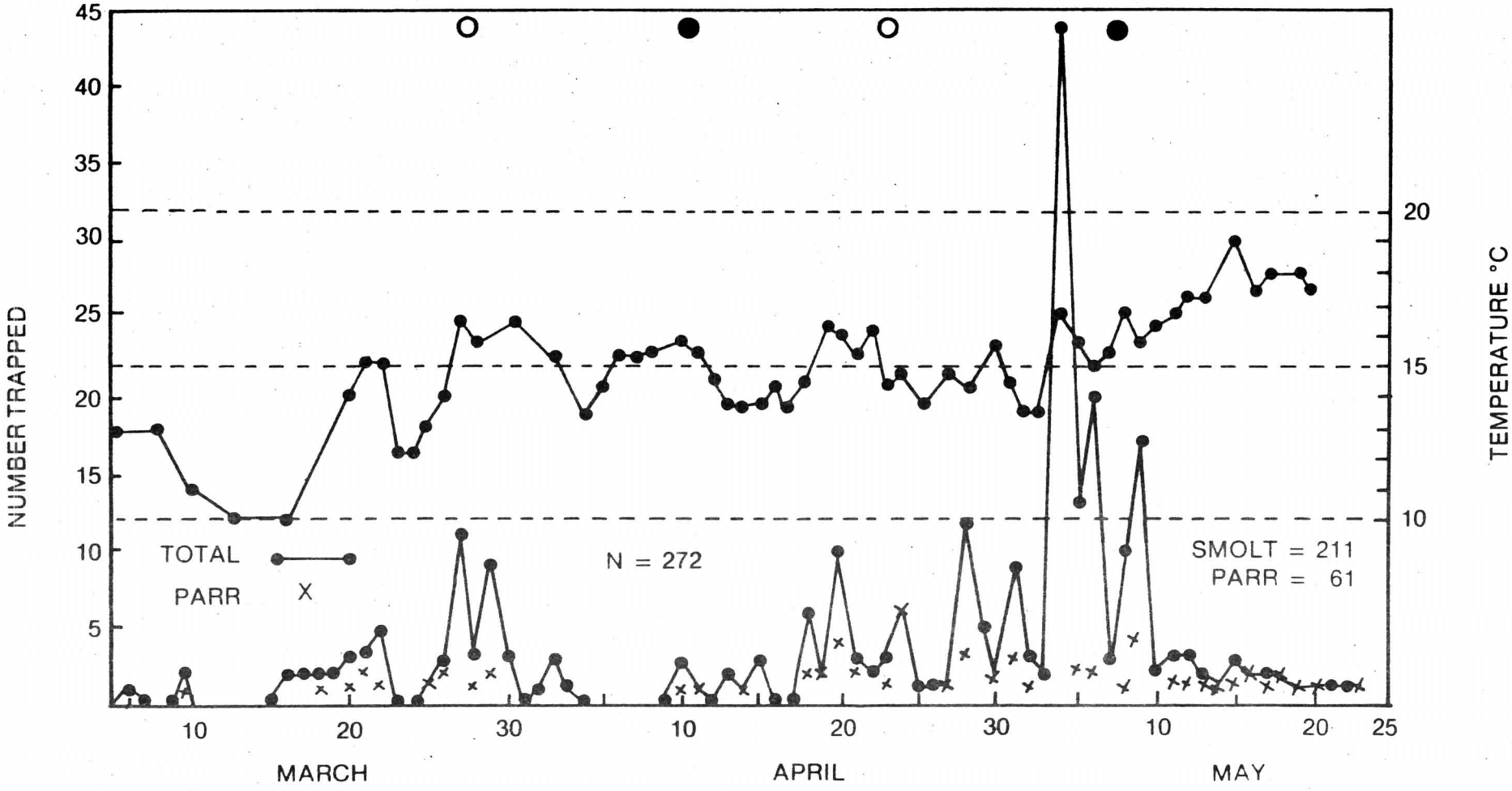

Figure 6. Catch of steelhead-rainbow trout in smolt trap compared with moonphase and surface water temperature, Winter Pond No. 2, City of Arcata wastewater-seawater aquaculture project, March-May, 1986.

Table 6. Length, weight, and condition factor of rainbow (UM) and steelhead (LV-marked) smolts captured in smolt trap, Winter Pond No. 2, 11 April and 5 May, 1986.

Measure	Sample period			
	11 April		5 May	
	UM	LV	UM	LV
Fork length (cm)				
Mean	19.9	18.0	19.8	20.0
Range	15.4-24.0	17.6-18.4	16.5-23.8	20.0
Weight (gm)				
Mean	96	60	74.0	66.6
Range	44-166	50-70	41.5-128.0	66.6
CF	1.22	1.03	0.95	1.11
N	10	2	25	1

a sample of 26 steelhead smolts trapped on ~~5~~ 4 May 1986, in addition to normal smolt morphology we noted 25 percent of the individuals exhibiting anal fins with very intense darkening of the distal edge, and with the anal rays layered with extremely irridescent (silvery) scales.

DISCUSSION

Peak out-migration of coho smolts in 1986 from the pond occurred a month earlier than recorded in previous years (e.g. 24 April 1975; 25 April 1978; 19-20 April 1979; 19-23 April 1982). The early migration in 1986 was correlated with major differences in water temperature regimes. Normal weather patterns produce a gradual warming occurred during spring months, with average pond water temperatures reaching 17 C in late April or early May (2 May in 1975 and 1 May in 1981). In 1986 fierce winter storms with freezing rain swept central and northern California in early March, keeping pond water temperatures around 10 C. This was followed by a period of unusually hot, clear weather that produced the rapid rise in pond water temperatures (17°C on March 27) (Figure 5, 6). In contrast, small urban creeks remained cool despite the intense warm weather of March 1986, with water temperatures only reaching or exceeding 15 C by late June (Figure 3). Out-migration behavior of coho smolts of the same stock in stream and pond environments in 1986 in which freshet conditions were few or absent showed water temperature apparently the most important environmental stimulus to out-migrant behavior under conditions studied ("releasing factor", Wagner 1974). Early migrational stimulus due to sharply using water temperatures, however, was only limited to about 24% of

the coho smolt population removed by trapping. This result was under a salinity level of about 10 ppt during the smolting and out-migration period.

Most juvenile steelhead placed in Winter Pond No. 2 were above the minimal size for smolting, but only migrated in small numbers with a late mid-March rise in water temperature. Major smolt out-migration was recorded in early May, the more usual time of DSM of steelhead smolts from stocks of the local area (Harper 1980). Only 39 percent of the steelhead that were left on pond draining were considered "smolt-like" (189/484, Table 5), although an unknown percentage of the smolt classification were probably in a pre-smolt stage.

Steelhead DSM smolt behavior inhibited by elevated water temperatures (above 17^{o}C) was congruent with temperature inhibition of gill sodium-potassium stimulated adenosine triphosphatase activity reported by Adams et al. 1973 and Zaugg and Wagner 1973. Brackish-water rearing environments (20 to 10 ppt) have not ameliorated the inhibitory effect of elevated temperature. We have noted in previous rearing experiments that only a small percentage of "smolt-like" steelhead larger than the general minimal size required for smolting (15-17 cm range) exhibited DSM behavior by entering outmigrant traps. Johnson (1981), however, produced in pens 65 percent "smolt-like" steelhead feeding ground Dover sole carcasses. One of his Dover-sole fed smolts released into Jolly Giant Creek returned as a ten-pound adult after two years in the ocean (1% rate of return). Yearling steelhead-rainbow trout in Winter Pond No. 2 were only fed lightly, the pond had only a few brush-bundles, and a minimal level of natural food was probably present due to a short period before pond filling and introducing test fish. Thus I feel there might have been a nutritional factor impairing smoltification and DSM migration behavior patterns which contributed to the low rate of production of steelhead smolts in Winter Pond No. 2 in spring 1986.

MANAGEMENT CONSIDERATIONS

We consider that removal of smolts from our pond units by voluntary migration will cause less stress than smolts removed by seining or by pond draining. Poor water-quality often occurs during the late stages of pond draining (high temperature, increased turbidity, low dissolved oxygen). Presumably such conditions produce stress that could reduce marine survival, although this was not shown for 1981-brood smolts harvested by pond-draining which had the same rate of escapement to Jolly Giant Creek as trapped smolts (Miyamoto 1979). Smolts taken at pond draining, however, were retained for about a week in cool water. Since our present facilities are not adequate to process large numbers of smolts in a short period of time or to hold large number under a cool-water regime, extending the period of smolt removal by trapping is very important management strategy for improving our operations. Controlling water temperature by an inexpensive, rapid response, pond shading device is under consideration for our winter ponds. Specific objective of this pond shading will be to keep pond temperatures under 17 C during our normally expected out-migrant period for coho, (late April-early May), and mid-May for steelhead. The goal appears feasible for coho but dubious for steelhead given our current technology for shading ponds and minimal level of finances.

Additional management options might exist in the manipulation of pond salinities. Hume (1976) found chinook out-migration could be curtailed by pond salinities above 10 ppt. Most of our coho experiments have ended with salinities in the ponds at or above 10 ppt. We plan on pond salinities ranging from 5 to 8 ppt during spring smolt migrations in future operations.

ACKNOWLEDGMENTS

Graduate students assisting with smolt trapping at ponds included: David Couch, Dave Oullette, Brian McFadden and Stephen Fox. Undergraduate students monitoring smolt migration in streams were: Geir Aasen, Janes Creek, and George Waller, Jolly Giant Creek. Jay Brown assisted with graphics and Delores Neher, California Cooperative Fishery Research Unit, assisted with preparation of the manuscript.

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Distribution of Oregon coho and chinook salmon in the ocean fisheries.

Robert L Garrison

ODFW

The Oregon Department of Fish and Wildlife initiated a Stock Assessmant study in 1976 to evaluate the distribution of catch and survival rates of Oregon coastal chinook and coho stocks. This project is responsible for tagging a representative group of smolts from each major coastal chinook and coho production release from ODFW hatcheries and for tagging samples of native stocks that are being evaluated for potential future use in the hatchery system.

This presentation summarizes the distribution of catch for some of the Oregon coastal and lower Columbia River chinook and coho stocks.

Early Columbia River coho represented by the Sandy stock usually enter the ocean fishery in California and progress norhtward in Oregon where approximately 71% of the harvest occurs. The remaining catch in usually made in southern Washington and northern California. The late Columbia River coho generally are caught around the mouth of the Columbia River in northern Oregon and southern Washington. The Oregon coastal coho represented by the Nehalem, Trask, Salmon River, Siletz, Alsea, Eel Lake and Umpqua stocks have a catch distribution similar to

that of the Early Columbia River coho. The farther south the coastal coho enter the ocean generally the higher the contribution to the California catch and the less the contribution to the Washington fisheries. The contribution to Oregon from these stocks is usually in the range of 65 to 70%.

The Rogue and Coquille coho usually move north later in the season and therefor are caught primarily in Northern California. They enter the Oregon catch very late in the seasen in southern Oregon. Very few of the Rogue coho are caught as far north as southern Washington. Columbia River Tule fall chinook tend to be a northern stock and provide the bulk of their contrbution off the west coast of Vancouver Island in British Columbia and off Washington. A small catch of Tules is made off northern Oregon around the mouth of the Columbia River and as far south as Newport. Less than 1% of the Tules are caught in California. The Columbia River Bright fall chinook are a far northern stock caught mainly in Northern British Columbia and Southeastern Alaska. A few are caught off Washington and Northern Oregon as they migrate back to the Columbia River to spawn. The Willamette Spring Chinook is also a far northern stock very similar in its catch distribution to the Columbia River Bright fall chinook. They have been caught as far north as the Anchorage area and around the Aleutian Islands.

The Trask, Salmon River, Yaquina, Alsea, and Siuslaw fall chinook are also northern fall chinook stocks with their primary contribution occuring in the British Columbia and Southeastern Alaska fisheries. The Elk River fall chinook has a similar

northern pattern of migration except it does make a significant contribution to the southern Oregon catch around the mouth of Elk River in the extended troll season. This may be the result of a delay in entering the river that often occurs due to a sand bar that frequently discourages their entering the river before the first major fall freshet. The Rogue and Chetco fall chinook can be classified as southern stocks. Their contribution to the ocean fishery usually occurs in northern California and southern Oregon. The Rogue spring chinook catch is very similar to that of the Rogue fall chinook. The Umpqua spring chinook enters the ocean on the mid Oregon coast and has a catch distribution centered right off Oregon. They also make a minor contribution to the northern California, Washington and southern British Columbia fisheries. The Trask spring chinook catch is more northerly but does provide a small contribution to Oregon. Its primary area of catch usually occurs in British Columbia with small numbers being caught in Washington and Southeastern Alaska.

The Coquille spring and the Coquille, Coos, and Umpqua fall chinook have also been tagged but insufficient recovers have occurred at this time to characterize their primary area of ocean contribution.

A certain amount of variability occurs in the area if catch from year to year. The distribution of catch appears to be influenced by the changes in the ocean environment and the timing of the fishing seasons in the various catch areas.

5. GENERAL TOPICS

CABINET GORGE HATCHERY

Ed Schriever, Manager
Idaho Dept. of Fish and Game

Slide presentation of hatchery designs and concepts in operation. Designed capacity is for 20 million Kokanee fry at 1000 per pound.

Topics deal with egg husbandry and upwelling incubator operation. The emphasis is on quick yet accurate methods of enumerating, treating and picking up to 25 million eggs with limited manpower.

IRRIGON FISH HATCHERY UPDATE

PRESENTED BY: RAY HILL

Irrigon fish hatchery, located 3 miles west of Irrigon, Oregon, was completed in 1986 by the Army Corps of Engineers. Irrigon is one of 10 hatcheries included in the Lower Snake Fish and Wildlife Compensation Plan. The plan was authorized by congress in 1976 to compensate for losses in anadromous fish species attributed to construction of Corps dams on the river. Irrigon hatchery is Oregon's summer steelhead facility for this plan. Production schedules call for 1,350,000 smolts @5.0 fish per/lb for the Grande Ronde River system and 330,000 smolts for the Imnaha River system. Eyed eggs are received from Wallowa hatchery near Enterprise, Oregon, hatched and reared to smolt size and then transported by truck back to North East Oregon. Smolts are put into acclimation ponds or planted directly into the appropriate stream. Water for Irrigon hatchery is supplied by two Rainey wells. Total capacity is 25,000 gpm. Water temperature fluctuates from 52^{o}F during winter months to 62^{o}F in late summer. There are 32 20X100' raceway ponds completly covered top and sides by a bird netting to stop predation by fish eating birds. Please feel free to visit us when you are in the area.

FISH CULTURE IN NEW ZEALAND

Peter Brown
Fisheries Branch
B.C. Ministry of Environment and Parks
Kootenay Trout Hatchery
Wardner, B.C. VOB 2JO

From January to August of 1986, I was granted a leave of absence from my work at the Kootenay Trout Hatchery in British Columbia and travelled to New Zealand where a six month work experience had been arranged with the New Zealand Wildlife Service at their Ngongotaha Trout Hatchery and Research Station. My twelve year old son accompanied me and attended public school during our stay.

New Zealand is a small independent country which is only slightly larger than Oregon, or less than 1/3 the size of British Columbia. It is located in the South Pacific between 34°S and 47°S latitude which would equate in North America to southern Washington to southern California.

New Zealand is internationally renown for its trout fisheries, with such names as Taupo, Rotorua, and Tongariro. It is locally known for its South Island salmon fisheries. As no salmonids were native to New Zealand, all stocks have been imported, requiring 'acclimatization' of some sort or another. The acclimatizing and culturing of salmonids has a long and interesting history. Some important dates in that history are:

- 1865 to 1875 - Acclimatization Societies were formed by interested individuals to import flora and fauna common to their homelands.
- 1867 - First introduction of brown trout eggs from Tasmania.
- 1868 - First hatchery in operation.
- 1870's- First introductions of chinook salmon, called quinnat in New Zealand. These introductions were unsuccessful.
- 1876 - Acclimatization Societies received statutory powers as fish and wildlife administrative bodies.
- 1878 - First introduction of Tahoe trout from Lake Tahoe. This attempt was unsuccessful.
- 1883 - First successful introduction of rainbow trout from Sonoma Creek, CA to Auckland A.S. Although some minor introductions were made in later years, this is considered to be "the" parent stock of New Zealand's rainbow trout.
- 1901 - First successful introduction of chinook salmon from Baird Station, McCloud River, CA to tributaries of Lake Ohau, South Island, by the Marine Department.
- circa 1907 - Establishment of the Central North Island Conservancy under the Department of Internal Affairs. This was the first governmental control of a fish and wildlife area.

At the present time there are three bodies with responsibilities for freshwater fisheries:

1. Acclimatization Societies
   Historically up to 35 societies existed at one time. Presently, 22

societies enhance and/or maintain fisheries and wildlife resources under their jurisdiction. With statutory powers to institute and enforce their regulations, these locally elected societies have been given a great deal of autonomy. Each one seems to have its own operating philosophy; some are becoming very professional in their management techniques while others seem to continue with their old policies "because it's always been done that way". There is now a National Association of Acclimatization Societies which brings all of the societies together, and I think it is bringing about an overall improvement in management techniques. Funding for societies is from licence sales within their area. They generally hire and pay their own staff, as well as rely on volunteer assistance.

2. Department of Internal Affairs, Wildlife Service
A government department which functions as an acclimatization society. It has control over two areas, the Central North Island Conservancy (includes Rotorua and Taupo) and the Southern Lakes Conservancy, South Island. Funding is from licence sales with government subsidization. Staff are government employees.

3. Ministry of Agriculture and Fisheries (MAF)
A government department with several divisions involved in fisheries work. It has final responsibility to the Crown in relation to fisheries. Although it principally manages marine species, it is also involved with salmon enhancement, it is the control agency for aquaculture, and it carries out most of the country's freshwater fisheries research. Staff are government employees. Funding was by government allocation but has recently changed to become a cost recoverable operation.

As each society and the Wildlife Service were independent bodies, individual fisheries, (and wildlife), policies were developed. These policies often conflicted with and contradicted those of the others particularly in bordering areas. There was and is much disagreement, jealousy and animosity between the three organizations. There has never been a coordinated national freshwater fisheries policy. There is presently a reorganization attempt underway which may amalgamate at least the freshwater aspect of MAF and the Wildlife Service into a new Department of Conservation. Fish are cultured to one extent or another by each of the three bodies.

Most of my time was spent with the Wildlife Service and I will begin by describing their operations. The Ngongotaha Trout Hatchery is located near Rotorua. It was originally built in the 1930's as a game bird farm and was used to some extent as a trout liberating station. It began fully functioning as a hatchery in 1958. It has a protected spring water supply of 7200 l/m (1870 US gpm) flowing at a constant 11°C. The main hatchery building includes vertical stack incubators, forty 2.6m concrete starter troughs and six 5m X 2m rearing tanks. Ngongotaha has a fair variety of outside rearing containers from a couple of Burrow's ponds, earth bottom circulars, converted stock watering tanks, milk vats, etc. The variety has risen over a period of years as needs arose and usually money didn't. The Ngongotaha Hatchery raises rainbow and brown trout as well as a few brook trout-brown trout hybrids, called tiger trout. Annual production is variable but would average about 100,000 rainbow yearlings, 20,000 brown yearlings and 1,000 tiger yearlings, with a total mass of 2500 kgs being produced. Most eggs are collected from wild stocks though some brood fish are presently on hand for production of river resident

strains of both rainbows and browns. As numbers are obviously low compared to North American standards, their high priority is placed on the quality of the product as well as to the returns that these fish provide to the fishery. There is a research office and dry lab on the property. A great deal of the hatchery's work in the past 4-5 years has been directed toward the rearing of specialized groups of trout for research stocking programs. Dr. Peter Mylechreest, the research scientist for the Rotorua Lakes district, has many projects on the go, including the Tarawera selective breeding program. Much of my time was spent on this program. For many years, Lake Tarawera was considered to be the most consistent producer of large rainbow trout in New Zealand, producing many fish over 4.5 kg (10 lbs). From the time of its original stockings, probably around the turn of the century, up until the 1950's, its population was self-sustaining. However, heavy fishing pressure brought the need to supplement the lake with hatchery stockings. The plantings over the next 20 years, by the Wildlife Service utilized an earlier maturing (2 year old) stock from Lake Taupo. The average size of the fish declined significantly until by the late 1970's very few fish over 4.5 kg were evident. Dr. Mylechreest's work has centered on the premise that by re-introducing stocks by later maturing (3-4 years old) rainbows, produced from remnants (of the original population) the overall size of the rainbows in Tarawera can be brought back to its former levels. One of the major spinoffs of this project has been the hard won co-operation which has developed between the angling community and the Wildlife Service. Although one stream was trapped in 1986, the Service cannot maintain traps on all of the streams of Tarawera. Also, because many of the largest fish are caught at the stream mouths, or in the outlet stream just prior to spawning, particularly the more aggressive males, a voluntary system of angler donations of these prize fish has been instituted. In this process various angling clubs are given responsibility for a particular stream mouth. They are supplied with equipment to hold the fish after capture, as well as a radio to contact the Wildlife Service to arrange for pickup of the fish. With the use of effective holding equipment, the fish are generally held at the capture site for a minimum of 12 hours and possibly longer depending on local conditions. This gives the fish the opportunity to normalize after the initial stress of capture. The fish are then transported back to the Ngongotaha Hatchery to their quarantine area for holding, spawning and eventual return to Tarawera. This is a high profile project and a great deal of care is taken in the handling of these fish that the anglers feel still belong to them. Special floating holding bags and tubes as well as carrying sleeves have been designed and made using non-abrasive fabrics. They work very well for a project such as this. The Tarawera program is becoming an integral part of the fisheries management plan in the Rotorua area.

The second Wildlife Service hatchery is located at Turangi, near the south end of Lake Taupo, on the famous Tongariro River, after which it is named. This hatchery produces up to 100,000 rainbow yearlings, though they act as a collecting station for up to 300,000 rainbow eggs per year (Taupo stock). Many of the eggs and fry are distributed to the acclimatization societies, as well as to Ngongotaha.

Both of these hatcheries feature children's fishing ponds which are maintained as a public service to encourage young people to take up the sport, with an emphasis given towards fly fishing. These ponds are only open 6 or 7 Sundays in the year and in co-operation with local

fly fishing clubs, the children are first instructed on fly casting technique, then they must purchase their angling licence, and only then are they allowed the opportunity to test their skills. After they've caught their fish it has to be weighed and measured. It appears to be a very popular and successful program.

The third Wildlife Service hatchery is located at Wanaka on the South Island. This small facility operates on a very limited water source. They raise a wide variety of species including brook trout, lake trout, and their hybrid, splake, as well as Atlantic salmon and chinook salmon. Their incubation and rearing tanks are similar to those described for Ngongotaha. A fair proportion of their egg supplies come from brood stocks. I noted in my diary the small numbers of brood fish and the limited genetic background, and am concerned with the future of their program. They do have the real problem of trying to keep alive species that are becoming quite rare, and they cannot import salmonids into the country any more. Plans to incorporate the production from the Wanaka Hatchery into a new facility to be built near Queenstown are a possibility in the near future. This modern hatchery is being built by New Zealand Electricity as mitigation for their dam project on the Clutha River system.

We were given the opportunity to tour a few salmon facilities, both public and private, in the Christchurch area. This tour was in late May which was at the very end of the salmon spawning season, (corresponds to our November). Nelson Boustead, a pathologist with the Fisheries Reasearch Division of MAF was our guide and companion. Our first stop was a private facility, the Peacock Springs Salmon Farm. They grow chinook salmon on site in freshwater to the 500-750 gm size. Eggs for this operation are from their own brood stock as well as being purchased from MAF at the Glenariffe Research Station. This operation includes a complete, modern processing plant on site, they even do their own hot and cold smoking. They hope to be producing 60 metric tonnes annually in the next year.

Our next stop was the New Zealand Salmon Co.'s Coleridge Hatchery on the Rakaia River. This station was originally intended to be a sea ranching operation, however because of its distance from the ocean, the market quality of the fish was unsuitable for the fresh market. It now operates as a smolt station for their two large grow out projects at Tenburn and Stewart Island, as well being the source of their eggs. They collected 4 million eggs of their own in 1986 and purchased a further 1 million from Glenariffe Station.

We then visited the Glenariffe Salmon Research Station operated by the Fisheries Research Division of MAF. It is also on the Rakaia River a few miles above Coleridge. This facility began as a fish counting fence in 1965 and has been gradually added to over the years by a couple of people with lots of ingenuity and of course, no money. The majority of fish trapped are chinook salmon though some trout are passed through as well. They have a brood stock of sockeye salmon on site. The salmon are sorted at the trap then have to be individually carried over to the adult holding ponds, where they are held for later spawning. The eggs which are fertilized on site are incubated in modified pails set up in an empty raceway. Eggs for transfer to other facilities are spawned into plastic bags with the sperm being stored separately, fertilization taking place when they arrive at their final destination. The spawning season is in April and May, with the fry being ponded about August.

Since 1983 (1982 brood) an intensive time and size of release study has been undertaken with their chinooks and which are beginning to produce some very good results. The best returns to date have been from three groups released in July 1983 (corresponding to our January) as almost yearlings at 65 gm. The total of heads actually recovered and tags read has exceeded 7% in each of the groups.

Our trip to Christchurch ended at the Silverstream Hatchery which was closed as a rearing station in 1984 due to economic problems and poor water quality. Its main water supply, a tributary of the Waimakariri River, is also one of several systems which contains Whirling disease (Myxosoma Cerebralis). This was the only disease of major importance to be introduced into New Zealand. First discovered in 1971, evidence confirms its presence as early as 1966. There was also a report of an isolated case of PKD in 1986. These diseases have only been found on the South Island. The Silverstream Hatchery, a MAF facility, operates as an egg eyeing station only at the present time, using a disease free well water supply. I did not have the opportunity to visit any of the acclimatization society facilities and am told they are very small operations. I did visit a grass carp station in Rotorua run by MAF which has been the centre of a great deal of controversy between MAF and the Wildlife Service.

I found in my travels that New Zealand fish culture looks very much toward the North American example, though because of their isolated location and a general lack of funds, have had to innovate and to their credit are making some good progress. I would suggest we keep an eye on Kiwi fish culture in the future.

USE OF PURE OXYGEN IN FISH CULTURE

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ABSTRACT

In most fish culture operations, the greatest limiting factors in rearing fish are water quantity and quality. This is especially true in facilities that must pump all rearing water either from wells or through gas stabilization devices. This project was designed to test the use of pure oxygen to increase carrying capacity of water available for use at a fish rearing facility. The potential exists to reduce required water flow by as much as 38% at temperatures of 10 degrees C while not exceeding 125% oxygen saturation. A reduction in water flow of this magnitude while still meeting the metabolic requirements of the fish could significantly reduce pumping costs and allow the rearing facility to operate more efficiently. An alternative to reducing total water flow is to increase fish loadings in available water. By-products of the increased oxygen levels are a reduction of nitrogen to below 100% saturation levels while maintaining total gas saturation at or near 100%, and increasing the quality of the fish rearing environment.

INTRODUCTION

Currently, Fort Richardson Hatchery fish production is being limited by lack of water. The cost of producing more ground water (if it can be found) is quite high, so alternative measures are being sought for meeting fish production goals. This project is designed to test the use of pure oxygen to increase the carrying capacity of water already available for use at the hatchery. By using pure oxygen, we have a potential to reduce required water flow by as much as 38% at a temperature of 10 degrees centigrade. A reduction in water flow of this magnitude while still meeting the metabolic requirements of the fish could reduce our cost of pumping water significantly. This technology is being used in European and State of Michigan hatcheries to produce dissolved oxygen levels above saturation while at the same time stripping nitrogen to below 100% saturation. These higher than normal oxygen levels allow very heavy loadings of fish to be supported. The immediate potential use for this technology at Fort Richardson Hatchery will be to increase oxygen saturation so that better use of available water can be made. A by-product of the increased oxygen levels is a potential reduction of nitrogen to below 100% saturation levels. Although the work will be carried out at Fort Richardson, the potential uses of this technology at other hatcheries are staggering.

The one criteria that almost all fishery biologists can agree upon is the need fish have for water to survive and grow. The major constraint faced by most fish culturists is to provide their fish with this much needed commodity. In actuality, the most important thing being provided is dissolved oxygen. Keeping this factor in mind, by increasing oxygen availability we should be able to increase production capacity without increasing water flow. This can be acheived through increased pond loadings. An added benefit of increased oxygen saturation or partial pressure is in the passive transport of oxygen across gill membranes. When fish are initially ponded and fed mash, there is a tendency for them to exhibit hyperplasia and/or hypertrophy of gill membranes. This stress is sometimes enough to let other pathogenic agents get the upper hand and cause severe mortality. By improving their environment, we may produce higher quality fish with fewer disease problems, better growth, and higher survival.

Unless either temperature or pressure is manipulated, we cannot supersaturate water with oxygen or nitrogen by using the atmosphere which surrounds us. All we can do is approach saturation (100%) levels. Remember that the atmosphere is made up of roughly 20.9% oxygen and the balance (79.1%) nitrogen, argon, and carbon dioxide. For the purpose of discussion, we will refer only to oxygen and nitrogen as making up the atmosphere. Again, whether we are removing nitrogen or adding oxygen to water, all we can hope to do is

approach 100% saturation levels. The closer we get to that level, the more energy is required to acheive each additional increment. By using pure oxygen which is about five times the partial pressure of atmospheric oxygen, we can supersaturate the gas in water. Since other gases can be physically displaced when pure oxygen is added to water, nitrogen supersaturation (which is harmful to fish) can be reduced or eliminated completely.

MATERIALS AND METHODS

A three phase approach will be used to execute this project. Phase I will be one of design, purchasing, and construction; Phase II will test the efficiency of the system without fish; and Phase III will compare duplicate lots of fish reared using supersaturated oxygen and controls.

PHASE I

Four incubation building raceways (.91m X 9.1m X.76m) will be used for this project. The raceways will be in one bank, operating off one pneumatic temperature controller to remove any possibility of temperature fluctuations between test groups. Raceway bank 4 was chosen for the experiment because of location relative to the control room and logical placement of the oxygen generator. During Phase I, a liquid oxygen delivery system will be installed. This liquid oxygen supply will be used until we receive and install the actual oxygen generator in Phase II. The liquid system will then become a backup supply of oxygen in case of oxygen generator failure during Phase III. A single liquid oxygen bottle should provide enough oxygen for approximately 40 days at the rate of use we expect. The liquid oxygen bottle will be placed in a stand at the head of the test raceways (4A and 4B). An oxygen/water contactor will be installed at the head of each of the two test raceways. The oxygen supply hose will be split, and a regulator installed ahead of each contactor. Mass flow meters will be added to each supply line for accurate measurement of oxygen flow. Back-up regulators will be stored in the incubation building for fast replacement should a failure occur. The contactor itself will be a vertical pipe (8" PVC) approximately five feet in length. One contactor will have a plexiglass window in the side to allow us to view inside conditions. Oxygen will be metered directly into the top portion of the pipe where there will also be a vacuum gauge. Discharge from the contactor will be through a four inch valve below the water level in the raceway. The contactors are designed to handle a flow of approximately 425 liters per minute (maximum design flow for these raceways). Modification of the water delivery system will be necessary for both test raceways. The inflow pipes will have to be extended upward to make room for the contactors. Existing water supply valves in both test and control raceways will be replaced with valves allowing finer

adjustment of flows. Four new standpipes will be manufactured for the study raceways to match the length/width/depth relationship of the main outside production raceways during Phase II testing.

Monitoring and alarm capabilities are an extremely important part of this entire project. Dissolved oxygen and total dissolved gases must be continuously monitored in the influent and effluent of both test raceways and at least one of the control raceways. To accomplish the monitoring tasks, a minimum of six total gas and oxygen monitors will be used. The probes will be tied into the new Spartan monitoring system now being installed at Fort Richardson. If oxygen flow were to stop to either of the two contactors, the influent oxygen probes would note the drop in oxygen level and create an alarm situation. The same would occur if the effluent oxygen level were to go below the minimum set point.

PHASE II

During this phase of the project, multiple experiments will be run without fish in the system to determine how efficiently the system will operate under varied conditions. The oxygen generator will be installed and tested during this phase. Following is a list and description of tests to be run during Phase II.

Test 1:

Initially, a transfer efficiency (T') of 50% will be assumed for our contactor. This is what the State of Michigan is using for their bio-engineering criteria at present. Our actual transfer efficiency will be determined during this test. Three water flows will be used through the contactor. These flows will be set for water exchange rates (R) in the raceway of 2.0, 3.0, and 4.0 per hour. Oxygen flow to the contactor will be set to achieve an increase of oxygen saturation to the 125% level assuming a 50% transfer efficiency. Varying oxygen flow rates will be used with each water flow to determine the maximum T'value. Tests will be run at each water and oxygen flow rate until values in the effluent of the contactor have stabilized (no change in gas values for at least 5 minutes). Stabilization should occur within half an hour after flow rates have been set. During the tests, the following parameters will have to be continually monitored: total dissolved gases (TDG) prior to and after treatment in the contactor; and dissolved oxygen prior to and after treatment in the contactor. Water flow will be set at the beginning of the test, and checked daily until rate of flow has been changed. The data gathered during this test will give us actual transfer efficiency of the contactor at different oxygen and water flow rates. Most importantly the T' values that match our design parameter of 125% oxygen saturation can be calculated. The transfer efficiency (T') of oxygen for these tests will be computed as

follows:

$$T' = \frac{\text{Water Flow (lpm)} * \text{D.O. Increase (mg/l)} * 100}{\text{Oxygen Weight (mg)} * \text{Oxygen Added (lpm)}}$$

Where: T' = Transfer Efficiency of Oxygen
Water Flow = Water Flow to Test Raceway (lpm)
D.O. Increase = Effluent - Influent D.O. (mg/l)
Oxygen Added = Oxygen Flow to Contactor (lpm)
Oxygen Weight = Weight of one liter of pure oxygen at Standard Temperature and Pressure equals 1430 mg. For 90% pure oxygen the weight changes to ~1290 mg.
100 = Used to convert T' to percentage

Example: Water Flow = 2200 lpm
Influent D.O. = 8.0 mg/l
Effluent D.O. = 24.0 mg/l
D.O. Increase = 16.0 mg/l
Oxygen Added = 45 lpm
Oxygen Weight = 1430 mg (pure)

$$T' = \frac{2200 * 16 * 100}{1430 * 45} = 54.7\%$$

Test 2:

Contact height and vacuum inside the contact chamber will vary with different water flow rates. To determine what effect these parameters have on the Transfer Efficiency, we will duplicate several of the specific contact height and vacuum pressures used in Test 1 with different water flow rates. To accomplish this, adjustment of the discharge valve will be necessary. Data gathered in Test 2 will be compared with results from Test 1.

Test 3:

Transfer efficiency should change with increased influent nitrogen saturation. To test this theory, the oxygen/water contactor will be supplied influent water that is higher in nitrogen saturation than standard hatchery water. Test 3 will be conducted in the same manner as Test 1 except for the higher nitrogen saturation in the influent to the contactor. The number of oxygen and water flow combinations will be reduced from those in Test 1 because of time and budget constraints. The resultant data will be compared to the T' values found during Test 1 and the percent increase or decrease in efficiency noted.

Test 4:

Transfer efficiency should change with decreased influent oxygen saturation. To test this theory, Test 3 will be duplicated with the exception that influent water will be pumped from a raceway effluent low in dissolved oxygen because of fish metabolism. This test will duplicate what would happen in a multiple pass system with oxygen contactors between passes. The exact situation we face at Fort Richardson if this technology is to be used on outside production raceways. Data gathered during Test 4 will have a direct impact on sizing the oxygen generation equipment to most economically achieve our goals should we decide to implement this technology at Fort Richardson.

Test 5:

Transfer efficiency should change with water temperature changes. We will compare T' at three water temperatures: the highest rearing temperature used at Fort Richardson (15 degrees C), the lowest rearing temperature commonly used (5 degrees C), and a mid point (10 degrees C). Differences in T' between these temperatures will be compared and analyzed to determine the effect of temperature change on the process of oxygen transfer. Temperatures for each phase of Test 5 will be regulated by the pneumatic temperature controller on inside raceway bank 4. Data gathered in Test 1 will be used in Test 5 analysis also.

Test 6:

It is assumed that water supersaturated with oxygen will lose some of that oxygen to the atmosphere along the length of a raceway. This non-consumptive loss will be determined prior to loading the system with fish. In order to accomplish this, total dissolved gas and dissolved oxygen will be monitored at the influent and every 10 feet along the length of the raceway to the effluent. One test will be conducted using a standard 2.5 foot standpipe and another using a standpipe that will make the length/width/depth relationship of the raceway the same as the outside production raceways. This test will be repeated for three water exchange rates (R=2.0, R=3.0, and R=4.0) with each standpipe height.

Test 7:

Installation of the oxygen generator is an important part of Phase II and will be happening concurrently with Tests 1-6. The unit will be installed in the incubation building on an existing electrical service pad located in the mechanical room. Power is available and a duct providing outside air is located within a few feet of this pad. Computer data gathering panels are also located in the mechanical room so alarms can be easily tied into the monitoring system. The east wall of the mechanical room will be penetrated to

provide access for the hose which will carry oxygen from the generator to the oxygen/water contactors. The oxygen bottle delivery system described in Phase I will be used as an emergency back-up in case of equipment failure.

A pressure alarm will also be installed on the oxygen generator's surge tank. Prior to operating the oxygen generation system with fish, a two week systems check must be conducted. The first week of these checks will be spot checks of Test 1 data to determine the reduction in efficiency using generated oxygen rather than pure bottled oxygen. The purity from the generator is rated at 90% +or- 5%, so we can expect at least a 10% reduction in efficiency. The second week of systems checks will consist of a trial run operating at design parameters for rearing fish. The water flow, oxygen flow rate, and temperature will be calculated using data gathered in previous tests and from the first week of Test 7 to achieve a raceway influent that is 125% saturated with oxygen. Continuous monitoring of total dissolved gases and dissolved oxygen is required in the influent and effluent of each test raceway during this week. Water and oxygen flow rates will be set at the beginning of the test and checked on a daily basis for the duration of the week. If a problem should arise, we could then be prepared to handle it when fish are in the system.

PHASE III

After installation of the oxygen generator we will begin the fish rearing phase of the experiment. Initially indoor raceways 4A, 4B, 4C, and 4D will each be loaded with equal numbers of coho salmon fingerling. Minimum density during this phase will be 0.5 pounds per cubic foot per inch of fish length. Maximum density will be set at 1.0 pounds per cubic foot per inch of fish length. Feeding rate will be the same for each of the four raceways. Except for influent water, all raceways will receive identical treatment. Raceways 4C and 4D will act as controls. Water flow will be set in these raceways to achieve a minimum of 7.0 mg/l dissolved oxygen in the effluent. Flow in the test raceways will be adjusted so that the influent dissolved oxygen is at 125% of saturation and the effluent is maintained at a minimum of 7.0 mg/l. At a rearing temperature of 10 degrees C, we expect a 38% reduction in necessary water flow to the two experimental raceways. Water and oxygen flows will be adjusted in all four raceways on a weekly basis to maintain effluent dissolved oxygen levels of 7.0 mg/l. Oxygen flow to the two test contactors will be set initially using figures derived during Phase II. Adjustments to the oxygen flow rate will be made only if required to keep influent oxygen levels at 125% saturation.

Formulas used to calculate water flows and their corresponding oxygen flow rates are as follows (note formulas

are theoretical and actual flow rates will be fine tuned to meet influent dissolved oxygen saturation levels as outlined above):

$$\text{Water Flow T} = (\text{D.O.Inc} / \text{D.O.Sat}) * \text{Water Flow C}$$

$$\text{Oxygen Flow T} = \frac{\text{Water Flow T} * \text{D.O.Inc}}{\text{Oxygen Weight} * T'}$$

Where: Water Flow T = Water Flow to Test Raceway (lpm)

Water Flow C = Water Flow to Control Raceway (lpm)

D.O.Sat = Dissolved Oxygen at 100% Saturation (mg/l) minus Minimum Dissolved Oxygen in Effluent

D.O.Inc = Dissolved Oxygen at 125% Saturation (mg/l) minus Dissolved Oxygen at 100% Saturation

T' = Oxygen Transfer Efficiency (divided by 100)

Oxygen Weight = 1430 mg for pure oxygen
1290 for 90% pure oxygen

Oxygen Flow T = Oxygen flow to contactor (lpm)

Example: Water Temperature = 10 degrees C
Dissolved Oxygen at 100% Saturation = 11.7 mg/l
Dissolved Oxygen at 125% Saturation = 14.6 mg/l
Minimum Dissolved Oxygen in Effluent = 7.0 mg/l
Oxygen Transfer Efficiency = 60%
Water Flow in Control Raceway = 425 lpm
Oxygen Weight = 1430 mg (pure oxygen)

$$\text{Water Flow T} = ((14.6-11.7)/(11.7-7.0))*425 = 262 \text{ lpm}$$

$$\text{Oxygen Flow T} = \frac{262 * 2.9}{1430 * 0.60} = 0.89 \text{ lpm}$$

During Phase III, the test and control fish will be observed to evaluate effects of high dissolved oxygen and low nitrogen saturation levels on health and growth. Biweekly samples will be taken to compute growth rate (mm/tu/day, and kg/tu/day), conversion of food to flesh, survival rate, metabolic rate, and condition factor. Visual inspection of gills and external appearance will occur biweekly with samples preserved for later histological examination if deemed necessary.

PRELIMINARY DATA

Two preliminary tests of the oxygen/water contactor have been run at Fort Richardson in the past year. These tests were set up to solve immediate problems encountered at two hatcheries. Data presented here is rough but results are very encouraging.

Sikisuilaq Hatchery was experiencing a high nitrogen saturation problem in December 1985. A test of the oxygen/water contactor to see if it would be a quick and effective way to reduce nitrogen without developing an elaborate and costly gas stabilization system. The available contactor (5 feet high, made of 8 inch diameter PVC pipe) was set up in gate house #2 at Fort Richardson Hatchery. Water from this source was over 150% saturated (pTOT) prior to being pumped through the contactor. Data collected from water that was passed through the contactor is in Table 1. A control was run with no oxygen added to the contactor. Oxygen was then metered into the contactor from a bottle at a rate of approximately 5.0 lpm:

Table 1: Data gathered during preliminary test of oxygen/water contactor to solve nitrogen saturation problems at Sikisuilaq Hatchery. (Oxygen was added at ~5.0 lpm, while control had no oxygen added. Results are expressed in percent gas saturation.)

Gas Pressure	Raw Water	Control	w/Oxygen Added
p(TOT)	>150%	122%	126%
p(N2)	N/A	125%	113%
p(O2)	N/A	113%	177%

It is apparent that the contactor worked to both decrease nitrogen and increase oxygen saturation. However, nitrogen saturation was not reduced enough to come within safe limits for fish rearing. Exact water flow through the contactor could not be determined but was estimated to be between 400 and 600 lpm, at a temperature of 20 degrees centigrade. Efficiency of transfer (T') at these oxygen and water flow rates was between 33.0 and 49.5% depending upon actual water flow. This agrees closely with data recently received from the State of Michigan where transfer efficiencies of 35% are being observed. This test suggests that total gas saturation will have to be reduced prior to application of this

technology. The current study should help answer some of these questions.

In past years, Fort Richardson Hatchery, has had unexplained mortalities in newly ponded fry. The only pathogen found was Pseudomonas sp., which is normally a secondary agent. We decided to install one contactor in an attempt to reduce nitrogen saturation below 100%, hoping to aleviate some of this mortality. If low level nitrogen supersaturation were predisposing the fry to Pseudomonus this approach might remove that stressor. Results were negative. Mortality was not lowered in the test raceway when compared to the average mortality in the entire population. Even though the expected results were not to be, the data collected is very encouraging. The contactor worked as it was supposed to and the fish exposed to high levels of oxygen saturation showed no ill effects.

Daily readings of total gas pressure, oxygen level, water temperature, and oxygen flow rate were recorded for a month. Oxygen and water flow rates were monitored but because of the metering device used and fluctuations in the water delivery system are not very accurate. Therefore, calculated data are not accurate, but a good starting point for further work. Data from three separate days (chosen at random) during the test were used to calculate the information in Table 2.

Table 2: Data from preliminary test of oxygen/water contactor used during rearing of rainbow trout at Fort Richardson Hatchery. (water flow of 151 lpm, saturated influent water, barometric pressure of 755 millimeters of mercury, and oxygen flow of 1.0 lpm. Normal TDG in the incubation building is between 100 and 102% in the influent water.

Date	% TDG	Oxygen (mg/l)	Water Temp.	% Oxygen	% Nitrogen	Transfer Efficiency
7-4	100.5	15.7	9.8C	137	90.4	45.4%
7-12	100.4	16.6	8.6C	142	89.1	51.7%
7-20	100.6	15.0	9.1C	129	92.5	35.9%

Data found in Table 2 supports the concept of using oxygen to increase loadings of fish. Although the increase in oxygen levels and the corresponding decreases in nitrogen saturation levels are not accurate, they show a trend. The information in Table 2 alone justifies continuation of this study.

CONCLUSIONS

Preliminary results are very encouraging indeed. By using

this new technology we can potentially increase production at facilities that are now limited by water availability. Theoretical values point to a savings of 35% or more on required water to rear equal numbers of fish. Even if this savings is limited to 25%, the monetary savings can be significant at facilities that are required to pump all of the water they use. The oxygen/water contactor itself will require eight to ten feet of head pressure to operate. Another operational cost of the system is in the oxygen generator itself. Using energy consumption figures provided for Xorbox Oxygen Generators, the cost of treating a flow of 4000 lpm would be approximately $80/month (this assumes 50% transfer efficiency, $0.05/kwh, and resultant oxygen concentration of 125% saturation). For increased flows, the oxygen generators become more efficient thus lowering cost per unit of benefit. If Fort Richardson could reduce overall water demand from 16000 lpm to 12000 lpm (a savings of 25%) we would be able to shut off one of our 4000 lpm wells. A cost of $1,350/month would be changed to something less than $250/month for oxygen generation. This would be a savings of more than $1,100/month.

Not only will we be able to more operate more efficiently, we could produce a product that may well benefit from the improved environment and show better growth and survival. We must do everything within our power to do our job, which is to make more and better fish!

PASSIVE GRADING OF CHINOOK SALMON AT MARION FORKS HATCHERY

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INTRODUCTION - PROBLEM

A common problem in the Willamette Valley spring chinook hatcheries, is having a bimotile length frequency curve in populations of ungraded smolts. In order to meet the fall release criteria of 100% above 150 mm, some sort of grading is necessary. Because of late time of this separation and the size of the smolt at this separation, stress and handling are major problems.

OBJECTIVE

Our objective is to grade late in the fall, just prior to fall liberations with minimal stress on the smolt. We took length frequencies monthly until August, then every 15 days, to determine when they were going to split. We found that this separation occurs when the pond run smolt reached between 10-14 F/lb. regardless of the month. Some pond populations showed 40-50% split.

METHODS

We built a non-adjustable bar style passive grader, using ½ inch electrical conduit and 2 x 6 fir lumber. We kept 7/16 of an inch between bars.

We have 48 circular ponds, 24 feet in diameter, with 15,000 fish per pond. We placed the grader so that the fish were swimming toward the grader and the current. We then crowded the entire pond into an area of about 4-5 feet in front of the grader and positioned it there for 2-3 hours. We then placed another crowder in and maintained separation. We took pond run length frequencies before grading and then sampled both larges and grade-outs after grading. We then moved the smalls to separate ponds for spring release.

PASSIVE GRADING OF CHINOOK SALMON AT MARION FORKS HATCHERY (cont.)

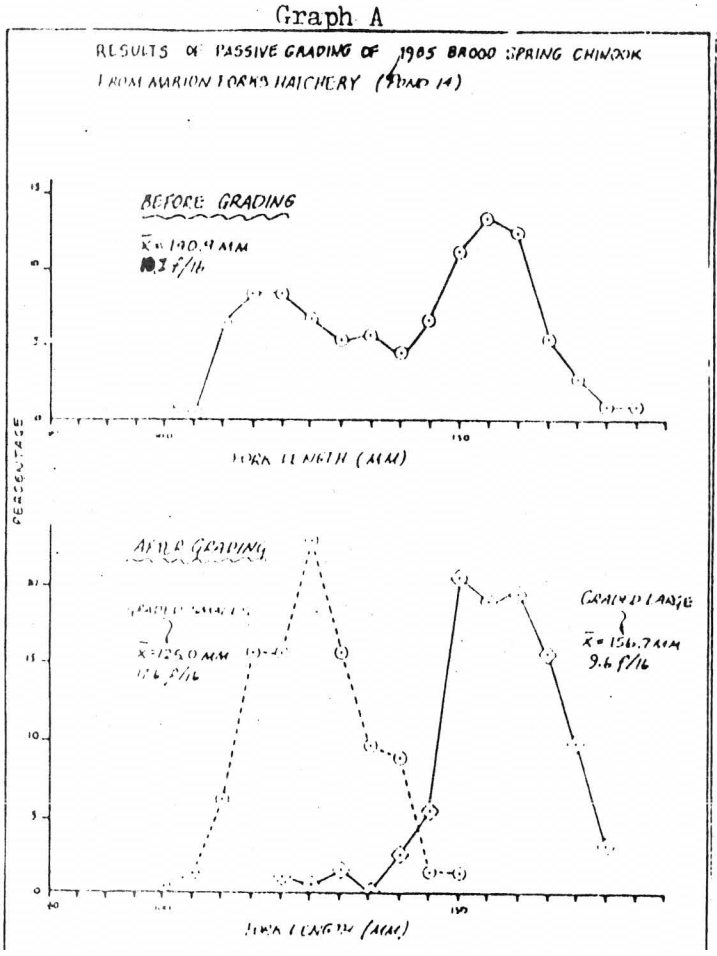
Graphs A and B both indicate the results of the passive grader. The top graph is the pond run length frequency, denoting the bimotile curve. The bottom graph is after grading results, showing the two populations separating out. The smalls $\bar{x}$ = 125.mm and 17.6 F/lb. and larges $\bar{x}$ - 156.7 and 9.6 F/lb. We graded approximately 300,000 smolts with the split hitting the same range. There was a wide range of percentages larges to smalls, but the split didn't vary.

DISCUSSION

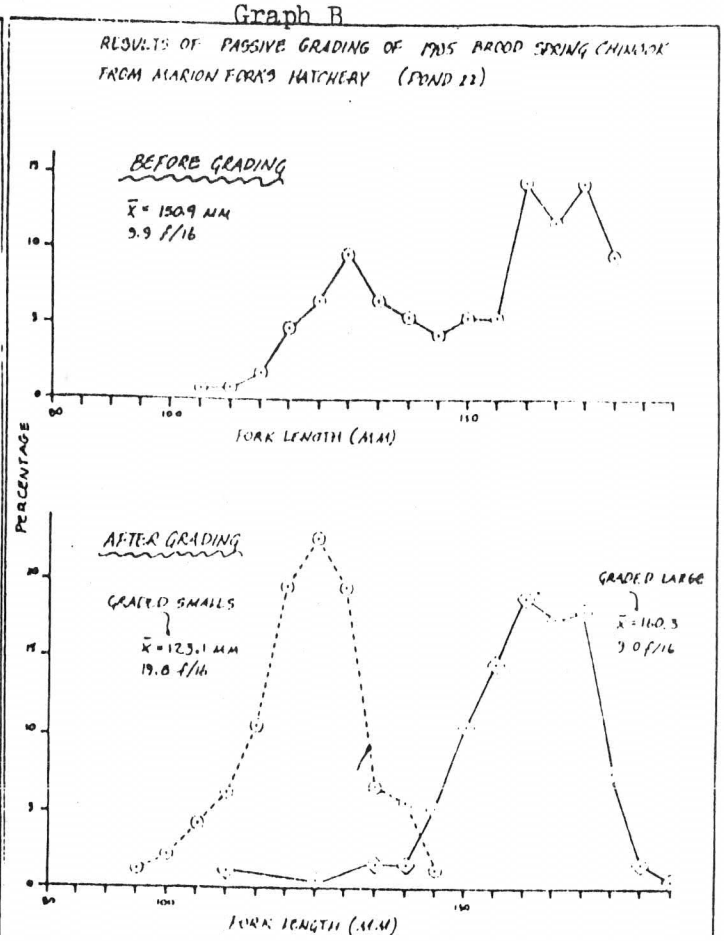
In our opinion, this is a good method of grading for the following reasons. We can grade late in the smolt stage without subjecting too much stress on the smolts and this is less stressful than the use of a fish pump during liberations. There is also less man-power drain than other forms of grading. Because of the low cost of the grader ($42.00), you could easily build two or three and could grade two to three ponds at the same time. This method of grading can also be used to separate pond populations in order to control size.

This project represents two years of data on steelhead and salmon.

Graph A



Graph B



Development of the "Ways and Means Manual"

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The idea for this manual was conceived in 1969, while I was serving as assistant manager of a new facility on the southern Oregon coast. We had struggled with several problems that always occur at a new station, then later found a solution while visitng another hatchery. It occurred to me that if we had a communication system for ideas between hatcheries, problems could be solved quicker and better, and a more effiicent operation could be achieved. In addition, I observed that many good ideas are developed, then later abandoned for whatever reason. Often the idea was lost, although it might surface again years later. I felt this would be a way to record and document these ideas for anyone who might be able to use them.

In 1983 I listed the project as an item on my yearly work plan and obtained approval to proceed with the project. A year was spent trying to develop a format for the manual and two years was spent collecting information by visiting all hatcheries in the State. It is hoped that the material included will be of value in making fish culture easier, more efficient, and a smoother operation. It is also hoped that this will only be a beginning. I envision that when someone has an idea they feel might be useful, that they could send me a photo and a short explanation of the purpose. I could then, as needed, make copies and make them available to those who are interested.

The manual is divided by five major areas of fish culture which are: adult handling, incubation, fingerling rearing, liberation, and miscellaneous. Each section is numbered by page, thus leaving the book open ended and additional pages can be added to each section in the future. If there is more than one page for a specific item (i.e. pond crowders), then the page number is the same, but a letter of the alphabet is also used (i.e. Page 10, then Page 10 A). As you will notice, each item that is included lists the hatchery it is at; therefore, if further information is needed, one can contact the hatchery that has the item.

SUCCESSFUL AND UNSUCCESSFUL REARING STRATEGIES FOR SPRING CHINOOK SALMON AT ROUND BUTTE HATCHERY

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During the 16 year history of Round Butte Hatchery, located on the Deschutes River, Oregon, we have reared and released spring chinook salmon under six different strategies. The least successful strategies involve incubating and rearing fish in constant 50°F water and releasing them as zero-age smolts in spring or as yearling smolts in fall or spring. Average return rates to the hatchery for these three strategies are less than 0.1%. The more successful strategies involve incubating eggs at 42°F, rearing at constant 50°F, and releasing them as yearling smolts in fall or spring. Average return rates for these strategies are near 0.3%. All of the above strategies require that the fish be trucked 12 miles to be released in the Deschutes River below Pelton Regulation Dam. The most successful strategy involves incubating eggs at 42°F, rearing at constant 50°F until November, transferring the yearlings to the Pelton fish ladder to rear overwinter, and allowing them to enter the Deschutes River on their own volition in spring. The average return rate for fish released from Pelton Ladder is 1.4%.

Advantages to rearing spring chinook salmon in Pelton Ladder are (1) very low density, (2) variable natural water temperature, (3) cover in the form of aquatic vegetation, (4) some natural food, and (5) volitional emigration which allows proper individual timing and eliminates handling stress.

ELECTRIC BARRIERS

Application and Status of Their Use by Oregon Department of Fish and Wildlife

Folkert Menger

The object of the electric barrier is by utilizing an electrical field to create a positive method of diverting fish. The use of an electric field can be used to divert up or downstream migrants; our primary interest today is the diversion of upstream migrants. At this time we have six barriers of this kind in operation with mixed results.

The late Roger Burrows described the typical electric barrier we have been using over a number of years. It is described in a Scientific Report - Fisheries No. 246 titled "Diversion of Adult Salmon by an Electrical Field." It describes the research of a barrier at the Abernathy Salmon Culture Development Center in Longview, Washington.

The reason the idea of an electric barrier became so attractive is the possibility of overcoming the difficulties encountered with mechanical barriers. They are costly to install, difficult to maintain, they impede stream flow and are sometimes destroyed at high water.

However, there are several requirements to be satisfied for the successful operation of an electric barrier. In the early 1950's it was concluded after some experimental investigations that an electrical field created by a 100 volt 60 cycle alternating current was the most effective method for the diversion of upstream migrants.

Until this date we have used this type of barrier rather successfully for the obtaining of an egg bank to continue our fish culture programs.

Such a weir consists of cable supported electrodes upstream from a parallel ground line. In plan the line of electrodes and naturally the parallel ground line should be oriented with a 30 degree angle perpendicular to the stream flow.

The reason for this is that the fish stopped by the electric barrier will feel their way along the barrier and be guided toward the fishway entrance. However, geometric configurations of existing facilities does not always present this opportunity. The effect of the electric field on fish depends on the size of the individual animal and the voltage should be adjusted accordingly.

The larger the fish the larger the effect of the electric field on the fish. Fish approaching the barrier, however, are not all the same size.

The conventional electric barrier produces an electric field stronger near the electrodes and weaker near the ground strap. So the thinking is that smaller fish would approach the probes (electrodes) closer to receive the same effect as larger fish would farther downsteam of the electrodes.

The initial investigations and tests were performed in the laboratory or on idealized installations. In the natural stream these circumstances vary. Harmonic reaction of the cable supported electrodes to the stream flow may cause violent bouncing of the electrodes on the deck and intertwining of electrodes, resulting in losing the probes and leaving gaps for fish to escape.

Sloping banks and irregular configuration of intake structures also provide opportunities for fish to escape. Even though these difficulties exist, the barriers provided sufficient adults to obtain eggs for our fish culture program.

A few years ago we were requested to provide a barrier impenetrable by fish so that all fish would be stopped. Our attention was directed to the existing electrical barriers as the most economical. High voltage near the electrodes and erratic voltage elsewhere caused substantial fish kill; not desireable in the public view.

We engaged the firm Smith-Root Inc., to assist us in modifying our barriers to a more acceptable level, stopping practically all fish wihout injury. We also have to consider possible accidental contact with humans.

Smith-Root suggested that we replace the 120 volt 60 cycle AC power supply with a pulsator capable of generating pulses of a much shorter duration with adjutable output amplitude and a wide frequency range.

A pulse dead time circuit should also be incorporated to allow fish to be released from the electrical field.

Because electrical barriers are still considered experimental, they also recommend that the pulsator used be controlled by a micro processor so that changes in output pulse parameters could be software incorporated without changing the electrical hardware.

Our Engineering field crew proceeded to install metal strips on the wooden apron of the electric barrier after which our electrician hooked them up to the power source via the programmable puslator (black box) according to recommendations from the consultant.

In our first attempt we included the series of existing probes as one electrode. This, included with the other electrodes, form zones (A, B, C & D). Initially the system was programmed for each zone to operate independently with the other zones in several combinations and separate sequences. The pulse width (length of time the current is on), the pulse rate and output voltage can also be adjusted.

Having the cable supported probes as part of the system still causes the problem of the behavior of the probes in high water and the effect of debris floating downstream. The goal is to eliminate the necessity of the cable. The latest modification would accomplish this when at the location of the probes we add another strip electrode in its place.

In this case, there are five zones and five pulse generators which are connected such that the output voltages are additive. This means that all zones are electrically pulsated at the same time. The voltage output can be different for each generator.

The electrical field pattern produced by this system is more horizontal and thus in the same direction as migrating fish and more effective in diverting them.

The pulsators described here generate pulses of a very high voltage, but with a short duration and on a low duty cycle (Duty cycle = Ratio of pulse on time to time duration between pulses). The pulse rate generated for each channel is adjustable from 1 to 10 pulses per second and has a pulse duraiton of 0.1 to 1 millisecond. Pulse voltage is adjustable from 0 to 1000 volts. These pulses are not lethal, but are very much felt by the aquatic animal as well as humans. This kind of voltage can be likened to a spark plug shock, which very quickly gets your attention, but does not kill you.

In my opinion, the application of electric barriers is still experimental but we appear to arrive at a solution as to how to safely and efficiently divert fish.

6. USES OF SUPPLEMENTAL OXYGEN

AN INTRODUCTION TO
WATER QUALITY MANAGEMENT IN INTENSIVE AQUACULTURE

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INTRODUCTION

Increasing fish density or reuse of hatchery water can significantly increase the production capacity of hatcheries. Generally, dissolved oxygen is the most limiting environmental parameter and reaeration can allow reuse. Several types of aerators can be used for hatchery applications, but pure oxygen systems may be the most economically method for many existing hatcheries. Limited documentation is available at this time on the optimum type of pure oxygen system or the effects of increased density or water reuse on adult return. Prior to the widespread implementation of intensive aquaculture systems, it will be necessary to clearly define the engineering solutions and biological needs at each location.

INTENSITY OF A HATCHERY

The intensity of a hatchery can be described by several parameters. The most common parameters are:

$$\text{Density (lb/ft}^3\text{)} = \frac{\text{mass of fish (lb)}}{\text{volume of rearing unit (ft}^3\text{)}}; \quad (1)$$

$$\text{Loading (lb/gpm)} = \frac{\text{mass of fish (lb)}}{\text{flow to rearing unit (gpm)}}; \quad (2)$$

$$\text{Exchange rate (number/h)} = \frac{(60)(\text{flow to rearing unit in gpm})}{(\text{volume of rearing unit in gallons})}. \quad (3)$$

Loading, exchange rate, and density are related by

$$\text{Loading} = \frac{8.02\ (\text{Density})}{\text{Exchange Rate}} \quad (4)$$

Typical densities used for salmon and trout fry range from 0.20 to 0.60 lb/ft^3, but may range from 0.60 to 2.50 lb/ft^3 for larger fish. If loading rates are maintained low (high exchange rate), densities in experimental systems have been as high as 34 lb/ft^3. Loading rates in production typically range from 4 to 10 lb/gpm. The maximum density will depend on both water quality considerations and the ability of the particular species to tolerate crowding.

IMPACT OF FISH ON WATER QUALITY

The metabolic activities of fish result in significant changes in water quality. For fed fish, some of the most important metabolic processes are shown in Figure 1. In flow-through systems, typically only dissolved oxygen and ammonia may need to be considered. As the intensity of a hatchery is increased it may be necessary to consider the impact of carbon dioxide, uneaten feed, and fecal solids. Fecal matter and uneaten feed contains high levels of bacteria and release small amounts of soluble organic compounds.

Both ammonia excretion, oxygen consumption, and carbon dioxide excretion rates show a significance diel fluctuation, depending primarily on the time of feeding. If feeding is stopped, the oxygen consumption, carbon dioxide excretion, and ammonia excretion rates will decrease to baseline values.

PROCESS CRITERIA

Density, loading, and exchange rate are the most important process criteria needed for the design and operation of fish culture systems. These parameters can be estimated from either empirical or mass-balance considerations.

Empirical Approach. Typically, fish culture facilities have been design by selecting a density and exchange rate based on past experience (Leitritz and Lewis, 1976; Piper et al., 1982; Shepherd, 1984). The total volume of rearing units needed is equal to production objective/density and water flow rate is equal to production objective x loading rate.

This approach works well in areas with an ample water supply at an acceptable water temperature. Generally, this approach will result in a conservatively designed hatchery, as many state and federal hatcheries were located on the sites with excellent water supplies. Application of these process criteria to areas of limited water supply may result in very high capital and operating costs. In addition, the applicability of empirical process criteria depends on how the new conditions compare to the conditions under which the original criteria were developed. For example, many trout hatcheries have pHs in the range of 6.5 to 7.0. Published process criteria would not be valid at a site with a pH of 8.4 and could result in significantly reduced production capacity.

Mass-balance Approach. This method is based on identification of the critical environmental parameters that may limit the growth of fish. These may include, dissolved oxygen, carbon dioxide, ammonia, and solids. Based on laboratory and production experiments, a water quality criterion is set for each parameter. Then the water flow required to maintain each parameter is computed for the specific hatchery conditions. In many cases, the largest flow required will be for maintaining the dissolved oxygen.

This method is quite flexible, especially when the dissolved gas concentrations, pH, salinity (or total dissolved solids), and temperature at a new site significantly different from previous sites. The major advantage of this method is that is allow one to estimate the effect of water treatment on the overall water requirement. For example, what effect will addition of 5 - 1 hp aerators have on water requirement? Most of the remainder of this article will discuss the mass-balance approach to the design of flow-through systems for the culture of salmon and trout.

LIMITING FACTORS

Four environmental parameters may influent the growth of fish in flow-through systems: dissolved oxygen, carbon dioxide, ammonia, and fecal solids. Temperature will also strongly influence growth, but under production conditions, it is generally not economically feasible to heat or cool water. This section will use growth as the biological endpoint. Ideally, either adult return or some

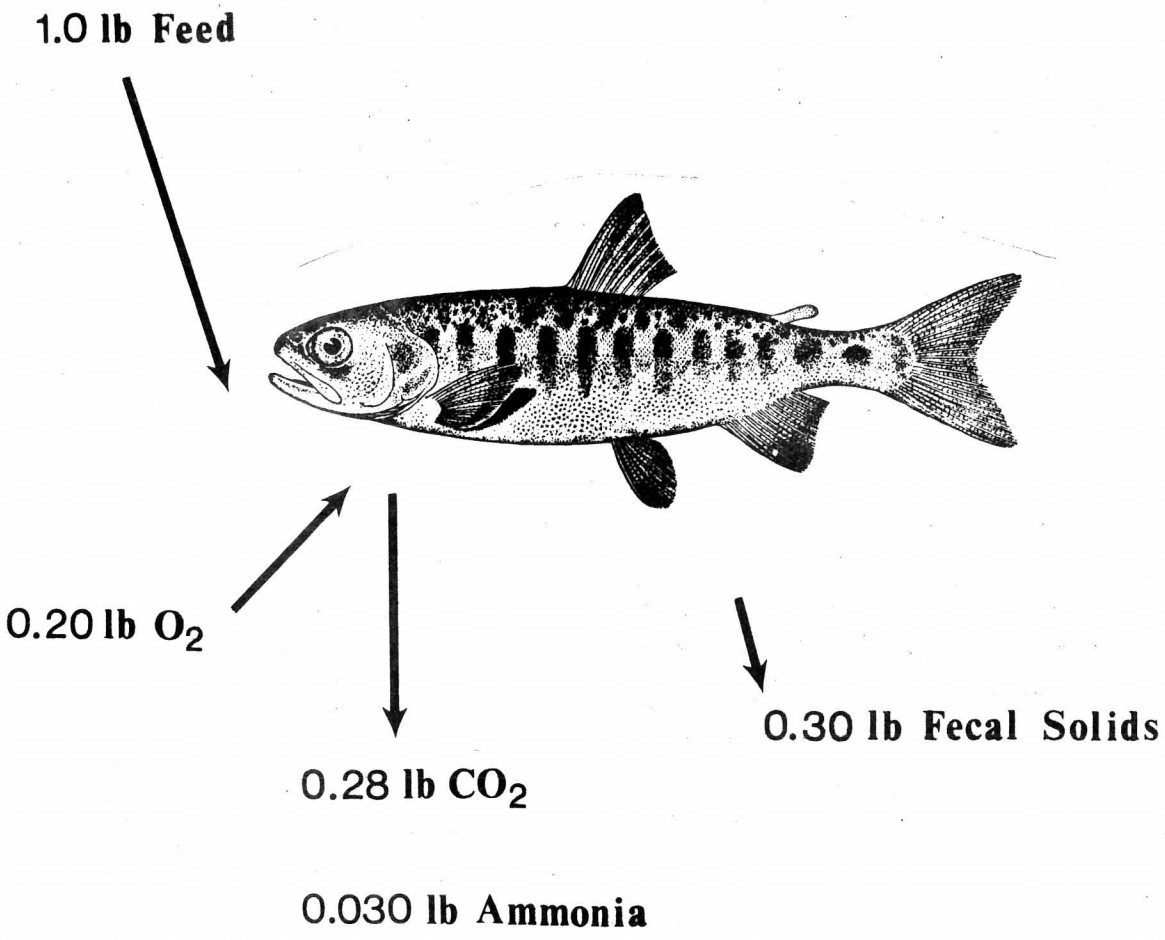


Figure 1 Impact of Fish on Water Quality

physiological quality index that is highly correlated with adult return should be used.

Dissolved oxygen. The mass of dissolved oxygen in equilibrium with air decreases with increasing temperature:

Equilibrium Concentration of Dissolved Oxygen

Temperature		Dissolved oxygen (mg/l)	
C	F	Saturation	Available
0	32	14.60	8.60
5	41	12.56	6.56
10	50	11.28	5.28
15	59	10.07	4.07
20	68	9.08	3.08

Any reduction in dissolved oxygen concentrations below 5 to 6 mg/l will decrease the growth of salmon and trout. Assuming a dissolved oxygen criteria of 6.00 mg/l, the difference between the saturation concentration (above table) and the criteria is the dissolved oxygen available for the fish and is presented the previous table. Increasing the water temperature from 41 to 59 F, decreases the available dissolved oxygen by 38 %. The actual carrying capacity will be decreased even more because the oxygen consumption rate of the fish will also significantly increase due the temperature change. This would be reflected by increased feeding levels.

The flow requirement for maintaining the dissolved oxygen concentration (Westers, 1981) for a raceway system (Figure 2) is equal to

$$Q_{oxygen}\ (lpm) = \frac{(K_{oxygen})(R)}{(DOin - 6.00\ mg/l)} \qquad (5)$$

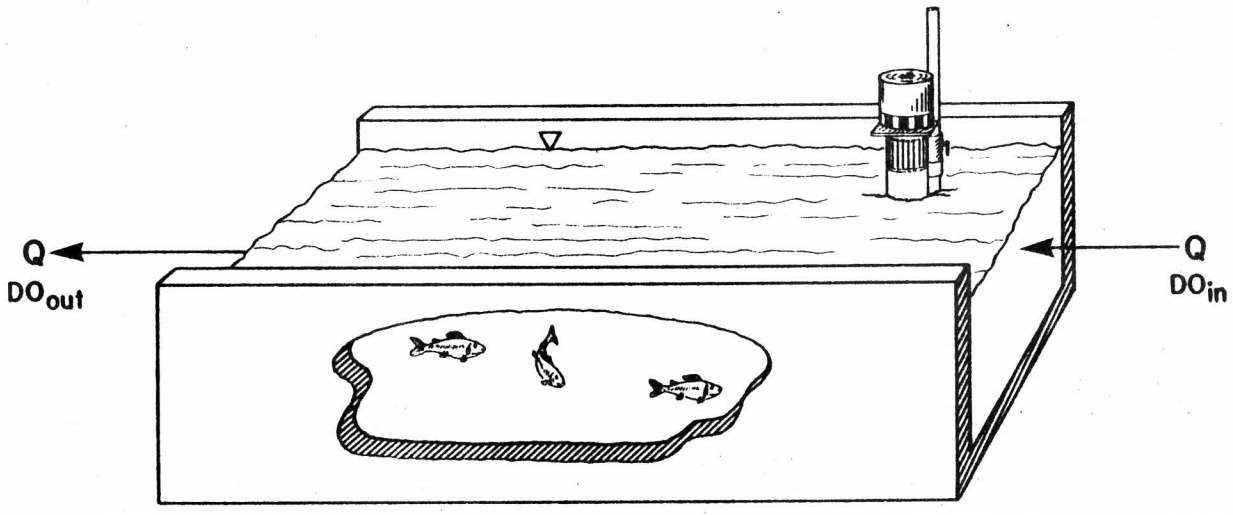
where

K_{oxygen} = 200 g oxygen /kg feed

R = total ration, kg/d

DO_{in} = influent dissolved oxygen concentration, mg/l

Assuming 5,000 kg (11,000 lb) of fish fed 2% of body weight per day and influent dissolved of 11.00 mg/l, the required flow (Q_{oxygen}) is equal to 4,000 lpm (1100 gpm). The observation that



SOURCES OF OXYGEN

- INFLOW WATER
- AERATION

CONSUMERS OF OXYGEN

- OUTFLOW WATER
- FISH

Figure 2 Oxygen Balance in a Raceway

oxygen consumption is proportional to feed consumption has been the basis for several procedures for the computation of loading rate or flowrate (Haskell, 1955; Westers and Pratt, 1977; Willoughby 1968).

Carbon dioxide. The carbon dioxide production of fish is equal to

$$\text{Carbon dioxide Production (mg/d)} = 1.375(RQ)(T) \quad (6)$$

where

RQ = respiratory quotient (approximately 1.0 under most conditions)

T = oxygen consumption, mg/d

The build-up of carbon dioxide can result in reduced metabolic activity and increased disease problems. Carbon dioxide concentrations should be maintained less than 20 mg/l, although higher levels can be tolerated depending on the dissolved oxygen concentration and temperature. If it assumed that all the excreted carbon dioxide remains in the water as dissolved carbon dioxide, then the flow required to maintain the carbon dioxide concentration below 20 mg/l is equal to

$$Q_{\text{carbon dioxide}}\ (\text{lpm}) = \frac{(1.375)(RQ)(K_{oxygen})(R)}{(20.0\ \text{mg/l} - C_{in})} \quad (7)$$

where

C_{in} = influent concentration of carbon dioxide, mg/l

For RQ = 1 and C_{in} = 0.50 mg/l, $Q_{\text{carbon dioxide}}$ = 1,400 lpm for the previous example. The assumption that all the carbon dioxide remains in solution as free carbon dioxide produces a very conservative estimate of $Q_{\text{carbon dioxide}}$. A better estimate of $Q_{\text{carbon dioxide}}$ will require information on alkalinity and pH of the water.

Ammonia. Ammonia (NH_3) is end-product of protein metabolic and is excreted primarily across the gills. As the ambient ammonia concentration builds-up, the rate of ammonia excretion decreases and feeding is reduced.

Ammonia is weak base and exists both as an un-ionized (NH_3) and ionized (NH_4^+) form. The un-ionized form is much more toxic than the ionized form and water quality criteria are written in terms of the un-ionized form (NH_3).

The concentration of both un-ionized and ionized ammonia are expressed on a nitrogen basis and the sum of both forms is the total ammonia nitrogen and can be measured by standard chemical tests. The concentration of un-ionized ammonia depends on total ammonia nitrogen, pH, temperature, and salinity (or total dissolved solids). The mole fraction (percent ammonia/100) of un-ionized ammonia for freshwater conditions is presented below:

Mole Fraction of Un-ionized Ammonia (α_{NH3})

pH	Temperature, C (F)		
	5 (41 F)	10 (50 F)	15 (59 F)
6.0	0.000124	0.000186	0.000273
6.5	0.000393	0.000587	0.000862
7.0	0.00124	0.00185	0.00272
7.5	0.00392	0.00584	0.00856
8.0	0.0123	0.0182	0.0266
8.5	0.0379	0.0555	0.0794
9.0	0.111	0.157	0.214

The concentration of un-ionized ammonia is equal to the mole fraction (above table) time the total ammonia nitrogen:

$$NH_3\text{-}N = (\text{mole fraction})(\text{total ammonia nitrogen}) \quad (8)$$

If the concentration of total ammonia nitrogen is express in mg/l, then NH_3-N will also be expressed in mg/l. Total ammonia nitrogen may be abbreviated as TAN. A change of one pH unit will change the concentration of un-ionized ammonia by a factor of 10 over the normal pH range. Westers (1981) proposed a maximum un-ionized ammonia concentration of 0.010 mg/l NH_3-N for salmon and trout. A truly safe, maximum acceptable concentration of un-ionized ammonia is not known at this time (Meade, 1985). Additional research is needed to increase our understanding of ammonia excretion and excretion products, to define the effect of ionic compound on ammonia toxic, and to determine the chronic effects of ammonia toxicity on several fish species.

As the intensity of culture is increased there is increasing incident of gill hyperplasia and more serve gill damage (Peters et al., 1984). Recent research indicates that ammonia alone is probably not the cause of gill hyperplasia (Meade, 1985). Fecal solids, bacterial solids, or other by-products of metabolism may contribute to the tissue damage attributed to ammonia.

Assuming that the concentration of ammonia in the influent water is zero, the flow require to maintain 0.010 mg/l or 10.0 µg/l NH3-N is equal to

$$Q_{ammonia} = \frac{(1319)(\alpha_{NH3})(Kammonia)(R)}{10.0\ \mu g/l} \quad (9)$$

where

α_{NH3} = mole fraction of un-ionized ammonia (see above table)

$K_{ammonia}$ = ammonia excretion rate (30 g TAN/kg feed)

R = ration, kg/d

At pH equal to 6.5 and temperature equal 10 C, only 232 lpm (62 gpm) would be needed to maintain the ammonia criteria for the previous example. Equation 9 does not consider the effect of respiratory carbon dioxide on the pH of the culture water. In waters of low alkalinity (and hardness), the accumulation of carbon dioxide may result in significant reduction in Qammonia.

Fecal Solids. The effect of solids strongly depends on the size, shape, and texture. Both uneaten feed and fecal matter may contain high levels of potentially pathogenic bacteria. Water quality criteria for fecal solids and uneaten feed are not well defined at this time. Since these solids can settle out in the rearing unit, the concentration of solids may significantly increase during cleaning, grading, or harvesting.

Cumulative Loading. Repeated reaeration and reuse can result in adverse physiological changes, such a reduced growth or tissue damage. For Lake Trout, this occurs at a cumulative loading of 50 lb/gpm (Meade, 1985) and may be due the synergistic effects of a number of metabolites.

Density. As the density is increased, the fish growth may decrease. Much of this effect is related to the impact of density on loading, rather than the biological impact of crowding on the culture animal. Increased incident of fin damage has been observed at higher density.

REUSE OF WATER

In the previous section, the following flows were needed to maintain the water quality criteria for the specific parameters:

Limiting Water Flows

Parameter	Flow (lpm)
Dissolved oxygen	4,000
Carbon dioxide	1,400
Un-ionized ammonia	232

Therefore, if additional oxygen was added to the water, the water flow could be reduced to only 1,400 lpm. If both dissolved oxygen and carbon dioxide were controlled, then the water flow could be reduced to only 232 lpm. Conversely, if the water flow was maintained at 4,000 lpm and aeration used to maintain the dissolved oxygen at excess of 6.0 mg/l, the carrying capacity of the hatchery could be increased by 2.9 times. Theoretical, if both dissolved oxygen and carbon dioxide

were controlled by aeration, the carrying capacity of the hatchery could be increased by 17 times. A number of production hatchery have been designed for up to 5 or 6 reuses.

Control of Reuse. It most cases, the reuse of water will be controlled by the dissolved oxygen and un-ionized ammonia criteria. The reuse ratio for oxygen and ammonia is equal to

$$RR_{OXY/AMM} = \frac{Q_{oxygen}}{Q_{ammonia}} \qquad (10)$$

and is presented in Figure 3 as a function of pH and influent dissolved oxygen. This parameter is equal to the number of times the water can be reused before the un-ionized ammonia criteria is exceeded. At low pHs, the water requirement is control by the dissolved oxygen and the water can be reused following reaeration. At higher pHs, ammonia becomes the limiting parameter and the water can not be reused as the ammonia criteria has already been exceeded.

Aeration. Under those conditions where the reuse ratio is greater than 1.0, reaeration can be used to increase production in hatcheries. Four common types of aerators are surface aerators, subsurface aerators, gravity aerators, and pure oxygen aerators (Colt and Tchobanoglous, 1981). One to 2 hp surface aerators can be easily mounted in raceways or ponds. This type or aerator may result in ice hazard in cold weather. Subsurface aerator such as diffused aeration or jet aerator are more efficient than surface aerators, but can result in gas supersaturation problems (Colt and Westers, 1982). Gravity aerators can be used to reaerate water if 1 -3 feet of head is available between the individual rearing units. These units will consist of horizontal perforated screens or high-surface area trickling filter media. These type of systems will require periodic cleaning.

Depending on the production schedule of a particular hatchery, aeration may only be required during the latter stages of the production cycle when the water temperature and biomass are high. In some newer hatcheries with higher densities, aeration may be required continuously.

The efficiency of aerators decreases as the dissolved oxygen concentration approaches saturation (Colt and Tchobanoglous, 1981). Pure oxygen system can be used to achieve dissolved oxygen concentration above the air saturation values. U-tube, down-flow bubble contractors, pressurized packed columns, and atmospheric pressure packed columns have been used in hatcheries. The build-up of carbon dioxide may be a serious problem with some of these units and require installation of small surface aerators or gravity aerator to strip off carbon dioxide.

Ammonia Removal. Removal of ammonia is not economically feasible in flow- through systems. The effects of pH on carrying capacity should be considered in the site selection process. The accumulation of carbon dioxide in hatchery water due to fish respiration may reduce the pH in waters with low hardless and significantly decrease the concentration of un-ionized ammonia.

Solids Removal. Depending on the velocity and geometry, the fecal solids can keep suspended or allowed to settle in the rearing unit. Some type of settling will typically be required prior to for discharge. In some cases, the fish will be removed from the last raceway section, andthe solids allowed to settle out there.

While the effects of fecal solids are not well-defined, they may have a major impact on the operation of reuse systems. Operationally, it is highly desirable to have self-cleaning rearing units. From a fish health view, this may be highly undesirable. Rather than pass all the fecal solids through the overall raceway, it is desirable to remove the solids from each section independently (Boersen and Westers, 1986). This will result in better solids removal, as the settling velocity of fresh fecal solids is higher than solids that have resuspended many times as they move down the raceway.

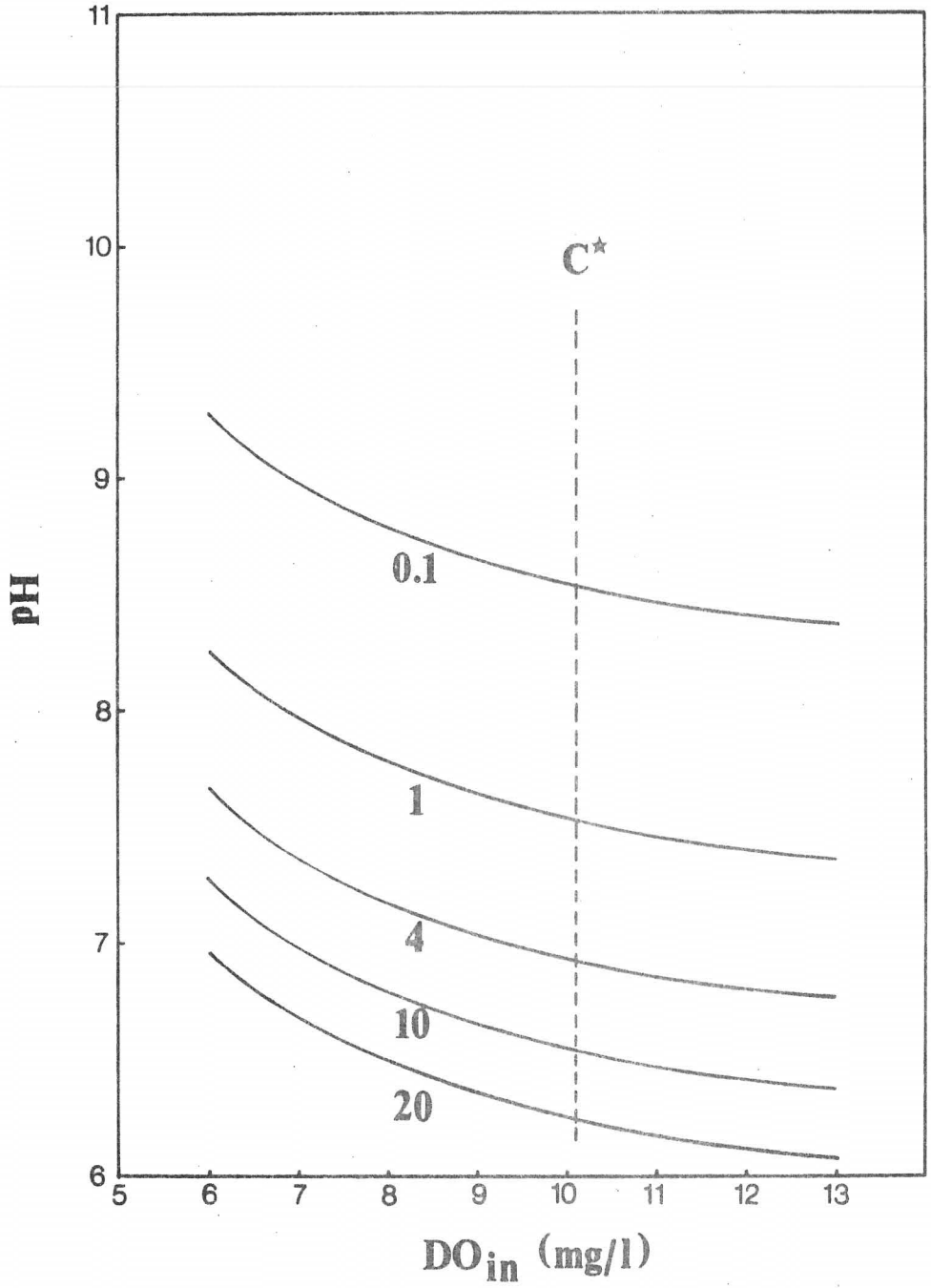


Figure 3 Oxygen-Ammonia Reuse Ratio

DEVELOPMENT OF NEW SYSTEMS

Increasing the intensity of hatcheries in the Columbia River basin can result in significant increase in existing smolt or fry production with small increases in capital and operating expenditures. The installation of pure oxygen or improved solids removal systems into existing hatcheries will require modification of both the physical plant and hatchery operations. Additional pilot-scale work is needed to evaluate the performance, operating characteristics, and economics of the most promising systems.

The impact of increased intensity on adult return is difficult to estimate at this time and will require pilot-scale evaluation. Ideally, this work should be conducted at a full-scale production hatchery with existing hatchery personnel. This will allow clear definition of the economic advantages of this approach to increasing the adult return of salmonid species in the Columbia River Basin.

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Michigan's Experience with Supplemental Oxygen in Salmonid Rearing

by
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presented at
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Introduction

From 1978 through 1983 three new salmonid production hatcheries came on line in Michigan. All three facilities provide for incubation (Heath incubators), indoor rearing and outdoor rearing. These units were built on spring and/or well water sources.

Basic designs include rectangular concrete tanks for indoor rearing with rearing volumes of 105; 210 and 420 cubic feet (3, 6 and 12 M^3) plumbed for a water exchange rate of four per hour. The outdoor raceways are all rectangular, concrete ponds approximately 9' x 90' x 3' deep, with an operational depth of 26" (60 M^3). These raceways are arranged in a three-pass serial reuse fashion and operate at four water exchanges per hour (1000 gpm). Baffles keep the ponds self cleaning and permit deposit of solids in a 9' x 9' feet section immediately behind the fish barrier.

The water quality at all three units meet or exceed aquaculture water quality parameters except for dissolved oxygen. (Daily and Economon, 1983)

The first two hatcheries were equipped with 15 feet deep aeration chambers into which a combination of air and water was introduced through special nozzles located on a manifold near the bottom of the chamber. Although very effective and efficient, this system is prone to cause high levels of dissolved nitrogen gas unless carefully controlled (Colt and Westers, 1982). For this reason, the third hatchery was designed with packed columns for initial as well as reuse aeration. Subsequently, the other two hatcheries were also changed over to packed columns. Despite the packed columns, all units experienced low level nitrogen gas supersaturation. Although no obvious gas bubble disease symptoms were observed, abnormally high mortalities were indicative of problems, suspected to be related to water quality (Westers, 1983).

After many diagnostic investigations it was concluded that the low level nitrogen gas supersaturation (101-103%) played a major role in the poor rearing performance of the fry and fingerling Rainbow and Brown trout, in particular at the Harrietta State Fish Hatchery (Figure 1). It was at that time the decision was made to reduce nitrogen gas levels to 100 percent or less! This would eliminate gas supersaturation as a variable in future evaluations of problems. It was decided to replace the packed columns with vacuum degassers.

In the interim, the Marquette State Fish Hatchery personnel experimented with pure oxygen and learned by trial and error that by injecting oxygen into a sealed packed column, nitrogen gas can be forced out of solution and be displaced with the oxygen. A means was now available to bring nitrogen below 100 percent while simultaneously increasing the dissolved oxygen to 100 percent saturation or higher. The advantage over the vacuum degasser was obvious, since with pure oxygen degassing and oxygenation were accomplished in a one step operation. Of further significance was the fact that industrial PSA (Pressure Swing Adsorbtion) oxygen generators

of various generating capacities had been developed during the past decade. This made a practical technology available to aquaculture, as oxygen can now be generated on-site in the proper quantities required. A number of Michigan's state fish hatcheries were equipped with Xorbox oxygen generators with capacities from 75, 200, to 400 cubic feet per hour, and combinations thereof.

Trial and error in design, such as sizing the column relative to flow, partial vacuum levels, packing materials, water distribution patterns (nozzles, etc.), oxygen injection location as well as rate of oxygen introduction per unit of water flow, etc., is still continuing. However, Michigan did derive at workable design parameters. These, along with some economic considerations, are covered in some detail in the paper "Engineering Considerations in Supplemental Oxygen" presented at this conference by Gary Boersen.

Although Michigan purchased oxygen generators for four hatcheries two years ago, not all installations have been completed. However, at Harrietta, where the installation is now complete for both the indoor and outdoor rearing, the positive results have been dramatic, as reflected in Figure 1. The vastly improved survival rate of Rainbow and Brown trout coinciding with the application of pure oxygen is most significant. Of interest is also a much improved growthrate for the Rainbow trout in particular.

Unfortunately, this information covers only one year of oxygen application for indoor rearing at the Harrietta hatchery, and just the beginning of this year's outdoor rearing cycle. Survival and growthrates continue to be very good, especially with the Rainbow trout with a rate of .5 inch per month, at a 1.2 conversion for a constant temperature of 45°F. It appears that the application of pure oxygen had its greatest impact on the Rainbows, however, the fourfold improvement in survival of the Brown trout certainly indicates a highly significant advantage for this species as well.

At the Wolf Lake State Fish Hatchery, where the application of pure oxygen has been in place to one degree or another for at least two years, the results have been equally encouraging. At this station the oxygen is also used to increase production. Dissolved oxygen levels have been tested as high as 180 percent saturation without obvious ill effects on the fish. It has allowed reduction of heated water requirements by nearly 50 percent for esocids (Northern pike and Muskies). Furthermore, the first pass in the three-pass series is operated at very high D.O. levels (135-150 percent) to conserve energy otherwise needed for reaeration of the second and third pass during much of the rearing cycle. Of interest and concern to all of us are the effects of supersaturated D.O. levels on fish quality relative to their ability to survive after their release into the natural environment. Research will be conducted at Lake Superior State College in Michigan, to determine the effects on blood chemistry, composition and cardio-vascular development.

Because of the relative newness of the application of the PSA oxygen generator technology to aquaculture, many questions remain yet unanswered. The need for research, both with respect to the technology and the biology, is obvious. It is our hope that Federal Fish Technology Centers will take on some of these tasks. As far as the state of Michigan is concerned, we are sufficiently convinced of the positive benefits that we will equip yet another hatchery this fiscal year with a Xorbox system. We further believe that Michigan's hatchery design and operational modes are uniquely suited to take advantage of this technology.

Michigan's Hatchery Design and Operational Mode

I believe that a brief discussion relative to Michigan's hatchery design is in order. The three new hatcheries are all designed as three-pass serial reuse facilities and operate at four water changes per hour through rectangular, linear raceways. The raceways are equipped with baffles to make them totally self cleaning and to provide high velocities for fish to select (Boersen & Westers, 1986). Production capacity and their relationships in terms of flow (lbs/gpm) and space (lbs/ft^3) can be expressed as follows:

$$lbs/gpm = 8/R \times lbs/ft^3 \quad \text{and} \quad lbs/ft^3 = R/8 \times lbs/gpm$$

where R represents the hourly exchange rate and 8 equals the number of cubic feet per 1 gpm for one hour. For an exchange rate of four (Michigan's design) we obtain:

$$lbs/gpm = 2.0 \times lbs/ft^3, \text{ and} \quad lbs/ft^3 = .5 \times lbs/gpm$$

For salmonids, Michigan uses a loading formula (lbs/gpm) based on an oxygen consumption of about 95 g per pound of feed. The formula is:

$$lbs/gpm = \frac{4 \times D.O.\ avail.}{\%\ B.W.}$$

At 2% feeding and 4.0 ppm D.O. available, the loading equals 8 lbs/gpm. At an exchange rate of 4.0 per hour, the corresponding density is 4 lbs/ft^3. At an exchange rate of 1.0 per hour this would be 1.0 lb/ft^3. We do produce densities of up to 10 lbs/ft^3. Finally, I like to make these observations:

1. Operational modes of four changes per hour, under optimum loadings (lbs/gpm), require but one fourth the raceway (concrete) space, compared to hatcheries designed on the basis of one exchange per hour.

2. Four changes per hour make baffles very effective, and provide for excellent solid control and interception (NPDES - Permit requirements).

3. Four changes per hour produce superior pond hydraulics and, therefore, a healthier rearing environment.

4. Baffles create high velocities, locally up to over .5 feet per second. The fish can, and will, select these areas (flush their gills?)

5. Relative high densities may change the behavior of fish from one of territorial (stress) to schooling (submissive). This needs to be explored and density thresholds should be identified for each species.

6. The use of pure oxygen offers the opportunity to maintain optimum D.O. levels throughout the raceway, including the effluent water.

7. Number of possible reuses, based on unionized ammonia toxicity (.02 mg/l) is determined with:

$$lbs/gpm = \frac{80}{\%U.A. \times \%B.W.}$$ (Westers, 1986)

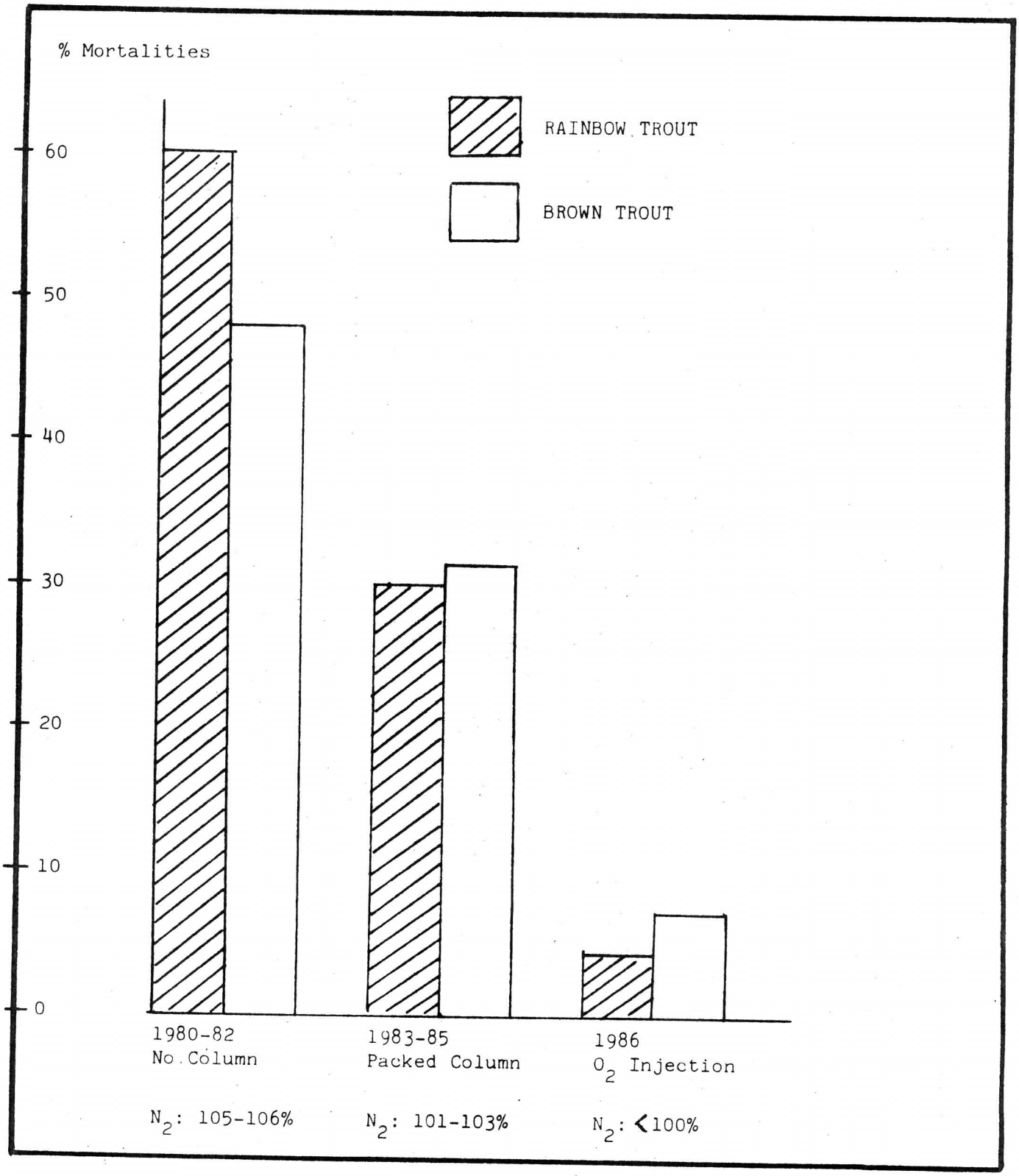

Figure 1. Average indoor rearing mortalities of Rainbow and Brown trout at Harrietta State Fish Hatchery under various nitrogen gas levels from 1980 through 1986.

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Engineering Considerations in Supplemental Oxygen

by

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Abstract

Michigan has experienced stress and mortality problems over the past several years due to total gas pressures greater than 100 percent. Pure oxygen has been found to be an effective means of controlling total gas pressure and increasing dissolved oxygen concentration. In selecting an oxygen source, several considerations as: facility location, capital cost, operating cost, existing facilities and the length of time oxygen is required must be evaluated. Pressure-Swing Adsorption systems were selected as the best option for a oxygen source. Several types of oxygen absorption structures have been developed. The use of pure oxygen has allowed facilities to realize their design potential at reasonable cost.

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Introduction

The Michigan Department of Natural Resources has recently completed a hatchery renovation program. With the completion of that program, rather severe stress and mortality problems started to occur with small salmonid fingerlings. After several years of investigations, gas supersaturation was identified as the suspected culprit (cause). All hatcheries with gas supersaturation problems were equipped with packed columns to degas the water. The packed columns provided adequate dissolved oxygen and reduced Total Gas Pressure (TGP) to 101-103 percent. Although these low supersaturation levels were not creating acute mortalities, it was assumed they caused stresses resulting in secondary problems, often leading to death. A vacuum degasser was built, which proved to be a costly failure apparently due to poor design. Experiments with adding oxygen to a packed column demonstrated that TGP could be reduced to less than 100 percent with the added benefit of increased oxygen levels. This was a successful method to control TGP, but how to economically obtain and use oxygen was another problem. Basically two options were available for pure oxygen, an on-site generator or purchase of bulk oxygen.

On-Site vs. Bulk Oxygen

Not long ago, bulk oxygen was the only choice available for fish culture. Until rather recently on-site generating oxygen systems required a monthly use of 8-10 million cu ft per month. This greatly exceeded the demands of almost all fish culture operations, where only 0.5 million cu. ft. would be required. Recently small on-site generation systems have become available which produce oxygen in quantities which meet fish hatchery requirements. A number of factors are involved in selecting whether bulk or on-site oxygen generation is best for a facility. Economic considerations include capital and operating costs. Other factors include backup system requirements such as standby power and alarms. These costs depend whether the oxygen is made into a life support system or is used as a supplementary system. It further depends on the existing facilities at the hatchery itself.

The maintenance requirements of both systems is minimal. On-site systems require occasional maintenance such as compressor lubrication and air filter changes.

System Design

The State of Michigan selected the Pressure-Swing Adsorption (PSA) system for its oxygen source. Table 1 shows a cost comparison between on-site and bulk oxygen systems. As a public agency the Fisheries Division decided to go with the up front capital costs, so that operational costs will not be a problem during tight budget years. A commercial application might obviously reach a different conclusion.

Figure 1 shows a schematic of a PSA-oxygen generating system. The primary components are a compressor to force air through the molecular sieve material. The molecular sieve is a ceramic material that adsorbs nitrogen gas, but not oxygen, so what exists the generating unit is nearly pure oxygen with some argon. This goes to a storage tank. The

sieve material is purged of nitrogen by decompressing and backwashing with some oxygen from the storage tank on a timed basis. The sieve material, if treated properly (moisture, oil kept to a minimum) should last indefinitely.

Three hatcheries now use the PSA systems. Each one applies the oxygen at their facility somewhat differently. All use oxygen to remove excess nitrogen, some increase DO levels while one facility supersaturates with oxygen.

At the Harrietta State Hatchery a specific room was available to install the oxygen generators. This room has 3-200 cfh oxygen generators and storage tanks. The compressors at Harrietta are housed in the mechanical room. The 40 hp compressor produces about 90,000 BTU per day and the fan from the compressor has been tied into the forced air heating system. Location of the compressor at this location has solved a couple problems that have developed at the another hatchery. At the Wolf Lake State Fish Hatchery the compressors and PSA systems are located adjacent to each other in a separate building. This has caused both the compressors and the oxygen generators to operate at elevated temperatures. The compressor at Harrietta is located about 150 ft. from the oxygen generators which apparently allows the air to cool prior to entering the generators.

Air enters the oxygen generators at about 60 psi and exits at 55 psi. A pressure regular maintains a constant 45 psi to the distribution system. Galvanized pipe and copper tubing is used in the distribution system. Three-quarter inch piping is used on trunk lines and 1/2" tubing to individual oxygen absorption columns.

At the Harrietta Hatchery both the indoor and outdoor absorption columns (Figures 2 and 3) are designed with the basic design criteria of 250 gpm/ft^2 (1 lpm/cm^2). A water seal is maintained at the bottom of the columns and the water falling into the column develops a vacuum of 3-4 inches mercury. The indoor absorption column is 55 inches high and 12 inches in diameter. Water flow rates through the column range from 50 to 200 gpm (200 to 800 lpm). Oxygen is added to the column at a rate of 1.5 lpm under all flow conditions. Oxygen in the water increases about 1.2 ppm from 10.0 ppm to about 11.2 ppm at 46°F. Total gas pressure of 102 to 103 percent is decreased to less than 100%.

The outdoor absorption columns are 38 inches in diameter and 72 inches high. The tanks are currently constructed of welded steel, but switching to aluminum in the future is anticipated. The steel tanks cost about $200 each as compared to $1700 for an aluminum tank. These tanks are going to be used in two different ways. The columns on the first pass water are used primarily to degas water. Oxygen is being added at about 15 lpm. TGP is decreased to less than 100% and oxygen concentrations are slightly increased. Oxygen absorption efficiency is about 50 percent.

The columns on reuse water will be used only to reoxygenate the water and the operating criteria have yet to be developed. Use of the columns seem to indicate poorer absorption than on the first pass columns. The exact reason is unclear. The design of these columns to develop a vacuum may

be part of the problem. Design of efficient oxygen absorption columns under varying conditions is one area where research is needed.

The indoor columns presently have 1½ inch media in them. Experiments with columns without media have not demonstrated better efficiencies. The outdoor columns have been built without media. It has been a major objective to have columns without media to reduce maintenance requirements.

The general maintenance on the system is minimal and has been incorporated into the hatcheries preventive maintenance program. Water condensate from the compressor is drained daily and the filters are cleaned on the oxygen generators weekly. The compressor operating gauges and the oxygen purity from the generators is checked daily. Because of the routine maintenance checks alarms have only been added at two locations. A pressure gauge from the compressor to the oxygen generator and another pressure gauge leading from the oxygen generator. Both of these are tied into the hatcheries alarm system.

Other systems for oxygen absorption have and are being developed at other state hatcheries. Figure 4 is from the Marquette Hatchery. A flow of 9000 gpm creek water needed treatment with only about 2 ft of head available. A slide was fitted on the weir boards of the dam. The water goes down this slide and enters boxes with an opening at the top of one side. The opening is too small to permit all the water to enter so the water helps form a seal at the top. The bottom of the box is below the water level. The oxygen with this system is added through a grid arrangement at the bottom with media in the intermediate area. The system has been able to reduce TGP's but not below 100 percent. The D.O. concentrations are increased from 10 mg/l to 14 mg/l. The oxygen absorption efficiency is about 40 percent. Oxygen is added to three boxes at a rate of 300 cu ft/hr.

The Wolf Lake Hatchery absorption system has two 18 inch corrugated pipes about 4 foot long with no media. The pumped water is discharged through a nozzle and also develops a slight vacuum. By adding 20 lpm oxygen, the D.O. level can be increased from 0 to 14 mg/l at a TGP of less than 100 percent for a flow of 300 gpm (1100 lpm). On reuse water, concentrations are increased from 7 to 14 mg/l with 12 lpm of oxygen.

Other equipment is also being developed. One example is the Aquatector. This device highly oxygenates a side stream which is then mixed with other water. This device is just being tested and many questions remain unanswered. Other techniques for adding oxygen such as U-Tubes and down flow bubble contactors may have their applications in specific cases. (Richard E. Speece, "Management of Dissolved Oxygen and Nitrogen in Fish Hatchery Waters," Proceedings of the Bio-Engineering Symposium for Fish Culture, Traverse City, Michigan, American Fisheries Society, FCS Publ. 1)

Costs

The cost per pound of fish produced with oxygen is not an appropriate assessment at this time. The use of oxygen allows the facilities to

realize their design potential. For example, at the Harrietta Hatchery it was believed the hatchery could produce 200,000 pounds per year. Prior to the use of oxygen, production of only 120,000 pounds was realized. This year, with oxygen applied, production is expected to reach 200,000 pounds for the first time. The capital cost of oxygen generators and compressors at Harrietta was about $40,000. Oxygen costs about 25¢ per 100 cu ft or about $36.00/day at maximum use. Installation of the compressor, oxygen generators and oxygen absorption columns was preformed by hatchery personnel.

How oxygen can enhance production and at what cost with a given volume of flow can be calculated readily. At an elevation of 800 ft., 50°F water at 90% saturation has a dissolved oxygen concentration of about 10 ppm. If that oxygen concentration is increased to 100 percent the oxygen is increased by 1.1 ppm to 11.1 ppm. If 6 mg/l is the lower limit for oxygen, the production potential based on an additional 1.1 ppm D.O. increases by about 25 percent (11.1-6/10-6 = 125%). At a flow rate of 4000 gpm and a loading of 5 pounds/gpm the peak load at a facility is increased from 20,000 pounds to 25,000 pounds. The amount of oxygen required for this increased production potential is about 53 pounds of oxygen per day (5.76 mgd x 8.34 x 1.1). Should oxygen absorption be only 25 percent, 212 pounds (53 x 4) of oxygen is required, which is equal to 2800 cf of oxygen per day. At an oxygen cost of 25¢/100 cuft, the operating cost to increase production by 5000 pounds would be $7.00 per day.

Conclusion

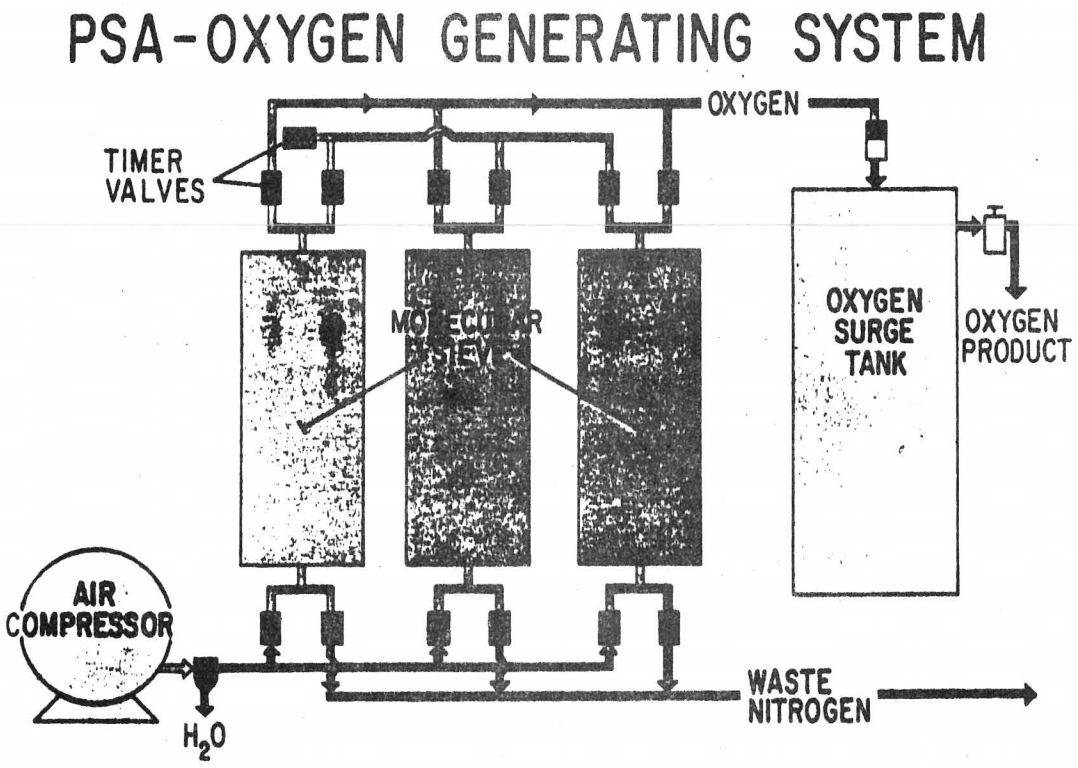
Michigan's use of pure oxygen in fish culture was facilitated by circumstances which are probably unique. First, high mortalities were occurring which were believed to be related to low level nitrogen gas supersaturation, something needed to be done. Secondly, the hatcheries had several items as alarms and standby power incorporated into their design, so using advanced technology was not a new concept. Thirdly, because Michigan had built "high tech" fish hatcheries a number of the components necessary for moving into the use of pure oxygen were already in place. For instance, alarm systems and standby power had already been provided for in the new hatcheries. These three factors, made moving into the use of pure oxygen a much easier process.

Appendix A
Common Conversions
Weight - Volume Equivalents of Oxygen

1 lb. (liquid) = 0.1371 gal (liquid) = 0.5190 (liquid)
1 lb (liquid) = 13.35 cu ft (gas) or 377.9 liters (gas)
1 gal (liquid) = 97.33 cu ft (gas) or 2756 liters (gas)
1 cu ft (gas) = 28.3 liters (gas)
1 liter (liquid) = 25.7 cu ft (gas) or 728.1 liter (gas)

Liquid is volume at normal boiling point
Gas is volume at 70°F and 14.696 PSIA

FIGURE 1



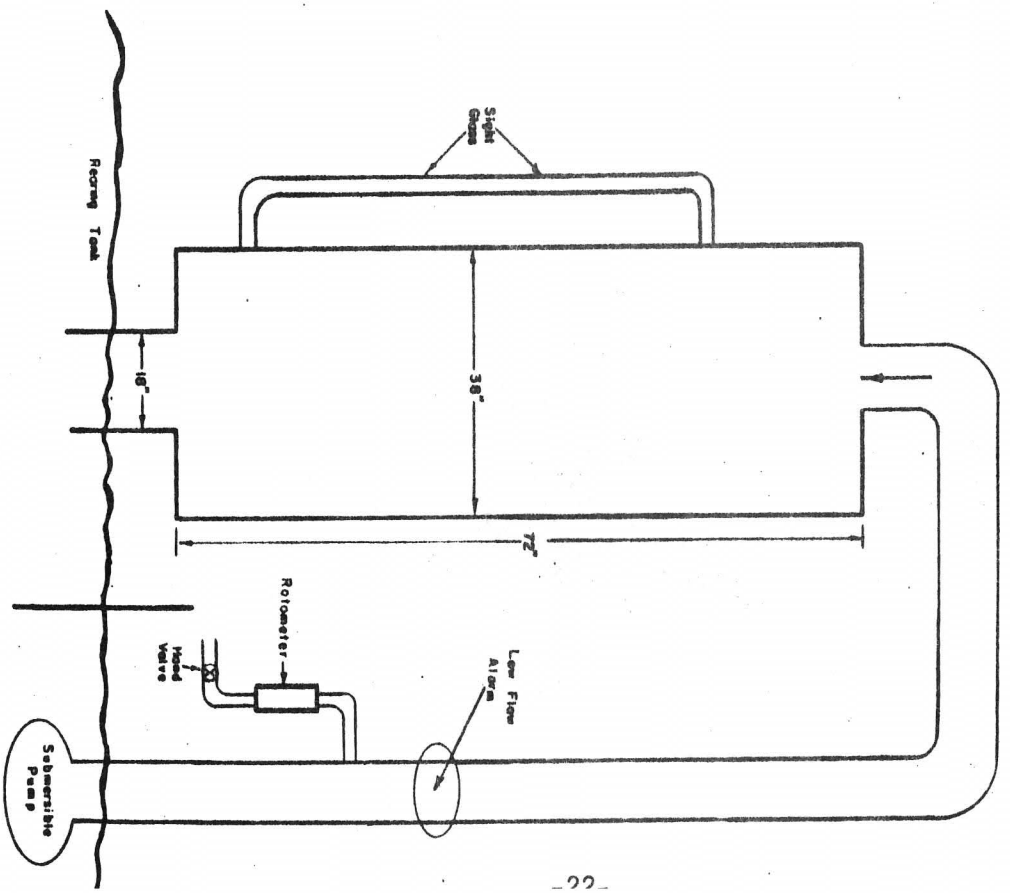


FIGURE 2

Harrietta Fish Hatchery
Outdoor Rearing Tanks
Oxygen Absorption Column

FIGURE 3

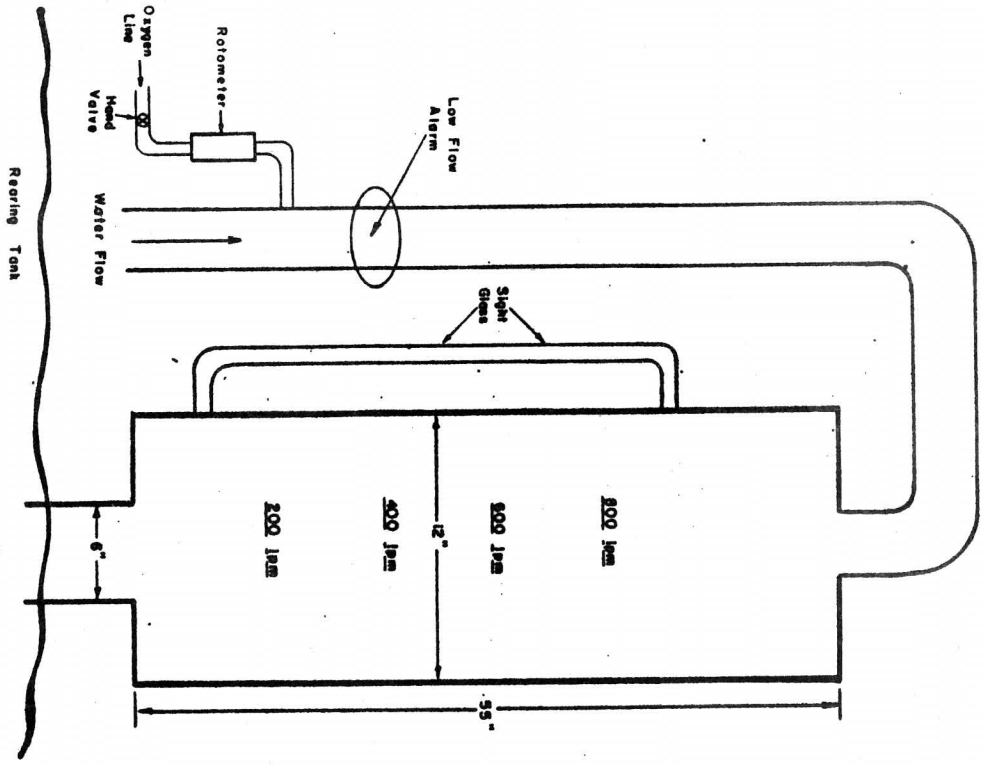


FIGURE 4

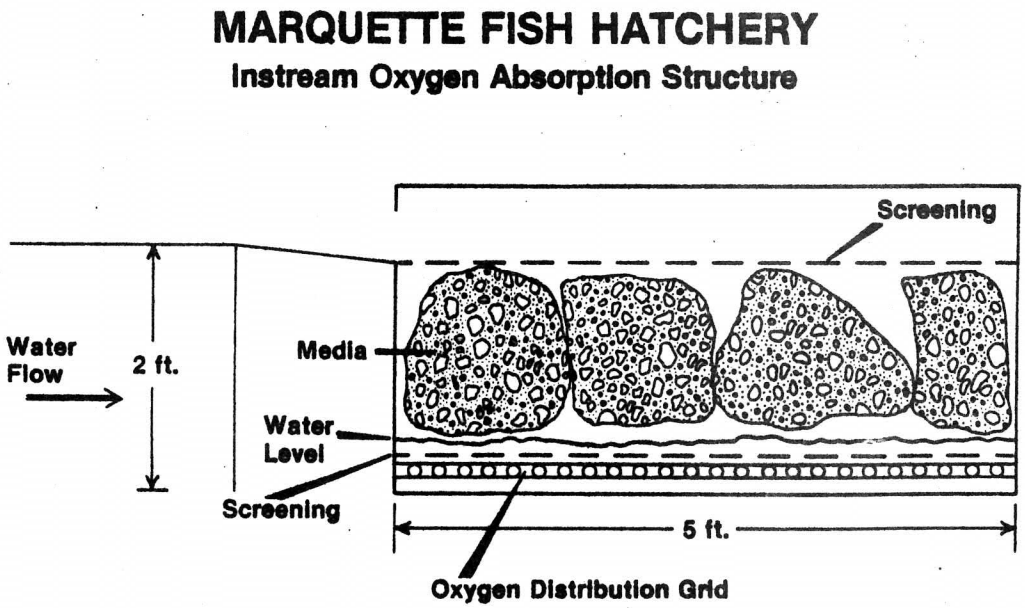


TABLE 1

COSTS OF OXYGEN SYSTEMS

PRESSURE SWING ABSORPTION[1]		BULK OXYGEN	
CAPITAL COST		CAPITAL COST	
40 HP Compressor	$10,000		
80 KW Standby Power	$15,000		
600 cfh PSA System	$30,000	Concrete Pad	$4,000
	$55,000		$4,000
OPERATING COST[2]		OPERATING COST	
Electricity	25¢/100 CU FT	Oxygen Cost	25-30¢/100 CU FT[3]
		Storage Tank Rental	$500/Month[4]
		Evaporation Lost	.25%/Day of Tank Volume

Other Considerations

1) Existing facilities

2) Length of time oxygen required

3) Equipment

   a) Absorption column
   b) Alarm systems
   c) Piping for oxygen conveyance

[1]Assuming a use of 10,000 cu ft/day.

[2]25 kw/hr X 6¢/kw X 24 hr ÷ 14,400 cu ft.

[3]Cost does not include transportation, cost of delivery depends on distance from air separator, ranges from 3-15¢/50 miles, at a use of 10,000 cu ft/day, delivery cost would probably be 3-6¢/50 miles.

[4]Length of contract for rental from 3-5 years for 6,000 gallon tank.

USE OF OXYGEN TO COMMERCIALLY REAR COHO SALMON

R.F. Severson, J.L. Stark, L.M. Poole

December 3, 1986

In 1977, Oregon Aqua-Foods, Inc. constructed a salmon hatchery on the McKenzie River near Springfield, Oregon. Among the unique features of the hatchery are the application of industrial waste heat in the form of non-process plant cooling water effluent from a neighboring pulp and paper mill, water treatment capabilities consisting of chlorination and sulphonation for disinfection of all incoming hatchery water supplies and the application of supplemental oxygen.

The hatchery's production capability consists of 36 raceway ponds totaling 385,000 cubic feet of available rearing space. The raceways are designed to provide a maximum rearing density and capacity to raise coho salmon at 1.5 lbs./cubic foot in order to meet production plan objectives. A combination of the mill heated water and McKenzie River ambient water provide a total flow of 32,000 gallons per minute to the hatchery. Operating experience during 1978 and 1979 determined that the relationship between flow capacity and available rearing capacity was disproportionate in that the facility was flow limited to meeting production objectives; i.e., a peak biomass of 165,000 kg (363,000 lbs.).

Based on 1978-79 operating experience which determined the hatchery to be flow limited, effluent dissolved oxygen (0_2) levels

were near or at 5 mg/liter when the average loading density for the facility was at 0.7 lbs./cubic foot. A decision was made to explore alternatives to provide additional oxygen to the facility which would allow for an increased average loading density of 1.0 lbs/cubic foot. This average loading further assumes that peak biomass within an individual raceway may experience up to the 1.5 lbs./cubic foot design capacity and would therefore require increased flow and/or oxygen to sustain such loadings. Without additional oxygen, the hatchery would be limited to produce approximately 6.5 million coho smolt which would underutilize the hatchery's rearing capacity by 50%. In addition to increasing oxygen for additional biomass, a secondary objective was to reduce dissolved nitrogen (N_2) gas supersaturation as symptoms of low level gas embolism had been observed in alevin (yolk-sac fry) during the winters of 1978 and 1979.

In order to determine the quantity of oxygen required to support the additional biomass, we first determined the total oxygen demand at peak biomass conditions. Next, we determined the amount of oxygen already available in our water supply coming into the hatchery in order to know the difference which would have to be provided as additional. Theoretical computations, provided by Dr. R.E. Speece, Professor of Environmental Engineering at Drexel University, determined our additional oxygen requirement to be 747 kg/day.

OXYGEN SYSTEM DESIGN ASSUMPTIONS

- Predicted peak biomass - 165,000 kg
- Flow capacity - 32,000 gpm
- Body weight/day feed rate - 3.5%
- Water temperature - 13.5°C
- Oxygen consumed/kg feed metabolized (fed) - 0.22 kg

1. Total Oxygen Requirement

165,000 kg. fish x 0.035 kg feed/kg fish day = 5,775 kg feed/day

5,775 kg feed/day x 0.22 kg O_2/kg feed = 1,270 kg O_2/day

Oxygen Transfer and Consumption Efficiency Safety Factor:

1.33 x 1,270 kg O_2 /day = 1,689 kg O_2 /day

2. Oxygen Available in Incoming Water Supply

32,000 gpm x 1,440 min/day x 3.785 l/gal. x (10.4 - 5.0 mg/l)
÷ 1,000,000 mg/kg = 942 kg O_2/day

3. Additional Oxygen Requirement

1,689 kg O_2/day - 942 kg O_2/day = 747 kg O_2/day

Oxygen consumption is determined on the basis of feed rate and temperature. A factor of 1.33 (75% efficiency) serves to take into account reductions in metabolic oxygen requirements at night, venting of a portion to the atmosphere as it enters the ponds and other miscellaneous inefficiencies either in the gas absorption in the water supply or in oxygen consumption rate of the fish.

Several alternatives were explored to provide the additional oxygen:

1. Increase fresh water flow by 12,760 gpm.
2. Add oxygen at the raceways through diffusers.
3. Add oxygen at the raceways through mechanical aerators.
4. Provide oxygen through high pressure side-stream injection at the raceways.
5. Inject O_2 at the River pumps or in ambient water pipelines after the water disinfection treatment.
6. Provide oxygen through a side-stream packed column with counter-current oxygen injection after the water disinfection treatment.

Option Number 1 was not practical due to hydraulic limitations, more specifically, the pipeline influent and effluent capacities from the river intake station to the hatchery and the prohibitive cost of expanding the water treatment capabilities. This option also implied an expansion of the hot water systems.

Options 2, 3, 4 and 5 were discarded because of the inefficiencies of oxygen gas transfer, high energy and maintenance costs and/or high capitalization costs and other considerations.

Option Number 6 was selected as the most efficient and cost effective. This alternative was based on the principle of a counter-current exchange process of oxygen and water creating an oxygen supersaturated solution and eliminating nitrogen gas supersaturation. Weyerhaeuser Aquaculture R&D evaluated the alternatives,

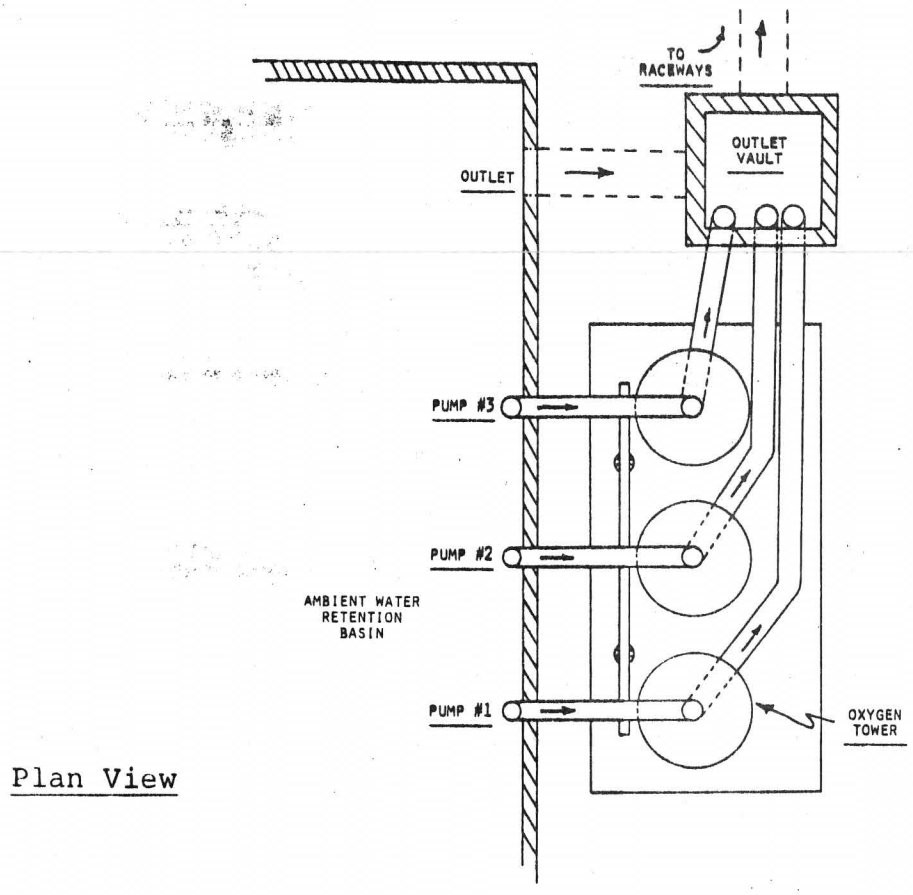
Dr. R.E. Speece, a consultant, developed the criteria for design, and CH_2M Hill provided the engineering.

Description of System

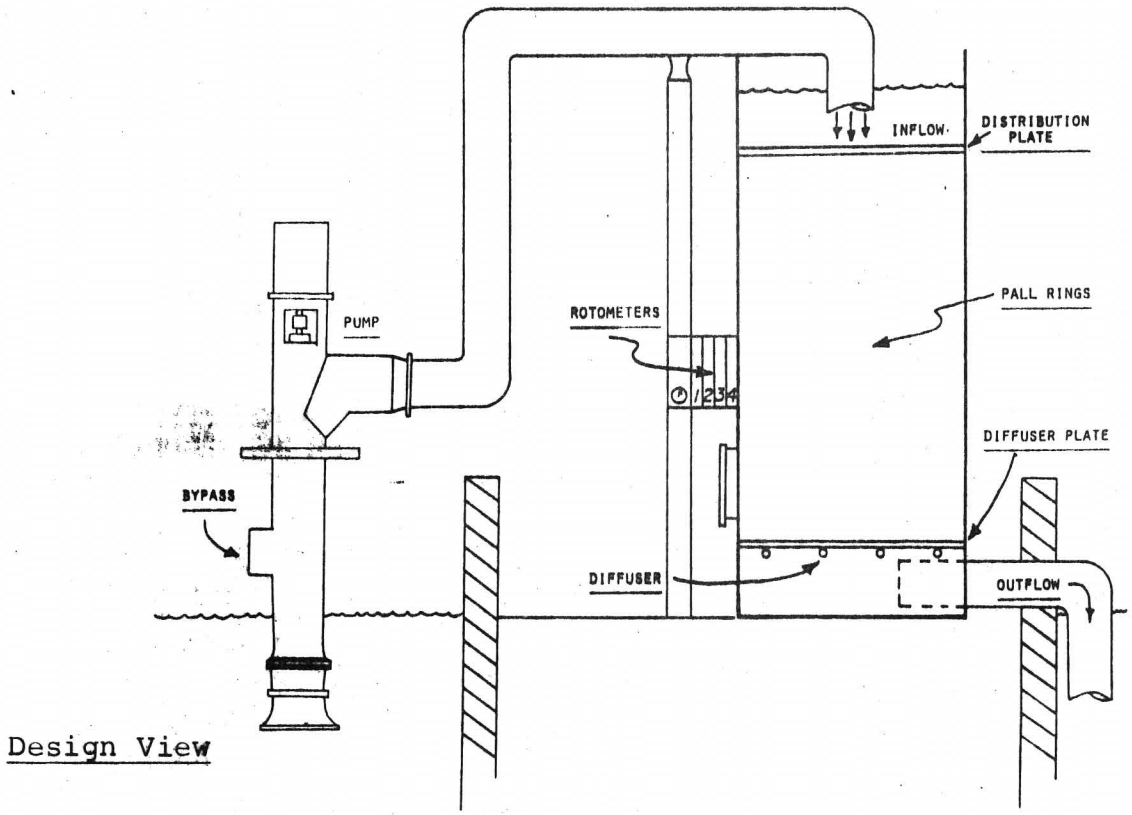
In March of 1980, construction was completed on a counter-current supplemental oxygenation system comprised of three 11' high by 5' diameter packed columns containing diffusers covering all four quadrants, a diffuser plate supporting six feet of pall rings (118 $ft.^3$), and a water supply distribution plate. Each column is fitted with a 15 h.p. vertical pump and during combined operation will pump approximately 9,300 gpm or 30% of the total hatchery ambient water supply (Figure 1).

The oxygen supply system consists of a 6,000 gallon liquid oxygen storage tank, vaporization unit, and flow meters. The oxygen supply system is supplemented with an ITT Barton differential pressure sensing system. The D/P sensing system can be calibrated to acknowledge interruptions in oxygen flow below 75% of normal operations, such as low storage tank level and/or leaks in the oxygen delivery line.

System operation is accomplished by filling the pall ring packed columns with water and controlling overflow via a by-pass valve located on the vertical pump. Once a volume (plug) of water is formed over the distribution plate, the water level within the column, rotometer pressure, and discharge volume can be controlled by a 16" column effluent gate valve. Liquid oxygen flows through the vaporization unit and then in a gaseous state, travels to a column by



Plan View



Design View

Figure 1. Counter-Current Supplemental Oxygen System

way of a four-place manifold. The individual locations on the manifold are connected to a Fisher and Porter flow meter. Regulated oxygen then flows into distribution diffuser pipes within the lower portion of the column where oxygen transfer occurs. Supersaturated side-stream water at 25-30 mg/l travels out of the packed columns and is blended back into the main stream water supply which supplies the hatchery's needs.

Performance Testing

After the start-up of the 0_2 system, performance testing was conducted to compare the effected supply of supplemental oxygen under varying operating modes. Variables included (1) quantity of oxygen supplied to column diffusers; (2) percent operating capacity of any individual column; and, (3) number of columns in operation. In the interest of accuracy, two YSI Model 57 oxygen meters were utilized to measure oxygen levels during the testing.

Performance testing was initiated by starting up one of the three columns. Rotometers on the test column were set at 90% operating capacity, and pressurized oxygen was injected into the column at 20, 25, 30, 35, and 40 psi increments. Increases in oxygen levels (mg/l) at the influent raceway headbox were documented between each pressure change. In a second test, two packed columns were initiated and rotometers on both test columns were set at 45% operating capacity. Pressurized oxygen (30 psi) was injected into the columns and dissolved oxygen levels were recorded. Finally, all three columns were tested at 30% operating capacity and pressurized oxygen supply was set at 30 psi.

Test results from the first test indicated that optimum pressurized oxygen supply to the packed columns be regulated at 30 psi. Supply pressures greater than 30 psi increased dissolved oxygen levels by only 0.4 mg/l at a substantial increase in cost. Supply pressures lower than 30 psi caused several column rotometers to malfunction. Test results also indicated that operation of two columns at 45% versus one column at 90% showed no significant increase in efficiency or operational cost savings. It should be noted that operation of three columns at 30% operating capacity versus two columns at 45% showed no significant difference. Although there was no difference in efficiency of oxygen gas absorption between the three tests, it was more cost efficient to operate one column rather than splitting the requirement between two or three, assuming the total requirement could be met with one column or less, due to the electrical cost of one pump versus two or three. The efficiency of gas transfer has been measured from time to time at the column's discharge and compared with measurements taken in the headbox to the raceways. Based on these measurements, the system was estimated to be 73% efficient in oxygen gas transfer to the water supply. The actual consumption, however, of the added oxygen was estimated at 75% as discussed previously in the theoretical demand computation. Oxygen values measured at the head of the raceways are shown in Figure 2 in relationship to various percent use of the oxygen system.

Operating Experience

Since March of 1980, Oregon Aqua-Foods has operated the oxygen system with measureable success. The Springfield hatchery flow capability of 32,000 gallons per minute can support a biomass of

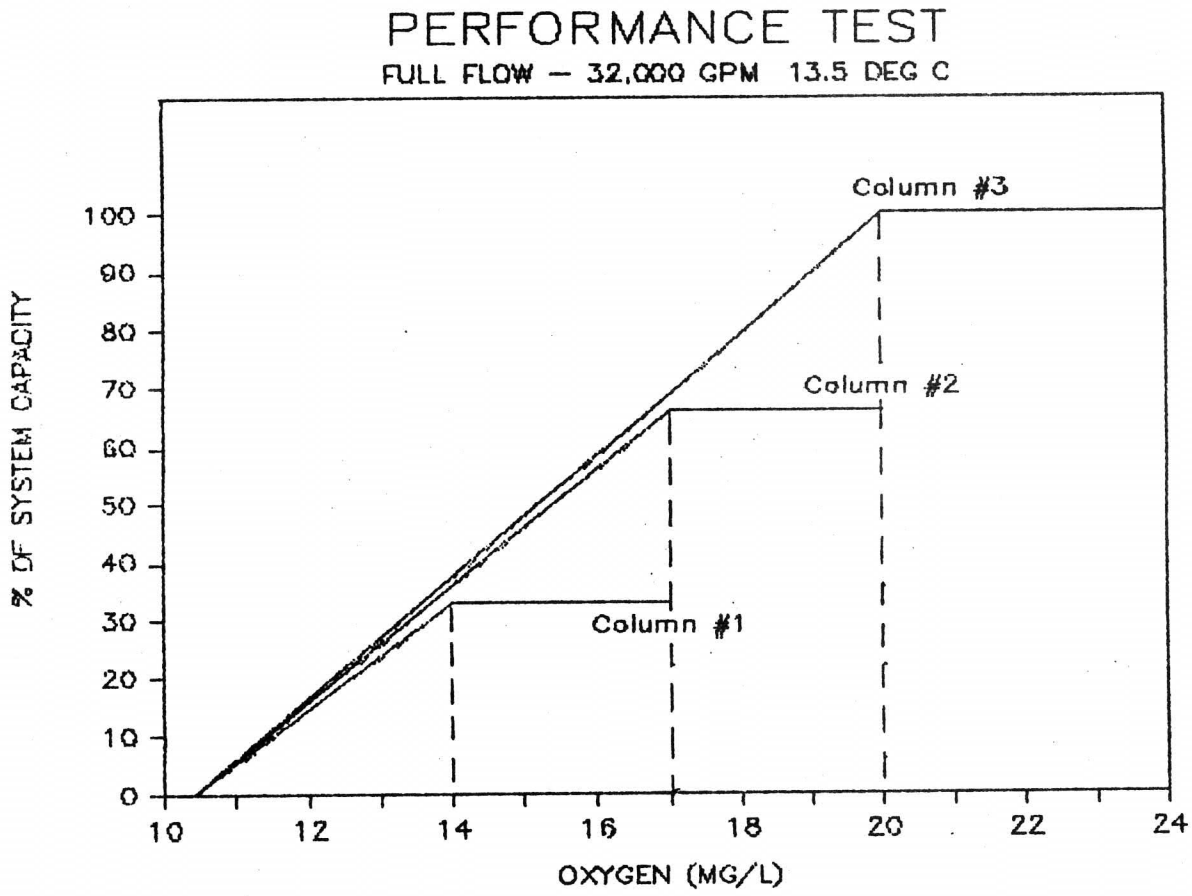


Figure 2.

Oxygen Level of Inflow to Raceways at Various Operating Percent of Oxygen System

100,000 kg (220,000 lbs.) consisting primarily of zero-age coho salmon smolt with an average weight of 10 g (45/lb.). In most years, the hatchery biomass typically begins to exceed 100,000 kg about mid-April, at which time supplemental oxygen is required to support the increasing biomass. This requirement will often extend until mid-July and often into August, depending on the level of chinook production following the coho.

Some additional performance testing has been conducted during the past seven years to evaluate cost/benefit of the oxygen system. However, operating experience has provided the best source of information to measure the effective benefit of supplemental oxygen. There are a number of variables which determine the amount of additional production which supplemental oxygen will provide, not the least of which are temperature and feed related. Under accelerated rearing conditions which implies temperatures in the range of 12-15°C and maximum feed rate, a doubling in capacity can be expected with addition of supplemental oxygen.

Influent dissolved oxygen levels to the raceways can be increased up to 200% depending on the percent of the oxygen system used. Management objectives require that the system be operated to maintain an effluent dissolved oxygen level of 5 mg/l. For example, at an operating temperature of 13.5°C, oxygen saturation of inflow water into the raceways would be approximately 10.4 mg/l. Assuming the maximum flow of 32,000 gallons/minute and 100% use of all three oxygen chambers, influent dissolved oxygen at the raceways can obtain 21 mg/l (Table 1).

Table 1. OXYGEN DEMAND AND SUPPLEMENTATION FOR ZERO-AGE COHO PRODUCTION

Required Biomass (1,000's kg)	Ambient Water Supply (gpm)	Influent Oxygen (mg/l)	Effluent Oxygen (mg/l)	Available Oxygen to Fish (kg 0_2/day)	Additional Oxygen Required (kg 0_2/day)	Total Oxygen Available to Fish (kg 0_2/day)	Oxygen Use in SCF/day 1/
25	5,750	10.4	5.0	169		169	
50	11,500	10.4	5.0	338		338	
75	17,250	10.4	5.0	507		507	
100 (220 k lbs.)	23,000	10.4	5.0	676		676	
125	32,000	11.5	5.0	941	191	1,133	5,080
150	32,000	13.8	5.0	941	593	1,534	15,792
175	32,000	16.1	5.0	941	994	1,936	26,478
200	32,000	18.4	5.0	941	1,395	2,337	37,160
225	32,000	20.7	5.0	941	1,796	2,738	47,844

1/ Standard cubic feet

The economic benefit derived from the use of supplemental oxygen is quite dramatic, particularly in light of the fact that approximately 50% or more of available oxygen present in the incoming water supply to a hatchery is not useable for fish production. For example:

Influent Dissolved Oxygen	10.4 mg/l
Effluent Dissolved Oxygen	5.0 mg/l
Useable for Fish Production	5.4 mg/l

In other words, approximately 50% of the cost of pumping water goes directly toward fish production and the remainder of those costs virtually go down the drain. On the other hand, each dollar spent to supplement the oxygen in the incoming water supply is returned directly to fish production. This is illustrated in Figure 2 which also demonstrates the relationship of oxygen demand based on actual operating experience as compared to the theoretical demand. An example of the computation used to determine the theoretical oxygen demand is as discussed on Page 3.

The experience at the Springfield hatchery would strongly indicate that supplemental oxygen is cost effective in increasing production capacity. For example, the operating cost ratio associated with pumping additional water versus oxygen addition is approximately 2.5:1. This, however, includes the cost of water treatment which would not be associated with most hatcheries. Disregarding water treatment, the ratio would still approximate 1.6:1 in favor of supplemental oxygen (Table 2). The capital costs associated with the oxygen system is also favorable as compared to additional pumping or other mechanical means of aeration. The capital costs

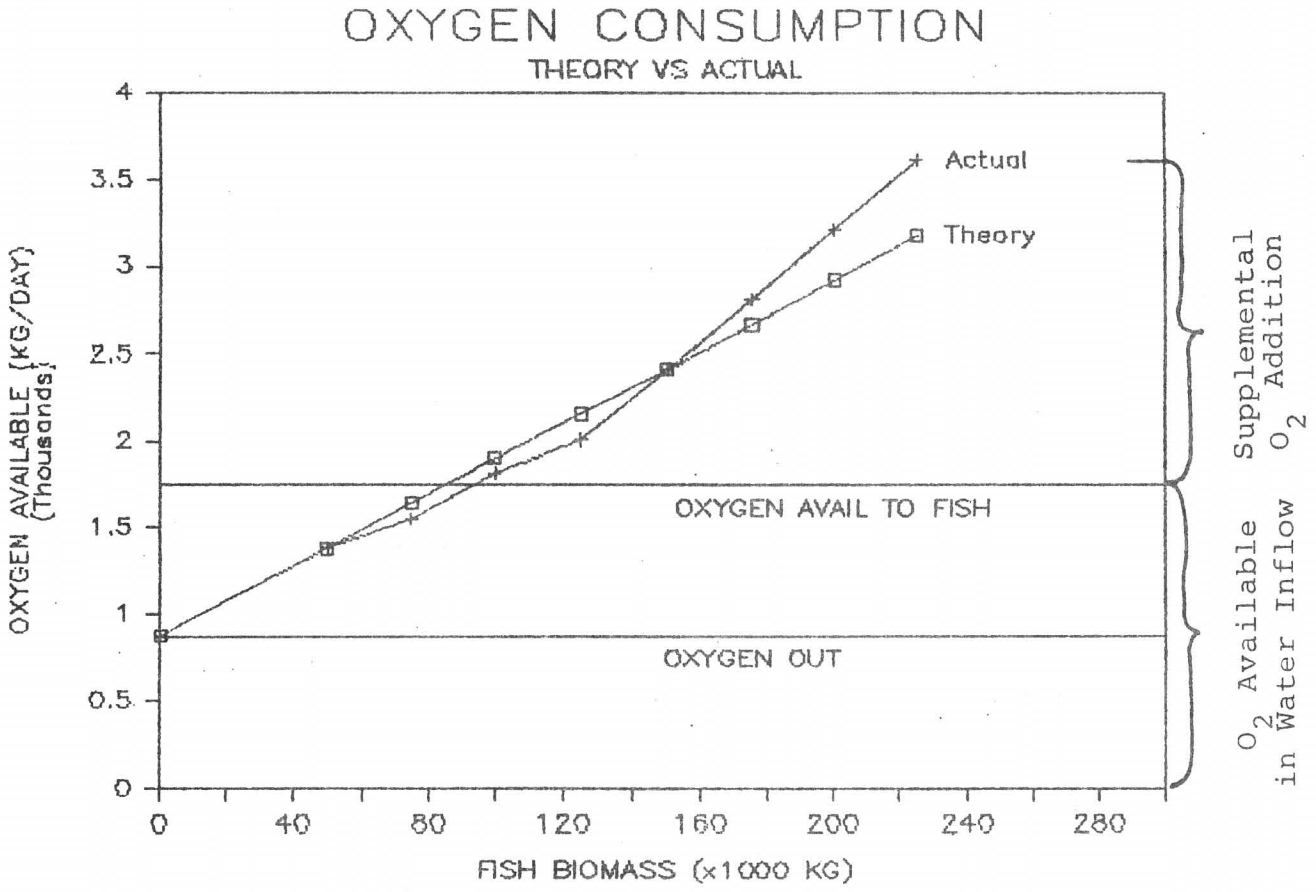


Figure 2.

Theoretical versus Actual Oxygen Consumption and Available Oxygen in Water Inflow versus Supplemented Addition

Table 2.

OPERATING COST TO INCREASE WATER FLOW VERSUS
COST TO INCREASE OXYGEN LEVEL IN AVAILABLE WATER FLOW

Biomass (kg (lbs) x 10^3)	Available Water Flow (cfs)	Additional Water Flow Required (cfs)	Total Water Flow Needed (cfs)	Cost/Day for Add'l Water			Cost/Day for Additional Oxygen
				Electrical	Water Treatment	Total	
100 (220)	71.3 (32,000 gpm)	-	71.3	-	-	-	-
125 (275)	71.3	7.6	78.9	$90.10	$17.35	$107.45	$19.42
150 (330)	71.3	23.4	94.7	138.87	53.45	192.32	60.01
175 (385)	71.3	39.1	110.4	187.64	89.56	277.20	100.62
200 (440)	71.3	54.7	126.0	235.93	125.32	361.25	141.21
225 (495)	71.3	70.5	141.8	284.70	161.42	446.12	181.81

Assumes

- All zero-age coho production.
- 13.5°C H_2O at 10.4 mg/l.
- Electrical Cost $0.29/kw hr.
- Water Treatment Cost $3.54/mgd.
- Liquid oxygen cost $0.38/100 sft^3.

for the oxygen system at Springfield as compared to the construction cost of a pump station and pipelines would favor supplemental oxygen by a cost ration of 1:4.2.

An additional benefit of the oxygen system is the reduction in nitrogen gas saturation and to some extent, total dissolved gas. Nitrogen (N_2) gas saturation of incoming water can approach 103.5% which, under chronic conditions, can cause nitrogen gas bubble disease symptons. Testing for nitrogen gas at varying oxygen flow rates of 0-100% has shown a reduction in from 103.5% down to 82% (Table 3). One management practice has been to increase oxygen during the winter months when flow rates in the River are at their highest and nitrogen levels are higher than at other times of the year and production in the hatchery is most vulnerable and susceptible to gas bubble disease. Since practicing this procedure of nitrogen stripping, we have not observed any signs of gas bubble disease in our production.

Table 3. EFFECT OF OXYGEN ON NITROGEN AND TOTAL DISSOLVED GAS AT 13.5°C

O_2 Gas Flow	% O_2	Headbox % N_2	TDG
100%	162%	82-92%	102.5%
40%	127%	96-98%	102.5%
0%	107%	100-103.5%	103.0%

Note: % N_2 in discharge of sidestream system is ~72%.

Conclusions

Our experience has shown that supplemental oxygen is a benefit not only to the economics of fish production, but also as it relates to fish health and quality of smolt. Although these benefits are less tangible, they can be measured over time by better survival and growth performance in the hatchery, and better marine survival. Supplemental oxygen is particularly advantageous under conditions in which a hatchery's rearing capacity is disproportionate to its water flow capacity as is the case at Springfield. If a hatchery is underutilizing its rearing volume due to lack of water flow, supplemental oxygen will more than likely be the least expensive alternative as it compares both in operating and capital costs.

USE OF SUPPLEMENTAL OXYGEN TO REAR CHINOOK IN SEAWATER

Presented by Dr. Ron Gowan

Anadromous is an ocean ranching company with a freshwater rearing facility near Klamath Falls, Oregon, and a salt water rearing facility at Coos Bay. The Company rears and releases coho, spring and fall chinook. In past years the company has released up to 2 1/2 million chinook smolts annually and will release over 5 million in 1987.

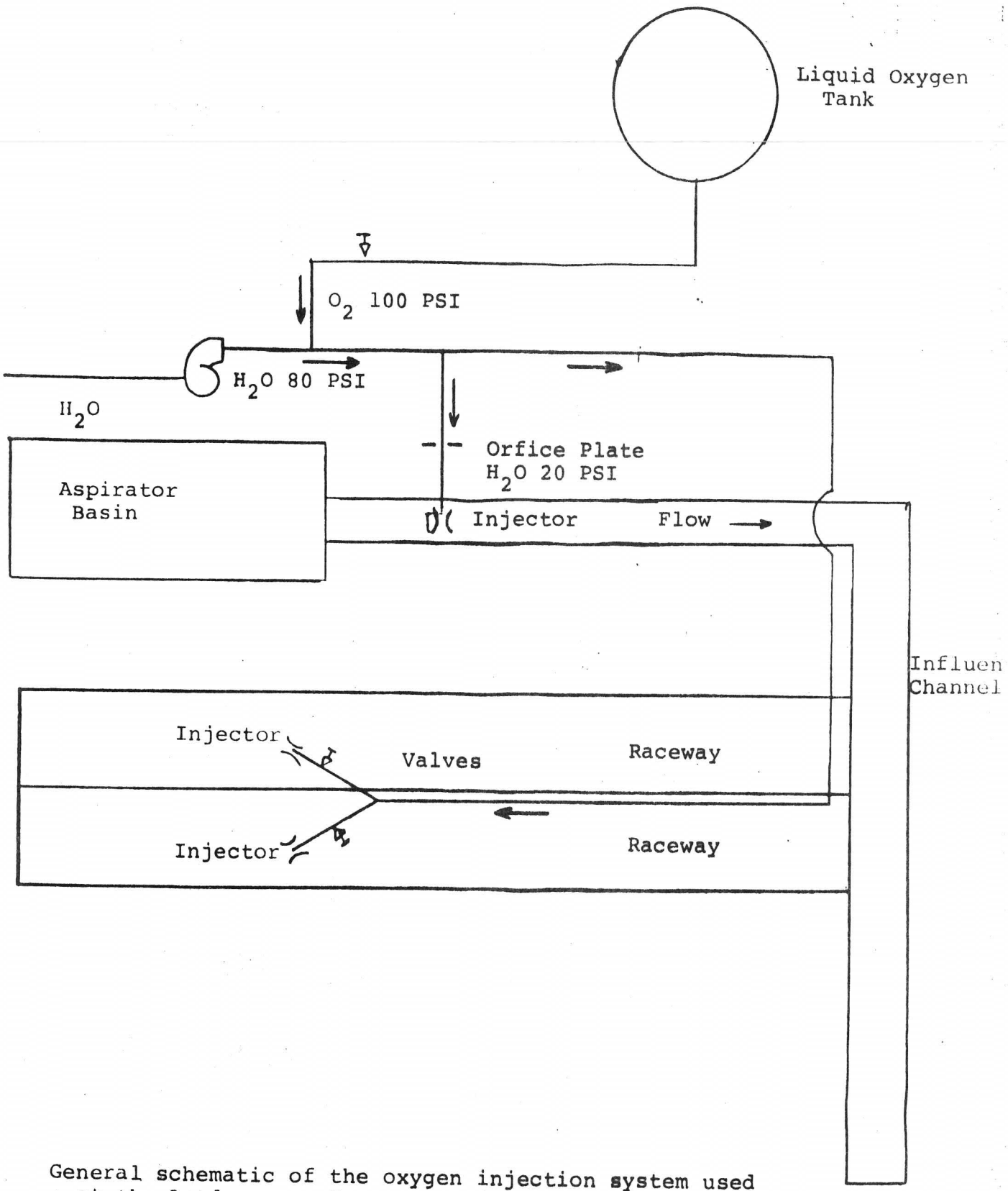
Two general rearing strategies are used for spring chinook. In the first, spring chinook are raised to 4 grams in freshwater then moved to the seawater site in May-June. At seawater they are grown to a size of 45 g and released in mid-August. In the second the fish are transported to seawater as 25-35 g smolts in July through September, held for 30 days in seawater, and released at 45-55 g.

Coos Bay is a pumped site on an estuary; tidal cycles cause salinity, temperature, and flow to change through the day. At low tide there is less flow than at high. In a 24 hour period salinity can vary between 10 and 33%, temperature from 8 to 16 C, and flow from 30-40,000 liters per minute. As a result of tide cycles, the amount of oxygen available to the fish from the pumped seawater also varies substantially within each day.

Because of the high biomass loads at Coos Bay, supplemental oxygen is used to rear all species at the facility. The oxygen system used at the Coos Bay site is an O_2 injection system (Figure). The system has been in use since May 1984.

The main incoming flow of seawater is pumped from a depth of 15-25 feet. The pumped seawater first goes through an aspirator basin to strip off nitrogen. The flow out of the aspirator basin is at saturation or above, and receives the super saturated oxygen flow from the injector. Oxygen is bled off as a gas from the liquid oxygen tank. The gas is injected into a 4" PVC water line. The water in the line is at 80 PSI and the oxygen is at 100 PSI, the pressure differential prevents water from entering the oxygen line. From there it goes through an orfice plate which serves to maintain back pressure in the line until just prior to entering the injector.

In addition to the main injector line there is a second injection line which has six injectors, one for each raceway. The raceway injectors are at the midpoint of the raceways and are individually adjusted for the biomass load in each raceway.



General schematic of the oxygen injection system used at the Anadromous, Inc. facility at Coos Bay, Oregon.

LOAD CALCULATIONS

The range of total oxygen available from the pumped water as it leaves the aspirator basin is approximately 7 to 11 mg/l. If an effluent D.O. of 5 mg/l is desired then 2 to 6 mg/l are available for rearing fish. It is the lowest available influent D.O. that is important; that number determines how much incremental oxygen capability is needed for any given time. The mean influent D.O. determines the total daily requirement.

The maximum load that could be carried at the Coos Bay site without supplemental O_2 is estimated as follows:

Maximum Biomass that could be held without supplemental oxygen

= 30,400 lpm * (7 mg/l) * (60 min/hour) * (24 hour/day) * (1 kg/1x10^6 mg)

= 306 kg O_2/day.

If an effluent d.o. of 5 mg/l is desired; then 219 kg O_2/day is "lost" in the effluent.

306 - 219 = 87 kg O_2/day for fish.

Assume that each kg of biomass requires 150 mg O_2 per hour X 24 hours/day [see appendix] = 3,600 mg O_2 per kg fish per day.

Then the maximum biomass without supplemental oxygen is:

$$= \frac{(87 \text{ kg } O_2) * (1x10^6 \text{ mg/kg})}{3{,}600 \text{ mg } O_2\text{/kg fish/day}}$$

= 24,166 kg (53,166 lbs.) fish/day standing stock.

That biomass load would mean holding fish at a density of 7.4 kg/m^3 (.47 lbs/ft^3).

In July 1984 after the system was installed, we held 68,000 kg of chinook and coho at the site. The chinook rearing densities for the month ranged from 15 to 22 kg/m^3.

The mean site density for that period was 20.8 kg/m^3 (1.33 lbs/ft). The amount of oxygen used by the system during that period was 37,636 kg O^2 (82,000 lbs).

ESTIMATION OF EFFICIENCY

A rough estimate of the efficiency of the system can be obtained by dividing estimated consumption by the actual use.

$$\frac{258 \text{ kg } O_2}{1{,}254.5 \text{ kg } O_2} = .126 \text{ efficiency.}$$

258 kg O_2 estimated consumed by fish. (assumes 150 mg O_2 per day per kg fish)

1,254.5 kg O_2 actual mean use per day.

COST OF SUPPLEMENTAL OXYGEN

The cost of liquid O_2 for the month of July 1984 was $7,500 ($.75/100 ft^3). So the cost to rear the additional 44,000 kg of fish for one month was $7,500 or 7.8 cents per pound of fish per month.

Reasons for Apparent Inefficiency

1) The system is said to be 80% efficient at delivering O_2 into solution, so 20% is lost immediately after injection.

2) The system is not self regulating; it has to be adjusted manually. Due to the high variability in inflow, the system is always set high as a safeguard. Peak oxygen utilization by the fish also varies with feed rate and activity; although it can be reduced by continual feeding.

3) The length of the raceways (420') is such, that some injected O_2 is lost to the atmosphere. It takes ~ 40 minutes for the flow to travel from the first injector to the second.

4) The second injection line does not distribute the O_2 evenly. The first injector in the line gets more O_2 than the next and so on. That means that the line has to be adjusted upward in order to get sufficient O_2 to the last raceway.

5) There is some leakage in the tank.

1984 was the first year that we used the system. At present we are using a more extensive monitoring system to reduce consumption. In October 1986, we carried a slightly larger biomass at Coos Bay for an O_2 cost of $4,000, which gives an overall efficiency of 24%. We hope to improve upon that with a better

distribution system.

ADVANTAGES / DISADVANTAGES

Advantages

1) It is cheaper to use supplemental oxygen than to install additional pumping capacity in a pumped site.

2) It allows greater production from existing facilities without expansion of raceways or ponds.

3) It allows more flexibility in size of fish and release scheduling.

4) Holding fish at higher densities results in better feed conversions.

Disadvantages

1) Infectious diseases may spread more rapidly at higher densities.

2) Any mechanical system is subject to failure and failure of an O_2 system could be a major disaster.

3) The use of a supplemental oxygen system requires extensive environmental monitoring to reduce the cost of the oxygen.

ADULT RETURNS

The return from 1984 releases of spring chinook at Coos Bay was .58% as 2 year jacks in 1985 and approximately 2% as three year fish in 1986. These numbers do not include ocean catch nor strays into the Coos River. The coho adult return rate was 3.8% from 1985 releases. If the system had not been in place our production in 1985 from the Coos site would have been one third of what it actually was. In 1985 we had even higher rearing densities at Coos Bay and the spring chinook jack return in 1986 was approximately .5% and the adult coho return from the 1985 release was 6.5%.

The oxygen systems used at both our fresh and salt water facilities have allowed us to greatly increase our production of coho and chinook salmon. The production is measured not only in numbers but in the size of the individual fish. Having an oxygen system does not mean that

it has to be used continually 12 months of the year but rather that it is available as needed. We feel that the advantages of supplemental O_2 systems far outweigh the disadvantages.

APPENDIX

Empirical Calculation of O_2 Consumption

On 24 and 25 November 1986, oxygen consumption was measured in one raceway section at Coos Bay. The inventoried biomass was 14,000 kg of coho salmon with a mean weight of 180 g. The mean flow into the raceway was 5646 lpm. Oxygen levels were measured before and after the first injector, at the head of raceway, and just prior to the second injector.

Tide Stage Time/date	LowHigh 1638/24 Nov	LowLow 2347/24Nov	HighHigh 0703/25Nov	HighLow 1245/25 Nov
before injection(mg/l)	10.1	10.0	9.4	9.8
after injection(mg/l)	16.6	15.5	15.4	16.0
top of raceway (mg/l)	15.8	14.8	13.8	15.3
middle raceway (mg/l)	11.3	10.5	9.5	9.9
O_2 (mg/l)	4.5	4.3	4.3	5.4
mg O_2/kg fish	108.6	104.0	104.0	130.9
temp. (c)	11	10	11	11
Salinity (%)	18.8	17.9	31.5	18.8

The O_2 consumption by smaller fish would be considerably higher. Oregon Aqua Foods estimates O_2 consumption at 350 mg O_2/kg fish/hour for 10 g. coho in freshwater (Dick Severson, Oregon Aqua Foods, Springfield, OR). The 150 mg O_2/fish/hour figure is a rough composite of several values in the literature.

EFFECTS OF RACEWAY INFLOW AND REARING DENSITY INTERACTIONS ON ADULT RETURNS OF COHO AND SPRING CHINOOK SALMON

by

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Raceway rearing density studies were conducted at Willard National Fish Hatchery using 1981 and 1982-brood coho salmon and are being conducted at Carson National Fish Hatchery using 1982 through 1985-brood spring chinook salmon. Objectives of these tests are to study the effects of different raceway loadings on: (1) fingerling performance, physiology, and disease status during hatchery residence and (2) post-release survival and adult contribution. At Willard, coho fingerlings were reared for approximately one year at densities of 25,000, 50,000, and 75,000 fish per raceway at water inflow rates of 200, 400, and 600 gallons per minute in a two-way factorial design with two replicate raceways per cell. A similar design is being used with spring chinook at Carson. Fingerling densities have been established at 20,000, 40,000, and 60,000 fish per raceway at inflows of 200, 400, and 600 gallons per minute. Treatment effects on post-release survival are being determined through evaluation of catch-release ratios of coded wire-tagged subpopulations from each raceway. Recovery data from the coho studies are limited to hatchery rack returns and non-finalized ocean recoveries. Spring chinook recovery data are from partial returns from 1982 brood tests.

Experimental treatment effects on percent recovery of coded-wire-tagged groups are summarized in Tables 1 and 3. Adult contributions (Tables 2 and 4) were determined by multiplying catch-release ratios of wire-tagged fish (within raceway) by total smolts released (within-raceway). The following observations are based on these data:

1. Percent recovery and adult contribution of coho was not affected by raceway inflow rates (Tables 1 and 2). This may have been a reflection of the year-around cold water temperatures (39-45^{o}F) at Willard. Inflowing dissolved oxygen was 11.9 and 11.5 ppm at smolt release for the 1981 and 1982 broods, while variation in raceway effluent oxygen was limited to 8.6 to 11.4 ppm between treatment cell extremes.

2. Although coho survival rates were reduced somewhat as rearing densities increased (Table 1), adult returns (Table 2) increased by a factor of 2.3 as fish reared per raceway increased from 25,000 to 75,000.

3. Results from tests of spring chinook suggested a trend of increased survival rate and contribution with increased inflow (Tables 3 and 4). At smolt release, dissolved oxygen at raceway inflows was recorded at 12.2 ppm. Effluent oxygen levels ranged from 7.0 ppm to 11.7 ppm between treatment cell extremes. The divergent response of coho and spring chinook to different levels of inflow may have been a reflection of variations in species tolerance to loading or the result of subtle differences between the two hatcheries or their water supplies.

4. Survival rates of spring chinook decreased significantly as rearing densities increased (Table 3). As a result, raceways with 20,000 smolts have produced as many returning adults to date as raceways where 60,000 fish were reared (Table 4).

The effects of dissolved oxygen on adult returns cannot be directly assessed within these studies. Although oxygen levels differed between rearing environments, direct oxygen effects were obscured by simultaneous variations in water inflow rates. Oxygen, however, may have been a contributor to the inflow-related differences in survival observed in the spring chinook tests.

The studies reported here were conducted at hatcheries with year-around cold water temperatures. Different results might be expected, however, from similar tests conducted at hatcheries with warmer water where the oxygen metabolism of fish is higher and oxygen carrying capacity of water is reduced.

TABLE 1. Percent recovery of 1981- and 1982-brood coded-wire-tagged coho from raceways within treatment groups at Willard National Fish Hatchery.

Inflow (gpm)	Race-way	1981 brood year Fish per raceway at start 25000	50000	75000	Mean	1982 brood year Fish per raceway at start 25000	50000	75000	Mean
200	A	0.31	0.29	0.27		0.44	0.44	0.26	
	B	0.31	0.33	0.27	0.30[c]	0.42	0.37	0.38	0.39[c]
400	A	0.27	0.28	0.23		0.30	0.35	0.36	
	B	0.34	0.29	0.21	0.27[c]	0.43	0.44	0.29	0.36[c]
600	A	0.31	0.24	0.25		0.44	0.27	0.40	
	B	0.47	0.29	0.28	0.31[c]	0.41	0.32	0.37	0.37[c]
	Mean	0.33[a]	0.29[ab]	0.25[b]		0.41[a]	0.36[a]	0.35[a]	

ab Within brood years, column means with different letters in their superscripts are significantly different ($P<.05$).

c Within brood years, row means were not significantly different ($P<.05$).

TABLE 2. Adult contribution of 1981- and 1982-brood coho from raceways within treatment groups at Willard National Fish Hatchery.

Inflow (gpm)	Race-way	1981 brood year Fish per raceway at start 25000	50000	75000	Mean	1982 brood year Fish per raceway at start 25000	50000	75000	Mean
200	A	72	141	185		87	185	147	
	B	74	158	184	136[d]	89	159	215	147[d]
400	A	63	131	159		63	151	204	
	B	79	138	148	120[d]	98	187	163	144[d]
600	A	71	115	177		91	104	243	
	B	110	136	198	135[d]	84	123	224	145[d]
	Mean	78[a]	137[b]	175[c]		85[a]	152[b]	199[c]	

abc Within brood years, column means with different superscripts are significantly different ($P<.05$).

d Row means within brood year are not significantly different ($P<.05$).

TABLE 3. Percent recovery of 1982-brood coded-wire-tagged spring chinook from raceways within treatment groups at Carson National Fish Hatchery.

Inflow (gpm)	Race-way	Fish per raceway at start			
		20000	40000	60000	Mean
200	A	0.057	0.057	0.007	
	B	0.041	0.017	0.011	0.032[c]
400	A	0.068	0.032	0.027	
	B	0.053	0.032	0.028	0.040[cd]
600	A	0.094	0.037	0.027	
	B	0.082	0.034	0.034	0.051[d]
	Mean	0.066[b]	0.035[a]	0.022[a]	

ab Column means with different superscripts are significantly different ($P<.05$).

cd Row means with different letters in their superscripts are significantly different ($P<.05$).

TABLE 4. Adult contribution of 1982-brood spring chinook from raceways within treatment groups at Carson National Fish Hatchery.

Inflow (gpm)	Race-way	Fish per raceway at start			
		20000	40000	60000	Mean
200	A	11	23	4	
	B	8	7	6	10[b]
400	A	14	12	16	
	B	10	12	17	14[bc]
600	A	18	15	16	
	B	16	14	20	17[c]
	Mean	13[a]	14[a]	13[a]	

a Column means are not significantly different ($P<.05$).

bc Row means with different letters in their superscripts are significantly different ($P<.05$).

7. INVENTORY METHODS

THE LEWIS RIVER LARGE POND SAMPLING DEVICE

Daniel Witczak and the Lewis River Salmon Hatchery Crew
Washington Department of Fisheries

Presented by David C. R. Ford

INTRODUCTION

A new sampling device was successfully tested on January 31, 1986, while conducting routine monthly juvenile coho and spring chinook yearling weight sampling in four 1/2 acre asphalt rearing ponds at the Lewis River Hatchery.

Juvenile pond seine sets had previously been used to attempt to obtain a random, representative population sample. Dip nets then subsampled the seined fish at the edge of the pond to provide the weight samples.

While this methodology is considered effective, an alternate strategy was investigated to circumvent certain "costs" accompanying the seining technique, both to the fish and in terms of manpower.

SAMPLING BY HAND HELD DIP NET

Obvious bias is introduced by broadcasting fish food (chumming) while attempting to induce a spatial shift of the population to the immediate vicinity of the hand held dip net. Differential, size-specific avoidance behavior by larger fish and the preponderance of pinheads and small fish at pond margins further limit confidence in samples secured in this manner.

JUVENILE POND SEINE NET AND POND DRAW-DOWN

Increasing poundages encountered during the final months of yearling salmon rearing make it less desirable to draw-down heavily populated ponds for sampling. The stress of crowding, disease and highly sensitive smolted fish are complicating factors. Physical abrasion is an inherent consequence of the mechanics of the pond seine operation. Sampling does not typically result in a measureable increased mortality, however it does necessitate handling a large portion of the population to obtain a relatively small sample.

NEW SAMPLING TECHNIQUE

The sampling device consists of a portable 42" diameter x 42" deep dip net manipulated via suspended ropes, cables and pulleys. Heavy duty cable was suspended between pulleys attached to a stanchion at the pond edge and the bird net support post in the center of the pond. A quick connect shackle with a pulley attaches the portable net to a fixed point on the suspended line. Tension, applied by hand to an independent rope line attached to the net rim (through the pulley) maintains the sampler above the water while shunting into position. Retrieval of the alternate suspension cable transports the net out to the sampling site. The sampling net sinks to the bottom of the pond under its own weight when slack line is fed to the independent hand line.

Fish food, widely broadcast from the side of the pond to hungry fish, randomizes the population and distracts the fish during sampling. Retrieval of the hand line raises the net rim through the unsuspecting fish. The net mesh material was darkened to avoid inducing avoidance behavior. The catch is then pulled back to the sampling station.

Several variables can be precisely controlled:

A) Sampling site (distance from shore)
B) Depth of water column sampled
C) Speed of vertical retrieve

BENEFITS

The most salient attributes of this sampling device include;

- simple design
- low cost
- time efficient
- reduced manpower demand (1person versus 3-4)
- minimal impact on the general fish population
- easily modified

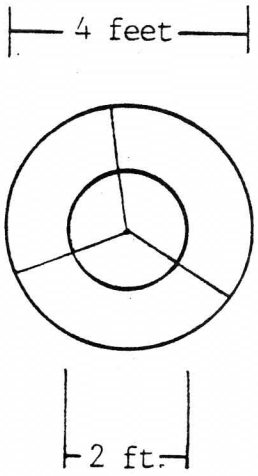
COMMENTS

There are two distinct issues to be addressed in seeking alternatives to traditional sampling methods; 1) Does the sampler meet expectation as a viable sampling mechanism? 2) Does the method furnish an accurate and appropriate sample?

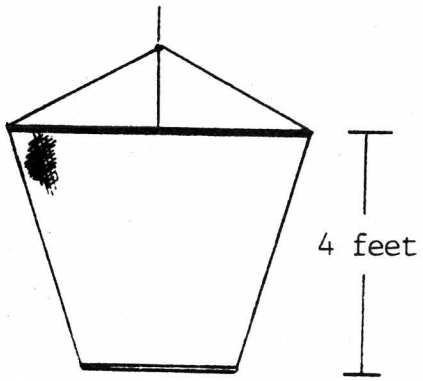
This innovative design is an effective fish collector which lends itself to consistency and repeatability while providing ample numbers of fish for weight sampling.

No significant difference was observed in results comparing fish per pound, standard deviation, and coefficient of variation between this sampler and the pond seining method.

Further testing and modification is anticipated as this technique evolves. It cannot claim the broad sampling scope of pond seining but offers merit as an alternative.

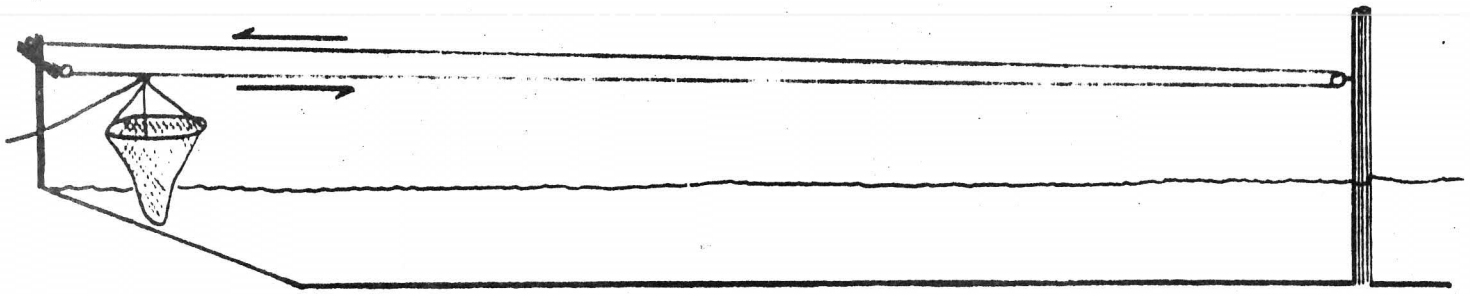


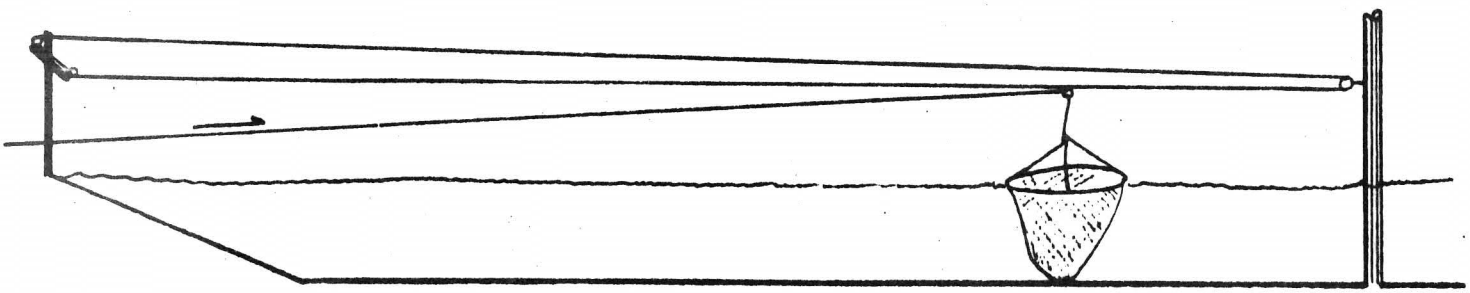
TOP VIEW

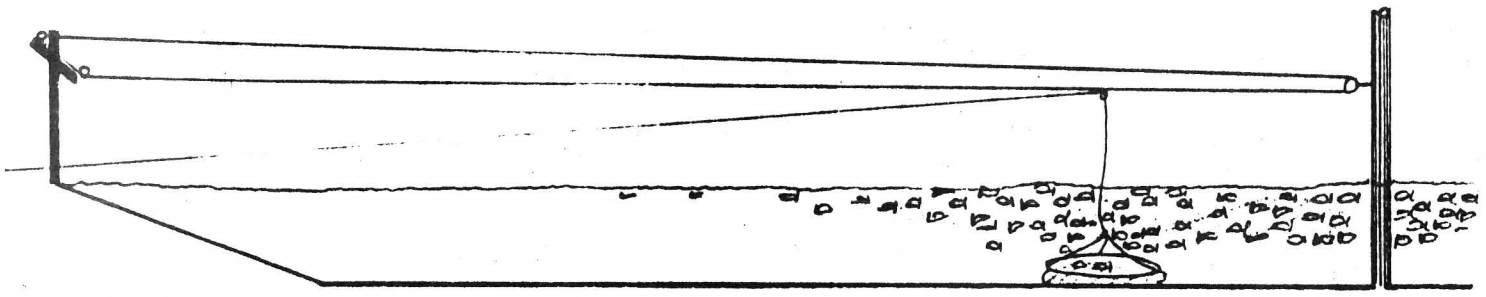


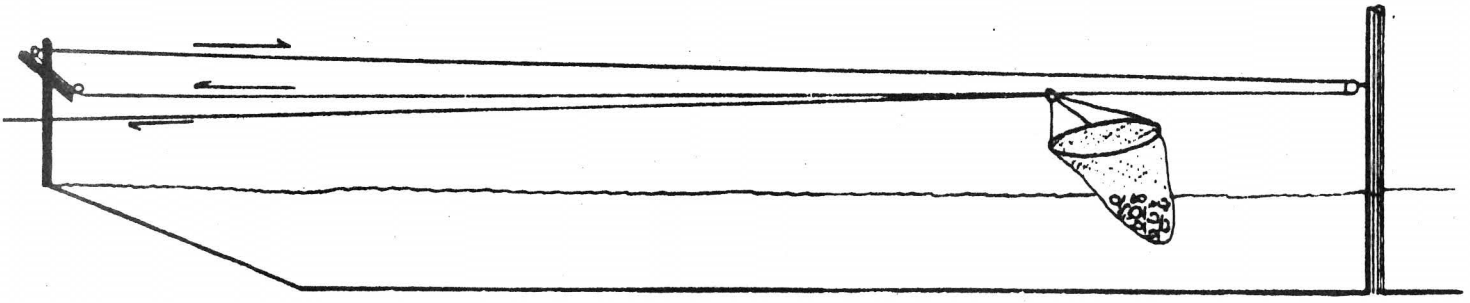
SIDE VIEW

note: both rings made from ½ inch aluminum rod









COMPARISON OF AVERAGE COHO SIZE (FISH PER POUND)

OBTAINED BY EACH METHOD

POND 15	
SEINE	21.6
TEST SAMPLER	21.2
POND 13	
SEINE	19.7
TEST SAMPLER	19.5
POND 14	
SEINE	20.7
TEST SAMPLER	20.4

COMPARISON OF AVERAGE SPRING CHINOOK SIZE (FPP)
OBTAINED BY EACH METHOD

POND 16		
SEINE	UPPER END	69.6
	MIDDLE	70.3
	LOWER END	69.6
SAMPLER		70.3
		70.3

Standard Deviations were almost identical.

Use of an Electronic Fish Counter for Steelhead Smolts

Jack Tipping
Washington Game Department

Use of an electronic fish counter to enumerate smolts offered several potential advantages over previous methods of loading fish out from rearing ponds: 1) increased accuracy 2) reduced stress on fish at a critical time and 3) reduction of manpower requirements.

Prior to 1984, fish were loaded out by crowding them in a raceway at the end of collection facility, taking sample counts to estimate number of fish per pound, then weighing fish out with a brail into the release site. This would take three people from one to three hours, repeated about twice per day. Accuracy of this method was unknown but 10 lb sample counts could vary considerably depending on where in the crowded raceway fish were netted. Accuracy was also questioned as fish were weighed out and water drained from the brail, the scale bounced, and weights always ended in 5s or 0s. During this process, fish were being stressed and thousands of scales poured off the fish as they were being weighed out.

In 1984, an electronic fish counter to count steelhead smolts from the Cowlitz Trout Hatchery rearing ponds was purchased from Smith-Root Company. The counter, a model SR-1600, consisted of an electronics box and a counting head, using a balanced resistance bridge to count fish. The counting head contained 16 tubes of 2 inch diameter with approximate dimensions of 20" x 8". The counter could count fish moving downstream, not upstream. Power source was a rechargeable battery contained within the electronics box.

Initially, the counting head was installed in one side of the two raceways at the collection facility using damboards with a rack above it to pass surplus water. A head differential of about 12" was used to force fish through the tunnels so multiple counts of the same fish would not occur. Need for counting head modifications became apparent almost immediately as fish entering the area of the counting head were being sucked against the face of the head often into two tunnels at once, resulting in unacceptle damage.

The counting head was then modified so the 16 tunnels tapered from a 5 inch opening down to 2 inch and they were spread out over the width of the raceway of about 8 ft. An operating head of 9 to 18 inches was tested while counter accuracy was verified. Accuracy was verified by allowing a few hundred fish to pass through the counter, shutting and blocking the counter off, and hand counting the number of fish passed through. After adjusting sensitivity, one series of tests showed the counter was consistantly low by about 1.5%, which was used as a correction factor. The counter was then run overnight to compare

with the brail method or a hand count the next two mornings. The counter was 21.8% and 40.0% high.

To determine the source of error, crowding racks were placed above and below the counting head to see if phantom counts would occur. None did. The rack below the counting head was then removed so the few hundred fish below the counter had access to it. The next morning no fish had moved upstream of the counting head but many additional counts had been registered, indicating fish had moved part way up the tunnels and triggered the counter.

In 1985, the counting head was split into two planks with eight tunnels each with each plank being placed where a finger weir existed at the head of each of the two raceways. After passing through the tunnels, fish would fall about two feet into the raceways, making it unlikely for them to re-enter the tunnels. A series of 13 verification tests showed the counter was usually high by an average of 1.3% (Table 1). The 1.3% was used as a correction factor for counting large groups of fish. Comparing counter numbers of fish with brail numbers of fish showed the brail method underestimated number of fish released by about 3.9% (Table 2). This difference is probably a result of where the fish are netted for a sample count; big fish seem to move near the surface and against the rack, a convenient netting location. If fish sample counted are bigger than the average raceway fish, the brail estimate would be low. A good example of this occurred on 5-1 (Table 2) where many small fish were present and the counter enumerated them but the sample count did not accurately represent the population.

Table 1. 1985 counter accuracy verification.

Test	Counter	Hand	Percent Difference
1	928	905	2.5
2	537	526	2.1
3	195	194	.5
4	231	220	5.0
5	444	435	2.1
6	731	714	2.4
7	619	612	1.1
8	578	578	0.0
9	618	626	-1.3
10	389	381	2.1
11	718	718	0.0
12	975	971	0.4
13	545	543	0.4
Total	7508	7423	1.3

Table 2. Counter and brail fish enumeration, 1985.

Date	Counter	Brail	Difference(%)
4-17	20,399	19,815	2.9
4-22	6,077	5,844	4.0
4-23	13,608	13,560	0.4
4-24	5,264	5,510	-4.5
4-25	8,667	9,377	-7.6
4-26	4,905	5,166	-5.1
4-29	24,213	22,500	7.6
5-1*	36,504	30,062	21.4
5-2	24,234	23,970	1.1
5-3	16,220	17,023	-4.7
5-6	2,601	2,559	1.6
5-7	16,222	16,127	0.6
5-8	16,780	16,929	-0.9
5-9	26,700	25,700	3.9
Total	222,394	214,142	3.9

* many small fish present

At the end of the 1985 release, it was felt the counter was satisfactory except for damage caused to fish as they passed through the tunnels. About 5% were incurring scale loss and about .5% were being killed as they passed through the tunnels sideways.

For the 1986 season, tunnels were enlarged to 3" diameter. This modification minimized damage to fish and still gave good results for accuracy. A series of verification tests showed the counter to be quite close in most cases (Table 3). However, the 1985-86 rearing season was severely impacted with Ceratomyxa shasta and many fish from the ponds were quite small and the counter appeared to miss some of these. However, since we were only interested in smolt production, accuracy of the counter was good enough.

Table 3. 1986 Counter verification tests.

Date	Counter	Hand Count	Difference
4-21	567	571	-0.7
4-21	200	200	0.0
4-22	407	406	0.2
4-22	532	537	-0.9
4-25*	605	616	-1.8
4-25*	555	579	-4.1
4-30*	606	619	-2.1
5-1	347	347	0.0

* about 81% less than 18 cm in length.

The counter was used on a production basis in 1986 and smolts were not weighed out. About 700,000 fish were counted and the counter was felt to work well.

CALIBRATING FISH LIBERATION TRUCK DISPLACEMENT GUAGES

TIM SCHAMBER

OREGON DEPT. OF FISH AND WILDLIFE

The accuracy of liberation truck displacement guages becomes very important during final stages of fish production, fish liberation. It is the final sum of the displacement guage readings that will determine how close a hatchery has come to meeting it's production goal and will also be used in determining the percent return. It is therefore very important that every measure possible be taken to assure an accurate liberation truck displacement guage reading.

In 1983 the N. W. Region began assessing the accuracy of the displacement guage in use at that time. Since inconsistancies were found it was considered necessary to develope a more accurate displacement guage. In the fall of 1985, using information previously gathered, the following criteria was used in constructing and calibrating a displacement guage.

1) The guage should be constructed so that it can be easily read: It was found that by constructing the guage with a white background and adding food coloring to the displaced water inside the guage, the guage reading became very visible.

2) Finger print a guage for each tank: In the past all guages had a standard calibrated rule. The new guages were calibrated for each tank so that the calibration would relate to that unit's tank structure.

3) The guage should be mounted in a fixed position on the tank: The purpose for mounting the guage in the fixed position was that each increment of calibration would always be representing the area of the tank for which it was originally calibrated.

4) Tank should be level while calibrating guage: If the tank is set off level the surface area inside the tank is increased, therefore, the area that the water would have to displace in is increased. Since the guage is calibrated in a level position it is important that the tnak be as level as possible when loading fish.

5) One pound of fish displaces 1.02 pounds of water. Since we wanted to calibrate the guages in fifty pound increments it was necessary to weigh off water fifty-one pounds at a time.

6) Scales used for weighing water during the calibration process should be checked periodically for accuracy during the calibration process. The need for using accurate scales for weighing water off the tank while calibrating the guage is obvious. We checked the scales by setting the scale for the desired pondage and adding accurate weights.

Using that criteria we constructed guages as shown. The guage is 4½" wide. The length of the guage is determined by the volume of the tank and the maximum load capacity. The guage is constructed of three layers of ¼" acrylic plastic. The top and middle layers are clear plastic, the bottom layer which provides the background of the guage is white. The middle layer has a ½" to 1" slot cut length wise through the middle and ends approximately 4" from the end of the guage. This slot creates a cavity for water displacement. A 1½" hole is cut into the top and middle layers only, this provides a place for the level vial to be installed. The three layers are then laminated together.

After the glue has set a 3/8" hole is drilled from the end of the guage to the starting point of the displacement cavity. Into this hole is inserted a 3/8" copper tube. This provides the connection for the water line between the tank and the displacement guage.

To calibrate the guages we found it was easier to remove water from the tank than to add water. This eliminated scales and containers being set up on the tank top. The tanks are filled to the point at which the water would be displaced if a maximum load of fish were loaded in the tank. This is usually within 4" of the spray bars in the tanks. The truck was then driven onto an enclosed, level shop floor. The tanks were then checked for level using a standard 2' level. After the tanks were leveled the recirculation system was operated to run water throughout the system and purge all trapped air. The system was then turned off to eliminate water loss from the tank during calibration. The guage was subsequently mounted in a position at an angle that would allow the calibration for a maximum load for the tank. To weigh water off the truck a platform postal scale was used. The scale was checked for accuracy using fifty poind weights obtained from Weights and Measures, Department of Agriculture. A 120 pound grease drum with handles welded on was used as a container to hold the water weighed off the truck.

The water is weighed off the truck utilizing one of the drain valves. Since a pound of fish displaces water at 1.02 pounds and we wanted to begin calibrating the guage in 50 pound increments water was weighed off 51 pounds at a time. For each 51 pounds of water weighed off the tank a mark was scribed on the guage surface. This process continued until the bottom end of the displacement guage was reached. The guage was then removed.

The next step is to mark the guage in 10 pound increments. This is accomplished by taking a measurement of the length between each individual 50 pound increment and dividing by five. This then gives the length needed between each 10 pound increment. This process is done for each 50 pound increment. The last step is to label the increments. We chose to label the increments beginning with 0 and label each 50 pound increment. For example 0, 50, 100, 150, 200, etc. Labeling tape was used to identify each 50 pound increment as it can be easily replaced when it becomes hard to read from wear. During the calibration process and during the normal use of the guage it was found that mixing a light soap with the colored water made a solution which reduced water cling in the displacement guage. This also permitted better visibility of the guage reading.

Since the guages were new, we decided it would be interesting to see how the new guages compared to a couple of the old guages which had proven to be fairly accurate. Using hand counted rainbow trout and going to great measures to reduce factors which could effect an accurate displacement guage reading, we checked the guages for accuracy. When loaded with rainbow trout at 3.1fish per pound the results showed the new guages to be within .03 percent error.

8. PAST, PRESENT AND FUTURE

LOWER SNAKE RIVER FISH & WILDLIFE COMPENSATION PLAN

The Lower Snake River Project, consisting of Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Locks and Dams was authorized by Congress in March 1945. Although it was authorized, project construction was delayed for many years while design studies were completed and construction appropriations were sought. The first dam, Ice Harbor, was not completed until 1962; the last dam, Lower Granite, was closed in 1975. In spite of the Corps efforts to maintain Snake River anadromous fish runs with fish passage facilities and other measures, it became obvious with the operation of Ice Harbor Dam that major losses to fish and wildlife resources were occurring, and that the losses were increasing with the completion of each succeeding dam.

In accordance with the Fish and Wildlife Coordination Act, the Fish and Wildlife Service and National Marine Fisheries Service prepared a special report on the impacts of the Lower Snake River dams. The report was completed in 1972 with input from the Columbia River Basin Fishery Technical Committee. It indicated that anadromous fish populations in the Snake River System had decreased by about one half in the first ten years of operation of the Lower Snake River Project. Consequently, to compensate for the project's large fish and wildlife losses, Congress authorized and funded the Lower Snake River Fish and Wildlife Compensation Plan (LSRCP) as part of the Water Resources Development Act of 1976.

The legislation authorized sufficient anadromous fish hatcheries and associated trapping and holding facilities to return 18,300 fall chinook, 50,700 spring chinook, 8,000 summer chinook, and 55,100 steelhead trout back to the project area. In addition, residence fish hatcheries and related facilities were authorized to produce 93,000 pounds of trout annually to replace lost resident sport fisheries in Washington and Idaho.

As shown on the following map, the program requires expansion or construction of twelve hatcheries and eleven satellite facilities in Idaho, Oregon, and Washington. Idaho Department of Fish and Game will operate four hatcheries, Oregon Department of Fish and Wildlife - three hatcheries, Washington Department of Game - two hatcheries, Washington Department of Fisheries - one hatchery and Fish and Wildlife Service - two hatcheries. Construction is complete and fish production is underway at ten of the hatcheries, with Magic Valley scheduled for completion in 1987 and Clearwater Anadromous to be completed by 1990 (see table).

The estimated-cost for development of the LSRCP is $177 million for construction features, and an estimated $9 million will be spent annually for facility operations and maintenance (O&M) when the project is completed. All anadromous fisheries and most resident fisheries compensation are allocated to project power costs, and Congressionally-authorized FWS budget expenditures are reimbursed to the Federal treasury from Bonneville Power Administration power revenues.

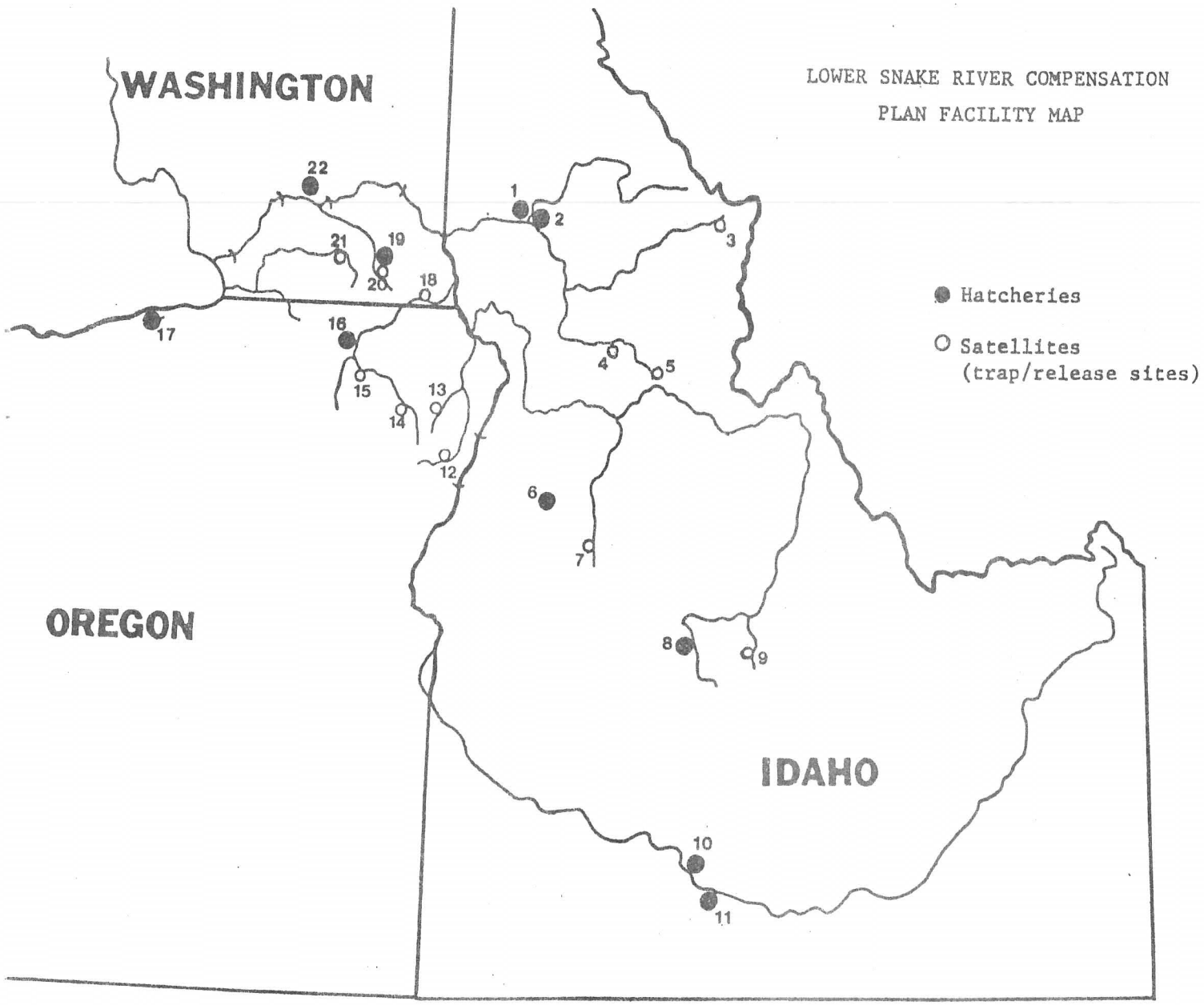
Included in the current and future O&M costs is an evaluation study program being conducted by the operating agencies. The program began in FY 1982 and is expected to continue for some time after the entire plan has been developed and is fully operating. The studies are necessary not only to determine if established hatchery production goals are appropriate and if the required adult compensation levels are being met, but also to assist in developing new procedures to overcome fish production and fishery management problems that are inherent in developing hatchery programs with native wild stocks of anadromous fish. Disease problems at the hatcheries, coupled with fishery management problems associated with establishing fish runs with insufficient numbers of native fish of unknown fish health, complicated the achievements of LSRCP goals early on and set the course for many of the first evaluation studies.

Many problems have surfaced in developing the LSRCP hatchery program which are being addressed by evaluation studies. These include 1) annual fish mortalities exceeding thirty percent in summer chinook fry at McCall Hatchery due to nutrition problems, 2) abnormally high fish growth resulting in excessive smolt residualism of steelhead smolts stocked from Hagerman National Fish Hatchery (NFH), 3) recurring spring chinook mortalities at Dworshak NFH due to BKD which sometimes exceeds sixty percent, and 4) persistent steelhead mortality of up to seventy percent at both Clearwater and Snake River hatcheries.

In addition to studies which addressed these initial problems, other evaluation studies have concentrated on documenting and improving fish cultural and release procedures and on determining adult returns to various fisheries, to hatcheries and to spawning areas. Coded-wire tagging and branding are two important and expensive tools being used by all operating agencies in their size, time, and location of release and fishery contribution and escapement studies.

The FY 1987 budget for evaluation studies is $923,000. When the program is completed and fully operational, the evaluation budget could be as much as $1.8 million and will involve all five operating agencies and several Indian tribes.

NWFCC.RPT



OPERATING AGENCIES

Idaho Department of Fish & Game

1. Clearwater FH
3. Powell
4. Crooked River
5. Red River
6. McCall FH
7. South Fork Salmon River
8. Sawtooth FH
9. East Fork Salmon River
11. Magic Valley FH

U.S. Fish and Wildlife Service

2. Dworshak NFH Expansion
10. Hagerman NFH

Oregon Department of Fish & Game

12. Imnaha
13. Sheep Creek
14. Wallowa FH
15. Big Canyon
16. Lookingglass FH
17. Irrigon FH

Washington Department of Fish

22. Lyons Ferry FH - Salmon

Washington Department of Game

18. Cottonwood Creek
19. Tucannon FH
20. Curl Lake
21. Dayton Pond
22. Lyons Ferry FH - Steelhead

LOWER SNAKE RIVER COMPENSATION PLAN - MITIGATION REQUIREMENTS

HATCHERIES State	Hatchery Name	Species/Release Site	Smolt Rel. At Design Capacity Numbers	Smolt Rel. At Design Capacity Pounds	Est. Adult Return	Current Status
IDAHO	Clearwater	Spring Chinook	1,369,500	91,000	12,200	Start 6/88
	Anadromous	Summer Steelhead	2,500,000	350,000	14,004	Complete 12/89
	-Crooked River Satellite					Complete 11/89
	-Red River Satellite					Complete 11/86
	-Powell Satellite					Complete 11/88
	Sawtooth	Spring Chinook	2,235,000	149,000	19,232	Completed
	-East Fork Satellite					Completed
	McCall	Summer Chinook	1,000,000	61,300	8,000	Completed
	-South Fork Satellite					Completed
	Hagerman	Summer Steelhead	2,400,000	340,000	13,600	Completed
	Magic Valley	Summer Steelhead	2,000,000	291,500	11,660	Complete 8/87
	Dworshak	Spring Chinook	1,050,000	70,000	9,000	Completed
	Eagle Disease Lab	Disease Diagnosis				Start 9/87
						Complete 4/88
OREGON	Lookingglass	Spring Chinook (Grande Ronde Stock)	900,000	44,600	5,813	Completed
		Spring Chinook (Wallowa Stock)	490,000	25,000	3,259	
	-Big Canyon Satellite					Complete 4/87
	-Imnaha Satellite					Complete 11/88
	Irrigon	Summer Steelhead	1,377,600	229,600	9,184	Completed
	Wallowa	Summer Steelhead	300,000	50,000	2,000	Completed
	-Little Sheep Creek Satellite					Complete 8/87
WASHINGTON	Lyons Ferry (WDF)	Fall Chinook	9,162,000	101,800	18,300	Completed
		Spring Chinook	132,000	8,000	1,152	
	Lyons Ferry (WDG)	Summer Steelhead (Total)	931,200	116,400	4,656	
		Sum. Steelhead Grande Ronde R. (Wallowa Stock)				
		Sum. Steelhead Tucannon R.				
		Sum. Steelhead Walla Walla R.				
		Sum. Steelhead Touchet R.				
		Sum. Steelhead Asotin Cr.				
		Rainbow Trout	135,000	45,000		
	Tucannon	Resident RB (Wash. & Idaho)	123,000	41,000	—	Completed
	-Dayton Pond Satellite					Complete 10/86
	-Curl Lake Satellite					Completed
	-Cottonwood Creek Satellite					Completed
	Instream Habitat	Rainbow Trout	21,000	7,000		Complete 9/86

TWO MILLION MORE ADULT SALMON BY 2000 A.D.:

A PROPOSED HATCHERY PLAN

by

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Executive Summary

This report is in response to Action Item 34.23 of the 1986 Columbia River Basin Fish and Wildlife Program: "Evaluate ongoing work under [Section] 704(h) and submit a plan to the Council for future efforts--[in improving hatchery effectiveness]. Consultations and recent literature were evaluated along with 22 ongoing BPA-funded projects. As a result, a plan was developed for quantitatively and qualitatively increasing the production of anadromous salmonids with existing technology and existing hatcheries. The rationale for this is as follows:

If the numerical goal for total adult salmon and steelhead production is set at 10 million per year, and if the Columbia River Basin's full propagation potential for wild/natural propagation is 3.5 million adults, then hatcheries must produce at least 6.5 million adults. Improved passage will decrease smolt losses and thus increase the number of adults, but the need for additional hatchery fish is still estimated to be in the order of 4 million adults per year.

An interim goal is proposed by BPA to quantitatively and qualitatively increase smolt production at existing hatchery facilities to produce 2 million additional adult fish/year by the year 2000. The goal appears to be realistic and attainable through existing technologies which have inherently different costs. The following approaches were considered:

1. Purchase of 200 million smolts per year from commercial sources to produce 2 million adults was estimated to cost $66.6 million/year. This is replete with biological and political problems, and is potentially the most expensive alternative.

2. Capital construction costs of typical hatchery facilities to provide 2 million adults per year were estimated assuming that the additional production would be 13.3 million pounds of smolts and that this would average $41.11 per pound of designed propagation capacity, or $548 million. However, hatchery construction costs have exceeded $70 per pound in recent years, and if this trend continues, the resulting capital costs would be nearly $1 billion. Required operation and maintenance (O&M) was estimated at least $32 million/year when full production is reached.

3. Modifications of about 50 existing facilities could provide at least 1.5 million more adult salmon/steelhead per year at an estimated capital cost of less than $100 million. Renovations would begin in year 5 and proceed at 20 percent per year. O&M would be zero until year six, when additional production would cost $5 million; this would increase over 5 years to an estimated $25 million/year. These proposed changes would allow full utilization of existing water supplies, provide supplemental oxygen for higher rearing densities in existing facilities, and minimize facility-related health problems. Total cost of this approach would be $175 million over a 10-year period.

4. Increased smolt quality and higher survival could produce at least 500,000 more adults per year, albeit, the potential benefits are much greater. Estimated costs are $1 million/year for increased fish health monitoring.

The most expeditious and cost-effective means of achieving the goal of 2 million more hatchery-reared adults appears to be through actions 3 and 4 above.

Investments in concrete and steel must be balanced with equally important investments in the skills of hatchery staffs who rear and protect the fish. These critically needed professionals must have both the motivation and the technological tools to effect improvements in smolt quality and survival. Primary needs include better technology transfer, peer-based evaluations, professional certification, and recognition, incentive awards, and basin-wide evaluations of smolt survival. Supportive objectives include the registration of medicine for use in hatcheries, better sanitation, and increased fish health monitoring.

Supplementing some streams with surplus hatchery fish of appropriate stocks also is a long-term objective of the plan, which depends in part on the registration of chemicals to control the resident competitors or predators of hatchery outplants. However, neither supplementation nor natural propagation are primary targets of this plan.

Additional hatchery facilities may be needed for other unmitigated losses, and these new hatcheries would be identified and planned by this effort, beginning with a fisheries bioengineering symposium.

Supportive research and demonstration projects are needed to further expand hatchery effectiveness. These projects address: improved strategies and practices in fish culture; better ways and means to protect the health and genetics of hatchery and wild fish; improved smoltification and early marine survival; and resolution of problems at existing hatcheries with records of poor success.

Implementation is proposed initially by structured technical workgroups that would identify the ways, means, and schedule to accomplish each objective. Peer panels are proposed for selecting the best and most cost-effective project proposals and evaluating active projects. These workgroups will be facilitated and supported by BPA.

Preliminary cost estimates are included for each objective in the Plan, and these total $231.5 million over a 10-year period. Each estimate is subject to revision pending refinement of the data. The budgetary process would usually require a minimum waiting period of 2 years for non-capital projects and at least 3 years for capital projects.

REFLECTIONS & VISIONS ON SALMON & TROUT HATCHERIES

BY
RICHARD E. NOBLE

The image of salmon & trout hatcheries has an interesting history. Hatcheries have certainly been an integral part of managing the trout and salmon resource since the first facility went on line. My personal bias is in favor of hatcheries! My first job in fisheries started at the Fort Klamath hatchery in 1947 with the Ore. Game Dept. My reflections on hatcheries started after visiting that hatchery about a year ago. Nothing had really changed at the Klamath hatchery from when I worked there 40 years ago. Yes they added some more concrete raceways, but the hatchery building itself was virtually the same. Lets reflect for a moment on the changes that have occurred over the past (not just 40 years but lets say 100 years).

Hatcheries certainly have gotten larger and more expensive! Its not at all uncommon to see a price tag of five to fifteen million dollars for a hatchery that will produce 100 to 300,000 lbs. of smolts. Rearing ponds come in all sizes and shapes- rectangular, circular, square, deep, shallow, and even coffin shaped. It's interesting to note the history of the Burrows pond; a circulating pond with turning vanes and designed to be self cleaning. Roger Burrows was emphatic about the design, and I know he would be disappointed to know very few stations currently use the "Burrows pond" as originally designed. Many have been modified into raceways and I personally know of only a couple of stations that use the ponds with the turning vanes. The design violated two basic criteria, A.- It was not simple to operate with turning vanes, corner jets and bottom screens that would plug. B.- Floculant waste material simply circulates in the pond and causes less than good water quality. In a hatchery production mode, I still favor the raceway design over any of the other pond designs. I will quote Jim Wood, former fisheries pathologist with Washington Dept. of Fisheries, "Clean water in, dirty water out".

Reflections on the incubation systems in hatcheries are similar to pond designs. Incubation systems constructed 70 years ago are still being used. Do we have any real standards for incubation systems?- Not really! Again a great variety of containers are used, from large barrels to Heath type incubators. Considerable research at the hatchery level has been completed on the use of media and its value in the development of newly hatched fry. The subtle affects of incubation on long term survival and growth is an area of reseach that needs more emphasis. There are still numerous hatcheries that do not use media, and do not realize the low level stress on developing fry when water movement and velocity exceeds that which is normally found in the gravel beds. No, I am not recommending the use of gravel. If anyone has ever attempted to use gravel on a production basis, it becomes rather obvious that there has to be a better way!

Once the fry are out of the incubators, feed comes into play. There have been great strides in both the private sector and government in the development of salmon and trout diets. There are frozen diets,

soft moist dry diets, dry diets, all packaged and ready to feed. Automatic feeders of all types are available on the market, some that measure oxygen levels, supply oxygen, moniter water temperature, and feed accordingly with every thing recorded by computer. .

Quite a difference from my start in the feed room at Klamath, where a variety of animal and fish by products were thawed, then ground and mixed to meet the desired ration. I can assure you that not all the products met quality control standards for freshness. Its very nice to open a bag or a hopper and measure out the amount of feed for the daily feeding. Many of the Agency people are critical of closed feed formulas, maintaining they simply don't know what is in a diet, unless it's an open formula. My argument against those that condemn the closed formulations is, they really don't know whats in the open formulation either, unless continued monitering is undertaken. I had the opportunity to work with Rangens Fish Feed Co. of Buhl Idaho for three years. Quality control of diet ingredients and formulation was the companies first priority. A reputable feed company simply can not afford to take short cuts and stay in business. Greater cooperation between the private sector and government operated hatcheries is essential to take advatage of the potential that exists in fish culture.

How do we measure the advances that have been made in fish culture in the past 50 to 100 years? The number of hatcheries? The hatchery size or number of fish reared? Survival from egg to adult? All of these factors have increased many fold! How much has really changed from the actual egg taking procedures, incubation procedures, feed and feeding methods?? We have an ever increasing number of biologists, environmentalists, and fishermen who condemn hatcheries and want to return to the good old "WILD" days. Fish culture has appeared to be to simple; we can obtain 95 to 98% survival from egg take to hatch. Survival to release can be as high as 85 to 90%. Survivals from release to catch and return can be as high as 40 and 45%. Unfortunately, most total survivals are below 10 percent, but when compared to many of the wild stocks even 10 percent is high. The result is that if fishing pressure is allowed to take the excess from the hatchery production, the "wild" stocks can be decimated. There are those that say we should get rid of all the hatcheries, but most realize that hatcheries are here to stay.

So what are the visions for the future in fish culture? What do I see in the next 20 to 50 years? For a classic in what the future may bring in the field of the Pacific Salmon, I refer you to the McKernan lectures--Pacific Salmon scenarios for the future, by Dr. Peter Larkin, April 15-17, 1980. A Washington Sea Grant Publication. Although the future of fish culture has as much in common for those rearing fish for release and recapture as it does for the aquaculturist, who raise fish to harvest in captivity, there are some basic differences in reaching the objective of a harvested product. A quote from Larkins paper concerning the economics of commerical versus sportfishing stands out as a classic statement and one I find to be quite accurate. "For purposes of negotiation, salmon caught by sportsfishermen have a value close to infinity, while salmon caught commercially are worth what someone will pay for them."

In spite of adverse publicity by those that are apposed to hatcheries, the future looks extremely bright. The base of knowledge

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Kay Brown
Marty Winkler
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Valerie Burton

ATTENDEES TO THE 1986 NWFCC

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Steve	Gump	29050 Fish Hatchery Road	Philomath	OR	97370
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James	Harvey	43863 Greer Drive	Leaburg	OR	97489
Al	Hemmingsen	920 NW 28th	Corvallis	OR	97330
Rod	Henderson	125 West Sunset Highway	Issaquah	WA	98027
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regarding fishculture is expanding so rapidly, that many of us will fail to keep up. Harry Westers has indicated that he is obtaining trout production that averages 8.0 pounds per cubic foot of space. During the past two summers, in surface water that has multiple species, and reached temperatures of 23 degrees C. (73+/F.), I personally raised trout at 15 pounds per cubic foot, with out disease treatment or fish loss. A test group at 25 pounds per cubic foot, had very little loss, however there was some gill erosion. The use of an oxygenation system will change many of the operating parameters that we presently use for fishclture guidelines. As the computer-and-micro-chips miniturize water quality measuring devices and the hatchery personnel become more congnizant of cause and effect relationships involving the growing of trout and salmon, hatchery fish will increase in quality and quantity. Cryopreservation will become common place and preservation of both sperm and ova will be routine. Genetic selection programs will be unlimited. Expansion of present hatcheries i.e. fish production, will be increased many fold without increasing new concrete monuments. The aquaculturists will benefit much more than those that release their fish into the streams and lakes. Although the hatchery fish of tomorrow with be stronger and better able to survive, and will be genetically selected to fit the niches formed by nature, we do not have control of the predator birds, animals, and fish. Thus those fish released into the wild will reach a level where further increases, simply reach the level of diminishing rates of return. When survival rates for the current level of production is increased, the numbers in the catch can be increased with out increasing actual numbers being produced. Changes in management strategies, and actual hatchery operations will increase survival rates in the future. The aquaculturists will pave the way to new concepts and technology in hatcheries. They have to increase their productivity to compete and stay in business.

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Bill	Wallien	Box 429	Winthrop	WA	98862
Bruce	Walters	1341 Ringold River Road	Mesa	WA	99343
Steve	Warner	4200 Oldgate Road	Lake Oswego	OR	97034
Jim	Warren	9317 Highway 99	Vancouver	WA	98665
Roger	Warren	580 Fish Lake Road	Butte Falls	OR	97522
Dan	Warren	P.O. Box 1110	Cordova	AK	99574
Willis	Weber	625 East Madison Avenue	Riverton	WY	82501
Steve	Wells	580 Fish Lake Road	Butte Falls	OR	97522
Carl	Westby	Pacific Biological Station	Nanaimo	CAN BC	V9R5K6
Harry	Westers	P.O. Box 30028	Lansing	MI	48909
Richard	Westgard	M2 Fisheries Ctr., WH-10, UW	Seattle	WA	98195
John	Westgate	17330 SE Evelyn Street	Clackamas	OR	97015
Dan	White	2100 West Broadway, No. 5	Eugene	OR	97402
Lorne	White	211 Mission Road	Kodiak	AK	99615
Andy	Whitener	W. 81, Highway 108	Shelton	WA	98584
R. A.	Whitlatch	39800 SE Fish Hatchery Road	Sandy	OR	97055
Josette	Wier	Rural Route 2	Nanaimo	BC	V9R5K2
Don	Wilcoxen	26915 Trask River Road	Tillamook	OR	97141
Charles	Willis	P.O. Box 59	Portland	OR	97207
DuWayne	Wilson	P.O. Box 712	Buhl	ID	83316
Einar	Wold	26507 NE 10th Avenue	Ridgefield	WA	98642
John	Wolowicz	90700 Fish Hatchery Road	Leaburg	OR	97489
Szczepan	Wolski	Rural Route 2, P.O. Box 2142	Clearwater	CAN BC	V011NC
Stanley	Woody	28 Beaver Creek Road	Cathlamet	WA	98612

Rod	Workman	90700 Fish Hatchery Road	Leaburg	OR	97489
Tim W.	Wright	Star Route, Box 72	Idanha	OR	97350
Terry	Wright	6730 Martin Way East	Olympia	WA	98506
Gary	Yeager	HC 30 Box 142D	Chiloquin	OR	97624
Dave	Zajac	2625 Parkmont Lane, Bldg. A	Olympia	WA	98502
Jeff	Zakel	3150 East Main Street	Springfield	OR	97478
Rita	Zamluk	P.O. Box 842	Campbell Rv.	CAN BC	V9W6X4
Brian	Zimmerman	2333 Linda Vista Drive	Klamath Falls	OR	97601

Mailing Lists

VENDORS

Argent Chemical Laboratory	8702 - 152nd Avenue, NE	Redmond, WA 98052
Atec, Inc.	625 East Madison	Riverton, WY 82501
Big Redd Incubators, Inc.	P.O. Box 88	Longville, MN 56655
Bioproducts, Inc.	P.O. Box 429	Warrenton, OR 97146
CH_2M Hill	2020 SW Fourth Avenue	Portland, OR 97201
Coffelt Electronics Co., Inc.	3910 S. Windemere Street	Englewood, CO 80110
Common Sensing, Inc.	7595 Finch Road, NE	Bainbridge Island, WA 98110
EMA Marketing, Inc.	5065 SW Nash Avenue	Corvallis, OR 97333
FAL Products	P.O. Box 9037	Tacoma, WA 98409
Industrial Plastics, Inc.	680 South 28th Street	Washougal, WA 98671-2567
Jensorter, Inc.	18934 Riverwoods Dr.	Bend, OR 97702
Lee Microsystems, Inc.	5331 Hammond Bay Road	Nanaimo, BC V9S5N7 CANADA
Magic Valley Heli-Arc & Manv.	P.O. Box 571	Twin Falls, ID 83301
Moore-Clark Company	P.O. Box M	LaConer, WA 98257
Nitrox	159 John Downey Drive	New Britain, CT 06051
Northwest Scale Systems	2100 W. Broadway, Ste. 5	Eugene, OR 97402
Northwest Marine Tech., Inc.		Shaw Island, WA 98286
Pfizer Vitamins	3418 South Chapman Road	Green Acres, WA 99016
Rangen, Inc.	Box 706	Buhl, ID 83316
Reiff Fiberglass Company	Route 4, Box 183	Walla Walla, WA 99362
Salmon/Trout Advisory Service	P.O. Box 6232	Olympia, WA 98502
Smith-Root, Inc.	14014 NE Salmon Creek Ave.	Vancouver, WA 98686
Sterling H. Nelson & Sons	P.O. Box 7428	Murray, UT 84107
VMG Industries	858 Grand Avenue	Grand Junction, CO 81501
Xorbox, Inc.	290 Creekside Drive	Tonawanda, NY 14150

ANNUAL NORTHWEST FISH CULTURE CONFERENCES

HISTORICAL RECORD

Year	Location	Host Agency	Chairman
1950	Portland, Oregon	U.S. Fish and Wildlife Service	Perry, T.
1951	Wenatchee, Washington	U.S. Fish and Wildlife Service	Burrows, R.
1952	Seattle, Washington	Washington Dept. of Fisheries	Ellis, B.
1953	Portland, Oregon	Oregon Fish Commission	Cleaver, F.
1954	Seattle, Washington	U.S. Fish and Wildlife Service	Rucker, R.
1955	Portland, Oregon	Oregon Game Commission	Rayner, J.
1956	Seattle, Washington	Washington Dept. of Game	Millenbach, C.
1957	Portland, Oregon	U.S. Fish and Wildlife Service	Johnson, H.
1958	Seattle, Washington	Washington Dept. of Fisheries	Ellis, R.
1959	Portland, Oregon	Oregon Fish Commission	Jeffries, E.
1960	Olympia, Washington	Washington Dept. of Game	Johansen, J.
1961	Portland, Oregon	Oregon Game Commission	Jensen, C.
1962	Longview, Washington	U.S. Fish and Wildlife Service	Burrows, R.
1963	Olympia, Washington	Washington Dept. of Fisheries	Ellis, B.
1964	Corvallis, Oregon	Oregon State University	Fryer, J.
1965	Portland, Oregon	U.S. Fish and Wildlife Service	Halver, J.
1966	Portland, Oregon	Oregon Fish Commission	Hublou, W.
1967	Seattle, Washington	University of Washington	Donaldson, L.
1968	Boise, Idaho	Idaho Fish and Game Department	Cuplin, P.
1969	Olympia, Washington	Washington Dept. of Game	Johansen, J.
1970	Portland, Oregon	Oregon Game Commission	Jensen, C.
1971	Portland, Oregon	U.S. Fish and Wildlife Service	Smith, M.
1972	Seattle-Tacoma, WA	Washington Dept. of Fisheries	Noble, R.
1973	Wemme, Oregon	Oregon Fish Commission	Jeffries, E.
1974	Seattle, Washington	University of Washington	Salo-Brannon
1975	Newport, Oregon	Oregon State University	Donaldson, J.
1976	Twin Falls, Idaho	University of Idaho	Klontz, B.
1977	Olympia, Washington	Washington Dept. of Game	Morrow, J.
1978	Vancouver, Washington	U.S. Fish and Wildlife Service	Leith, D.
1979	Portland, Oregon	Oregon Dept. of Fish and Wildlife	Jeffries, E.
1980	Courtenay, B.C.	Fisheries and Oceans	Sandercock, K.
1981	Tumwater, Washington	Washington Dept. of Fisheries	Ashcraft, W.
1982	Portland, Oregon	National Marine Fisheries Service	Wold, E.
1983	Moscow, Idaho	Idaho Fish and Game Department and University of Idaho	Parrish, E. and Klontz, G.
1984	Kennewick, Washington	Washington Dept. of Game	Gearheard, J.
1985	Tacoma, Washington	U.S. Fish and Wildlife Service	Forner, E.
1986	Springfield, Oregon	Oregon Dept. of Fish and Wildlife	Bauer, J.
1987		Washington Dept. of Fisheries	Hager, B.

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