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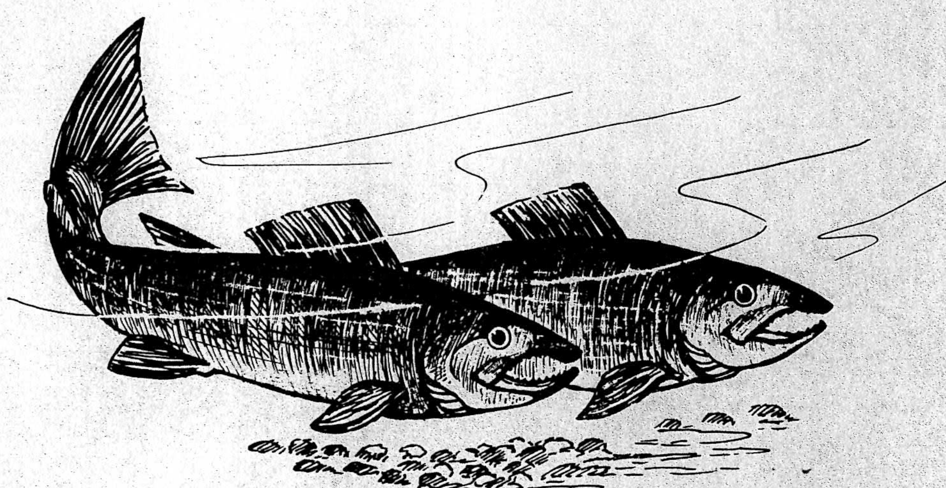
C. J. Campbell

22nd Annual Northwest Fish Culture Conference



PORTLAND, OREGON – DEC. 2-3, 1971

PROCEEDINGS OF THE

22nd ANNUAL NORTHWEST FISH CULTURAL CONFERENCE

December 2 and 3, 1971

The Conference was held in Portland, Oregon at the United States Department of Interior Building Auditorium. Approximately four hundred registered persons interested or associated with fish husbandry were in attendance.

The proceedings contain the unedited briefs of oral reports submitted at the Conference. In keeping with tradition you are requested to not quote or reproduce portions of these reports without express permission of the author(s).

My sincere thanks are extended to those of you who attended and participated in the Conference.

Mr. Ernest Jefferies of the Oregon Fish Commission was selected as the chairman for the 1973 Conference. Mr. Richard Noble of the Washington Department of Fisheries is your Chairman for 1972. A memorandum from Mr. Noble, requesting comments and suggestions has been included in the proceedings. Your co-operation is solicited.

Marvin A. Smith
Chairman, 1971

TWENTY-SECOND ANNUAL NORTHWEST FISH CULTURE CONFERENCE

Interior Department Building Auditorium
1002 N. E. Holladay Street
Portland, Oregon 97208

December 2 and 3, 1971

Marvin A. Smith, Chairman

Thursday, December 2

7:30 - 8:00	Registration	
8:00 - 8:10	Announcements	
8:10 - 8:20	Welcome -	Dr. Fred C. Cleaver National Marine Fisheries Service
8:20 - 8:40	A REVIEW: METHODS OF CALCULATING CARRYING CAPACITIES IN FISH HATCHERIES	Robert G. Piper Bureau of Sport Fisheries and Wildlife
8:40 - 8:55	PROGRESS ON THE TEHAMA-COLUSA FISH FACILITIES	Dale Schoeneman Bureau of Sport Fisheries and Wildlife
8:55 - 9:10	GRAVEL INCUBATION HATCHERIES FOR PINK AND CHUM SALMON	Derek C. Poon Oregon State University
9:10 - 9:25	YOLK SAC MALFORMATION IN PACIFIC SALMON	Hossein Emadi Oregon State University
9:25 - 9:40	HYBRIDIZATION AND ITS ROLE IN FISH CULTURE	Richard E. Noble Washington Department of Fisheries

9:55 - 10:10	HATCHERY CONTRIBUTION OF ANADRAMOUS FISH TO THE NORTH UMPQUA RIVER Jerry A. Bauer Oregon State Game Commission	
10:10 - 10:30	HATCHERY PRODUCTION OF SALMON SMOLTS IN ALASKA Joe Wallis Alaska Fish and Game Department	
10:30 - 10:45	PROGRESS IN ORAL IMMUNITY FOR *VIBRIO ANGUILLARUM* John S. Rohovec Oregon State University	
10:45 - 11:00	RECENT OBSERVATIONS CONCERNING *CERATOMYXA SHASTA* Keith A. Johnson Oregon State University	
11:00 - 11:15	PROGRESS WITH THE ABERNATHY DRY DIET Larry G. Fowler Bureau of Sport Fisheries and Wildlife	
11:15 - 11:30	PRODUCTION TRIAL OF ABERNATHY DRY DIET FOR COHO Dwain Mills Oregon State Fish Commission	
11:30 - 11:45	GROWTH OF PINK, CHUM AND CHINOOK SALMON IN HEATED SEA WATER Bernard Kepshire Oregon State University	
1:00 - 1:15	SMOLT CHARACTERISTICS DEPENDENT UPON WATER TEMPERATURES Bryant L. Adams Bureau of Sport Fisheries and Wildlife	
1:15 - 1:30	USING GILL ATPASE ACTIVITY TO DETERMINE THE INFLUENCE OF PHOTOPERIOD ON PARR-SMOLT TRANSFORMATION IN STEELHEAD W. S. Zaugg Bureau of Sport Fisheries and Wildlife	
1:30 - 1:45	PARR-SMOLT TRANSFORMATION IN WINTER STEELHEAD AS AFFECTED BY PHOTOPERIOD AND TEMPERATURE Harry Wagner Oregon State Game Commission	

1:45 - 2:00 WINTER RUN STEELHEAD TROUT RETURNS TO THE UNIVERSITY OF WASHINGTON

Robert D. Anderson
Lauren R. Donaldson
University of Washington

2:00 - 2:15 WHIRLING DISEASE AT LAHONTAN NATIONAL FISH HATCHERY IN NEVADA

William Walsdorf
Bureau of Sport Fisheries and Wildlife

2:15 - 2:30 PROGRESS IN THE STUDY OF ANTIOBIOTIC EFFICACY AND TERATOGENICITY IN ADULT CHINOOK SALMON (ONCORHYNCHUS TSCHAWYTSCHA)

Mark DeCew
Washington Department of Fisheries

2:30 - 2:45 STUDENT PROJECTS AS A SOURCE OF INTERESTING AND USEFUL INFORMATION

Charles Sowards
Bureau of Sport Fisheries and Wildlife

2:45 - 3:00 THE POSSIBILITIES FOR CULTURING CRAYFISH

Dr. Jack R. Donaldson
Presented by: Robert Coykendall
Oregon State University

3:15 - 3:35 PRELIMINARY STUDIES USING SYNTHETIC POLYMERS TO REDUCE TURBIDITY IN A HATCHERY WATER SUPPLY

Dean L. Chase
Bureau of Sport Fisheries and Wildlife

3:35 - 3:50 ASCORBATE IN RAINBOW TROUT

C. L. Johnson
Bureau of Sport Fisheries and Wildlife

3:50 - 4:05 VITAMIN C_3 FOR FISH

Dr. John E. Halver
Bureau of Sport Fisheries and Wildlife

4:05 - 4:20 CHINOOK SALMON PEN-REARING PROJECT IN PUGET SOUND

Dr. Ernest O. Salo
University of Washington

4:20 - 4:35 STEELHEAD REARING IN LAKE QUINAULT

Gary D. Stauffer
University of Washington

4:35 - 4:50 PROGRESS REPORT ON CONTRIBUTION OF HATCHERY PRODUCED SUMMER STEELHEAD TO SILETZ RIVER

John Fortune
Oregon State Game Commission

4:50 - 5:00 NEW USES FOR OLD FISH TREATMENT CHEMICALS

Wayne Brunson
Washington State Department of Game

Friday, December 3

8:30 - 8:50 HANDLING STRESS AND ITS PHYSIOLOGICAL CONSEQUENCES

Gary Wedemeyer
Bureau of Sport Fisheries and Wildlife

8:50 - 9:10 WILLAMETTE RIVER SPRING CHINOOK SURVIVAL STUDY

Don Swartz
Oregon State Fish Commission

9:10 - 9:25 HATCHERY WATER QUALITY MONITORING

Warren Shanks
Bureau of Sport Fisheries and Wildlife

9:25 - 9:40 ADULT STEELHEAD RETURNS FROM RELATED PLANTS

Marvin Hull
Washington State Department of Game

9:40 - 9:45 THE SUCCESSFUL USE OF CO_2 ANAESTHESIA FOR SPAWNING FALL CHINOOK SALMON

Elmo B. Barney
Bureau of Sport Fisheries and Wildlife

10:00 - 10:25 A PROGRAM FOR THE STUDY OF FISH HATCHERY WATER TREATMENT SYSTEMS AT THE BOZEMAN FISH CULTURE DEVELOPMENT CENTER IN MONTANA

Ronald D. Mayo
Kramer, Chin & Mayo, Consulting Engineers

THE NITRIFICATION PROCESS FOR RECONDITIONING FISH HATCHERY WATER

Paul Liao
Kramer, Chin & Mayo, Consulting Engineers

10:25 - 10:40 NITRITE TOXICITY IN TROUT HELD IN WATER REUSE SYSTEMS

Warren Williams
Kramer, Chin & Mayo, Consulting Engineers

10:40 - 10:55 EFFECTS OF NITRITE ON THE BLOOD AND TISSUES OF SALMON AND TROUT

Charlie E. Smith
Bureau of Sport Fisheries and Wildlife

10:55 - 11:10 PROGRESS IN WATER RECLAMATION STUDIES

Bobby Combs
Bureau of Sport Fisheries and Wildlife

11:10 - 11:25 EVALUATION OF ADULT STEELHEAD SORTING EQUIPMENT AND AIR SPAWNING AT DWORSHAK NATIONAL FISH HATCHERY

Einar Wold
Bureau of Sport Fisheries and Wildlife

11:25 - 11:45 HIGH VOLUME, ECONOMIC, ULTRA-VIOLET WATER PURIFICATION AND FILTRATION UNITS FOR HATCHERIES

Robert E. Flatow
R. E. Flatow & Co., Inc.

1:00 - 1:25 A NEW PROBLEM - DISPOSAL OF ADULT SALMON RETURNING TO HATCHERIES

Ernie Jeffries
Oregon State Fish Commission

THE STATE OF WASHINGTON SURPLUS SALMON PROBLEM

Bud Ellis
Washington Department of Fisheries

ANADROMOUS FISH ARE RETURNING

Paul Handy
Bureau of Sport Fisheries and Wildlife

1:25 - 1:40	JOB ACCOUNTING AT A SALMON HATCHERY	
		John Clayton Washington Department of Fisheries
1:40 - 2:00	LASER AND FREEZE MARKING OF SALMONIDS AND CRUSTACEANS FOR IDENTIFICATION	
		Dr. Thomas G. Bell Washington State University
2:00 - 2:15	SUMMARY OF COHO CONTRIBUTION FROM PUGET SOUND AND WASHINGTON COASTAL HATCHERIES	
		Harry Senn Washington Department of Fisheries
2:15 - 2:30	COST ANALYSIS OF REARING FIRST EGG COLLECTION IN REUSE SYSTEMS VERSUS RAW WATER	
		John Parvin Bureau of Sport Fisheries
2:30 - 2:45	PROGRESS IN EVALUATING FISH FEEDS ON THE BASIS OF DIGESTABILITY AND METABOLIZABLE ENERGY	
		Robert R. Smith Bureau of Sport Fisheries and Wildlife
2:45 - 3:00	STANDARD DESIGN LIBERATION TANK CUTS COST	
		Bill Harris Harris Thermal Transfer Products, Inc.

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A REVIEW: METHODS OF CALCULATING CARRYING CAPACITY IN FISH HATCHERIES

Robert G. Piper

Bureau of Sport Fisheries and Wildlife
Fish Cultural Development Center
Bozeman, Montana

In the past several years a number of methods for calculating carrying capacities in hatcheries have been published. It might be appropriate to review some of these methods and point out their advantages and similarities. Some methods will have advantages over others under certain hatchery situations.

Tunison (1945) presented a table based on fish size and pounds of fish per cubic foot. He mentioned that no fixed rule can be given for the volume of flow needed but that the range should approximate 8-12 gallons of water per minute in hatching troughs and that rearing troughs are supplied with about 20 gallons per minute flow. This was a good basic approach and assumed that the rearing conditions in your hatchery were fairly standardized and your water quality in regards to oxygen and temperature are constant.

Haskell, (1955) came up with what we consider to be a major approach in rearing capacity calculations based on two premises which have carried on through the years. The first, carrying capacity is limited by oxygen consumption and accumulation of metabolic products, and second, that the amount of oxygen consumed and the quantity of metabolic products are proportional to the amount of food fed. Haskell's formula is based on feeding levels, and you must know fish size and water temperature. We assume again standard rearing conditions, as constant water flow and water quality. He relates carrying capacity then to pounds per cubic foot of raceway.

Willoughby (1968) carried Haskell's approach a step further and related carrying capacity to the amount of oxygen which would be used to metabolize the food. Willoughby points out that his method can be used to predetermine carrying capacities without trial or error experiments. In addition to the feeding level which takes into consideration fish size and water temperature, Willoughby's formula has oxygen content of the water and water flow considered. He does not base his carrying capacity on lbs/ft^3 as Tunison and Haskell did, but refers to the total weight of fish that can be held in a rearing unit. You must assume that a pound of food contains 1,200 calories and uses 100 gms of oxygen to be metabolized.

Westers (1970) presented a formula and tables which could be used to determine the carrying capacity in salmonid hatcheries in lbs/ft^3. He measures water flow in terms of rate of changeover instead of gallons per minute, feeling that this value is responsible for the difference in carrying capacities in differenct sized units. This approach considers fish size, water temperature and the rate of water changeover. He cited water chemistry, hatchery design, individual pond design and species of fish as influencing factors on the rearing performance of a hatchery.

We presented a formula and table for calculating carrying capacities in hatcheries at the Bozeman Fish Cultural Development Center (Piper, 1970). This formula is also based on fish size, water temperature and water flow and follows Haskell's premise. It eliminates the requirement of calculating feeding level or amount of food to feed and interprets loading capacities in terms of fish length, since we have shown that there is a straight line relationship between the percent body weight to feed and the length of fish in inches. You must first calculate a "loading factor" for your hatchery using either empirical data based on the known permissible weight of fish of a given length of Willoughbys formula. Other fish lengths and water flows can then be calculated using this factor.

CALCULATION OF RACEWAY LOADING FACTORS IN FISH HATCHERIES

These formulas are based on trout feeding charts (the Buterbaugh-Willoughby feeding guide using a hatchery constant and other current feeding charts using water temperature) and can also be used to calculate changes in feeding levels at different water temperatures.

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<u>EXAMPLE</u>: A hatchery can hold 200 pounds of five-inch fish in a raceway having a water inflow of 25 gpm at 50° F. This would be a loading factor of 1.6 (lbs. of fish ÷ gpm = lbs./gpm, lbs./gpm ÷ length of fish = loading factor.)

Question: What would the loading factor be at a water temperature of 55° F?

The new water temperature is 5° higher, so the formula which should be used is:

$$X = \frac{Y \text{ (known loading factor)}}{1 + (^{\circ}\text{F rise in temp. x .o5})}$$

Substituting, we have 1.6 ÷ 1 + (5 x .05) or a loading factor of 1.33.

Likewise, if we had a drop in temperature of 5 degrees, to 45° F, we would use the formula:

$$X = Y + (^{\circ}F \text{ drop in temp. x } .04Y)$$

By substituting % of body weight to feed in place of the loading factor, you can see that we can calculate changes in feeding levels when different water temperatures are encountered. Since feeding levels are directly proportional to changes in water temperature, instead of inversely proportional as loading factors are, you would reverse the order of use of the above formulae.

Loading Factors as Related to Water Temperature and Altitude for Trout and Salmon to Estimate Weight of Fish Per GPM Inflow

Water Temperature F°	Elevation 0	1000	2000	3000	4000	5000	6000	7000	8000	9000
40	2.70	2.61	2.52	2.43	2.34	2.25	2.16	2.09	2.01	1.94
41	2.61	2.52	2.44	2.35	2.26	2.18	2.09	2.02	1.94	1.87
42	2.52	2.44	2.35	2.27	2.18	2.10	2.02	1.95	1.88	1.81
43	2.43	2.35	2.27	2.19	2.11	2.03	1.94	1.88	1.81	1.74
44	2.34	2.26	2.18	2.11	2.03	1.95	1.87	1.81	1.74	1.68
45	2.25	2.18	2.10	2.03	1.95	1.88	1.80	1.74	1.68	1.61
46	2.16	2.09	2.02	1.94	1.87	1.80	1.73	1.67	1.61	1.55
47	2.07	2.00	1.93	1.86	1.79	1.73	1.66	1.60	1.54	1.48
48	1.98	1.91	1.85	1.78	1.72	1.65	1.58	1.53	1.47	1.42
49	1.89	1.83	1.76	1.70	1.64	1.58	1.51	1.46	1.41	1.36
50	1.80	1.74	1.68	1.62	1.56	1.50	1.44	1.39	1.34	1.29
51	1.73	1.67	1.62	1.56	1.50	1.44	1.38	1.34	1.29	1.24
52	1.67	1.61	1.56	1.50	1.44	1.39	1.33	1.29	1.24	1.19
53	1.61	1.55	1.50	1.45	1.39	1.34	1.29	1.24	1.20	1.15
54	1.55	1.50	1.45	1.40	1.34	1.29	1.24	1.20	1.16	1.11
55	1.50	1.45	1.40	1.35	1.30	1.25	1.20	1.16	1.12	1.07
56	1.45	1.40	1.35	1.31	1.26	1.21	1.16	1.12	1.08	1.04
57	1.41	1.36	1.31	1.27	1.22	1.17	1.13	1.09	1.05	1.01
58	1.36	1.32	1.27	1.23	1.18	1.14	1.09	1.05	1.02	0.98
59	1.32	1.28	1.24	1.19	1.15	1.10	1.06	1.02	0.99	0.95
60	1.29	1.24	1.20	1.16	1.11	1.07	1.03	0.99	0.96	0.92
61	1.25	1.21	1.17	1.13	1.08	1.04	1.00	0.97	0.93	0.90
62	1.22	1.18	1.14	1.09	1.05	1.01	0.97	0.94	0.91	0.87
63	1.18	1.14	1.11	1.07	1.03	0.99	0.95	0.92	0.88	0.85
64	1.15	1.12	1.08	1.04	1.00	0.96	0.92	0.89	0.86	0.83

FL = W
F = Load Factor
L = Length of Fish in Inches
W = Weight in lbs. per gpm inflow

Example: 50° F., 5,000' elevation, 4" (40/lb.)
1.5 x 4 = 6.0 lbs. per gpm inflow

Calculated from a base of F = 1.5 at 50° F. 5,000' elevation.
Oxygen level assumed to be at or near saturation.

Prepared by Bruce B. Cannady
Revised May 1, 1970

PROGRESS ON TEHAMA-COLUSA FISH FACILITIES

Dale Schoeneman

Bureau of Sport Fisheries and Wildlife
Director, Tehama-Colusa Fish Facility
Red Bluff, California

The Tehama-Colusa Fish Facilities comprise a system of fish passage, counting and trapping structures, and a salmon spawning channel complex integrated with a large irrigation project on the upper Sacramento River. The first 3.2 miles of the Tehama-Colusa Canal was designed and constructed to meet basic requirements needed for spawning chinook slamon and contains 1.5 million square feet of select gravel. An access channel flowing from the lower end of the dual purpose canal to the Sacramento River consists of two smaller spawning channels and a fish conveyance channel. These supplementary single purpose spawning channels are each one mile in length and contain 385,000 square feet of gravel. The Fish Facilities also include drum screens, louvers, and electric barrier, and a gravel monitering system to measure intergravel water quality and percolation rate.

The dual purpose canal is 90 feet wide at the surface of the gravel and has a flow capacity of 2,530 c.f.s. The water will vary from six to eight feet deep. The concrete lining is covered with 30 inches of select gravel ranging from 3/4 inch to six inches in diameter. This spawning channel will have an ultimate capacity for over 30,000 chinook spawners making it the largest of its type in the world.

Construction of the spawning channels was started in July, 1969, and was completed in August, 1971. Trapping and stocking of adult chinook salmon commenced in October, 1971.

Emphasis on salmon production will be placed primarily on the single purpose spawning channels during the first several years of operation. Additional turnout structures in the lower irrigation reaches of the Tehama-Colusa Canal must be constructed before the dual purpose canal can be brought into full production. At the present time only the upper 3,000 feet of the canal has water velocities suitable for spawning. Flows in the single purpose channels are at designed capacity, 115 c.f.s. each, providing a velocity of approximately 2 f.p.s. and a water depth of 18 inches. An automated sprinkler system distorts the water surface thus reducing fish disturbance.

Between October 5 and November 12 a total of 5,036 adult chinook spawners in advanced spawning condition were stocked in the channels. Of these, 4036 were placed in the single purpose channels and 1,000 were placed in the dual purpose canal. All but 295 salmon were trapped at the east fish ladder trapping facility at the Red Bluff Diversion Dam and transported by fish trucks to the channel site. The remaining spawners volunteered directly from the Sacramento River via Coyote Creek. These fish were diverted by an electric barrier into a fish ladder, and allowed to enter the spawning channels via the conveyance channel.

The first redds were observed in the single purpose channels on October 15, ten days after placing began. Redd counts were conducted weekly and are summarized below:

DATE	CUMULATIVE REDDS OBSERVED SINGLE PURPOSE CHANNELS
October 21	70
October 27	210
November 2	311
November 8	489
November 15	675
November 19	957

Separator screens were placed at 1,000 foot intervals in the single purpose channels to provide favorable distribution of spawners.

By November 19, a total of 2,958 carcasses (58.7%) were collected from the spawning channels. Of these, 62.3% of the females and 86.4% of the males had spawned.

GRAVEL INCUBATION HATCHERIES FOR PINK AND CHUM SALMON

Derek C. Poon

Department of Fisheries & Wildlife
Oregon State University
Newport, Oregon

This report discusses the concept of gravel incubation in general and summarizes the development of the OSU Netarts Bay prototype hatchery.

The gravel incubation hatchery simulates conditions in a good quality spawning bed. This hatchery differs from the standard hatchery in providing for the larval salmon a gravel substrate for tactile support, a lowered water velocity to minimize premature activities, and a darkened environment to avoid disturbing the photonegative alevins.

Basically similar production models are being tested by the Fisheries Research Board of Canada in British Columbia, the National Marine Fisheries Service (Alaska Region), and Oregon State University. At Netarts Bay, OSU's effort is focused on the native chum, but non-native Alaska pinks were incubated as test animals. The prototype hatchery is constructed of 4' X 8' wooden tanks. The eggs are hatched on screen trays which overlie a shallow layer of 1/4" to 3/4" crushed rocks; the alevins develop on the substrate. The migrating fry release themselves through drain pipes. The hatchery is designed to handle up to 1.2 million chum eggs on 500 square feet of substrate. Water velocity through the system is held at 100 cm/hr. (volume/area).

Laboratory studies suggested that compared to standard hatchery incubators, gravel incubators may produce pink and chum salmon fry which are more robust, possess higher survival from the eyed stage, feed and grow at a higher rate with an unlimited diet, and are less likely to develop a malformed yolk sac during the alevin period.

Since its conception in 1968, the Netarts prototype has released 623,000 pink salmon fry and 706,000 chum salmon fry. There were no returns from the first release of pinks. The first return of 3-year-old chums is expected in the fall of 1972.

YOLK SAC MALFORMATION IN PACIFIC SALMON

Hossein Emadi

Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon

Yolk sac malformation has been observed to cause mortality of alevins of Pacific salmon. The objective of this study was to determine if environmental factors contributed to the occurrence of the yolk sac malformation.

The variables tested included temperature (8-10-12 and 14°C), water velocity (25, 100, 200, and 400 cm/hr), substrate (gravel and screen), crowding, and exposure to light. Three salmon species-pink, chum, chinook, and two salmon hybrids: pink X chinook and chinook X pink were used in the experiments.

Substrate was found to have a profound effect on incidence of yolk sac malformation in all test groups, where alevins were raised on a gravel substrate, regardless of temperature and water velocity, crowding or exposure to light. On the gravel substrate, pink and chum salmon penetrated into the gravel and hid. The chinook salmon remained on the surface. There was little activity observed in any of the test groups to the swim-up stage. On the screen substrate, on the other hand, all test groups except the chinook were very active. The level of activity was highest where alevins were exposed to direct light and where stocking densities were highest.

Temperature, velocity, crowding and light each had a modifying effect on the percentage of alevins exhibiting the malformation, but the screen substrate was found to be the main contributor to the occurrence of the yolk sac malformation. Frequent rubbing of the yolk sac on the screen causes an abrasion which allows water to penetrate and leads to coagulation of the yolk and an elongation of the posterior part of the yolk sac. The coagulation prevents the normal circulation of blook, and may contribute to mortality of alevins in extreme cases.

HYBRIDIZATION AND ITS ROLE IN FISH CULTURE

Richard E. Noble

Washington Department of Fisheries
Olympia, Washington

Last year I gave a talk entitled use of hybridization as a means of enhancing salmon production and indicated in the last paragraph that the potential within the hatchery system is virtually untapped and a selection of stocks for specific management purposes will be expanded dramatically in the near future.

I had no idea how dramatic this was going to be or to what degree it would impact the hatchery division in Washington. Imposed upon the Washington hatchery division this past fall has been a program I'll call "The Sports Salmon Enhancement Program of Puget Sound". This was brought on by several management and research biologists within the Department of Fisheries. This group of biologists set as a goal the tripling of the sports catch of salmon from Puget Sound in the next ten years. Present catch statistics indicates the catch to be about 0.2 fish per angler day.

The program was a combination of selecting special stocks, hybridization others, and changing general hatchery procedures in order to have coho and chinook remain in Puget Sound. To give you some example of what some of the superintendents were faced with this last fall, let me read a list of specialized groups that presently exists within the hatchery system.

A group of White river spring chinook males were crossed with Cowlitz spring chinook females and are destined for release into the Green River near Auburn, Washington. The males were trapped from the White River system located just east of Puyallup, Washington and held at the Department's Puyallup station. Sperm was collected from live males and transported to Cowlitz wherein the eggs were fertilized. Incubation to the eye stages was at Cowlitz and they were then moved to Puyallup. The reared fingerlings are to be liberated into the Green River. Survival to date has been about 50%. White River spring males were also crossed with Green river fall chinook females. The egg take totalled over two million and the resulting fry are to be reared at four different hatcheries and release is scheduled for five areas. Survival to date has been variable ranging from 91% to 70%.

Hoh River Fall Chinook were crossed with Green River Fall Chinook females. The Hoh river males were caught by sportsmen, the sperm flown to Green River and eggs eventually returned to Soleduck. Survival to date is 98%.

Elwha River Fall Chinook males were crossed with Hoodsport females. The sperm was obtained by gaffing the males from the spawning grounds and used to fertilize two million eggs that were transported to the Soleduck station from Hoodsport. This station also received regular springs from Dungeness, a cross of Umpqua males and Cowlitz River Spring Chinook females; Neham Fall Chinook crossed with Cook River Chinook; Quillayute Fall Chinook purchased from the Indian gill net catch; Issaquah Fall Chinook plus the local stock of Coho split into early and late timing groups. Survivals on the various groups have ranged from very poor to excellent. The Umpqua-Cowlitz cross was between 92-93%. The Hoh river group 98%, the Elwha-Hoodsport cross, less than 60%.

Another experiment involved adult Spring Chinook hauled from Sunset Falls, located on the South Fork of the Skykomish, to the Skykomish Hatchery located near Monroe, Washington. The resulting egg take was 217,000. The eggs were incubated to the eyed stage at the Skykomish Hatchery and then moved to a site near Tacoma and are presently being cared for by a sports group.

In its second year of effort, is the now famous Rivers Inlet Fall Chinook hybridization study. During the fall of 1970 Hoodsport fall chinook eggs, numbering 300,000, were fertilized by sperm collected from adult and jack males seined in the Wannock River at Rivers Inlet, British Columbia. The release from this lot occurred June 15, 1971 at 71 per pound; with a survival rate of about 72%.

The 71 brood project was expanded to include an egg take of 1 million, half destined for Issaquah and one half to Soos Creek, located near Auburn, Washington. Survival to the eyed stage of 78% was somewhat less than the previous year's, 85% survival to a comparable stage. The Rivers Inlet group is somewhat unique in that another country becomes involved; fish have to be captured in the wild and under somewhat primitive conditions. A short slide review will give you a better synopsis than a verbal report. A project in progress and started before the big push on Puget Sound sports catch enhancement, was the cross between male Cowlitz Springs and female Fall Chinook from Hoodsport. An egg take of 200,000 in the fall of 1970 resulted in an egg to fingerling survival of 80%. This group has been differentially marked into three sub-groups to gain information resulting from various release times. The first release occurred with the regular fall chinook on May 29, 1971. The normal falls were 95 per pound and the hybrid group 100 per pound. The non-hybrids were more uniform in length with the superintendent reporting the hybrids to have an approximate 5% population of pin heads. The second release period was August 10, 1971 at 27 per pound and we still have 54,000 on hand at our Hoodsport station going less than 10 per pound.

Results of this experiment will provide valuable information as to what may really eminate from some of the specialized hybridization programs in progress. There are other chinook hybrids and selected stocks involved in the 71 brood program, but I should summarize the coho program instigated for Puget Sound sports catch enhancement. This program started with the 1969 brood involving princely coho at our Minter Creek station. The emphasis was put upon trying to determine a method of keeping coho from leaving the Puget Sound area. Time, size, area of release, and genetics were the prime areas of study. Groups were marked by adipose fin clips and coded wire tags and included the following: coho released at normal time and size, i.e. April 1, at 17 per pound; Minter Creek-Chambers Creek hybrids that were accelerated at 56 per pound; Minter Creek stock accelerated at 56 per pound; Chambers Creek stock at 26 per pound; White River stock at 25 per pound; George Adams and Puyallup stock at 20 per pound and a group of Minter Creek stock delayed until July 1 and at 8 per pound. Returns to the fishery of the delayed group has been significantly greater than any other of the marked lots. This prompted a greater effort for 1971 brood with a refinement of specific relationships such as effect of size as related to time of release and early versus normal time of adult arrival.

Superimposed on the above, is a program of selecting specific coho stocks; direct imports of Toutle River coho (Columbia River system); hybrids of Toutle-Puget Sound stocks; and selected racial groups such as coho from Baker River (Skagit system) were initiated. The Baker River coho return as adults in September but do not spawn until December. The hypothesis is, of course, that an adult coho returning in very bright condition is more apt to bite than one nearly ready for spawning. The various groups of coho will be at several different stations.

In addition, to the Chinook and Coho program, a special group of pink salmon were seined from the Stilliguamish River, north of Seattle. Adults were held at the Skagit Hatchery and the eggs ultimately went to Minter Creek. The resulting fry will be then reared near Manchester and moved to the Tacoma Narrows for release via towing the net enclosure.

The final group was 30,000 Masu salmon eggs obtained from Japan.

In summary, I can say that selection of specific stocks and hybridization for specialized purposes occurred sooner and with a greater emphasis than anticipated. The shotgun approach leaves considerable to be desired on biological basis. On a biological basis the Puget Sound Sports Salmon Enhancement program should have proceeded on a regulated carefully designed basis. Politically, this was not possible and the end result may do as much harm as good. On a public relations-political basis the program has merit--only time will tell!!

HATCHERY CONTRIBUTION OF ANADROMOUS FISH TO THE NORTH UMPQUA RIVER

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Hatchery produced fish made up 53.6 percent of the 38,809 anadromous fish counted over Winchester Dam on the North Umpqua River in 1971. During the period 1961 to 1970, the Oregon salmon-steelhead punch card report demonstrates an increase of 938 percent in the North Umpqua sports fishery harvest.

The first of the various hatchery programs for anadromous fish began in earnest on the North Umpqua River in 1949. At this time the total number of anadromous fish passing Winchester Dam was 14,468 fish. A total of 38,809 anadromous fish passed Winchester in 1971 with 20,794 hatchery produced fish or 53.6 percent.

The 9,930 spring chinook run in 1971, although below the two previous runs, continues the increase in the average run. Table 1 presents a history of spring chinook counts at Winchester Dam and illustrates the increasing contribution by hatchery fish.

Table 1
Spring Chinook Counts
at
Winchester Dam 1946 - 1971

Period	Average Run	Averages for Hatchery Contribution	
		Number of Fish	Percent of Run
1946-50	2,745	-	-
1951-55	5,908	929	15.7
1956-60	5,355	822	15.3
1961-65	8,671	1,911	22.0
1966-70	11,863	4,498	37.9
1971	9,930	3,907	39.3

The present spring chinook program is one of an annual release of 150,000 smolts at 5-6 fish per pound, with a condition factor approaching 1.10, for release during the period January 15-March 1. Returns from this program for the last five completed brood years have averaged 5.8 percent with a high of 11.0 percent.

The fall chinook program began in 1967. The program has been one of an annual release of 450,000 (100-day) smolts reared either in Whistler's Bend Pond or at Rock Creek Hatchery. Eggs for the program have come from Oregon Fish Commission hatcheries on the Columbia. Early returns have been less than one percent and have returned late in the spring chinook run rather than in the fall chinook run.

The 1971 run of 16,000 summer steelhead again established a record high for the North Umpqua. The rapid rate of increase in summer steelhead passing Winchester Dam and the outstanding contribution of hatchery fish is presented in Table 2.

Table 2
Summer Steelhead Counts
at
Winchester Dam 1946 - 1971

Period	Average Run	Averages for Hatchery Contribution	
		Number of Fish	Percent of Run
1946-50	3,149	-	-
1951-55	3,439	-	-
1956-60	2,395	833	34.3
1961-65	3,874	1,339	34.6
1966-70	9,338	6,631	71.0
1971	16,000	13,440	84.0

The summer steelhead program is one of an annual release of 150,000 smolts, 5-7 fish per pound, with a condition factor of 1.0 or less, for release during the first two weeks of March. Returns from the last five brood years have averaged almost 7.0 percent with a high of 10.0 percent.

The present program calls for a release into the main North Umpqua of 70,000 smolts split between river mile 119 and 127 (Bait Area), 60,000 split into river miles 154, 160 and 166 (Fly Area), and 20,000 into a spawning tributary at river mile 173. Nearly complete returns from the 1968 brood indicate 9.3 percent return from "Bait Area" releases, 9.2 percent from "Fly Area" releases, and 6.2 percent from the tributary release.

Table 3 shows that the hatchery summer steelhead returns over a four-year period. The largest returns are split almost 50-50 after 1-plus and 2-plus years in the ocean. A favorable comparison in the size at return of the hatchery adult with the wild adult is presented in Table 4. The increased average size for the hatchery adult during the last five years is the result of brood fish selection.

Table 3
Pattern of Return to Winchester Dam
by
Hatchery Summer Steelhead

Life History Pattern	Fork Length at Return	Annual Percent Return	Accumulative Percent Return
1 / 1	15.9 inches	0.9	0.9
1 / 2	23.5 inches	43.7	44.6
1 / 3	27.2 inches	53.0	97.6
1 / 4	28.1 inches	2.4	100.0

Table 4
A Comparison of Average Fork Lengths
between
Wild and Hatchery Summer Steelhead Adults

Wild Fish		Hatchery Fish		
			1st 5 yrs.	Last 5 yrs.
Pattern	Fork Length	Pattern	Fork Length	Fork Length
2 / 1	19.8"	1 / 1	15.3"	15.9"
2 / 2	24.4"	1 / 2	22.6"	23.5"
2 / 3	27.5"	1 / 3	26.6"	27.2"
-	-	1 / 4	-	28.1"

The 1971 run of sea-run cutthroat contained 1,190 hatchery fish or 62.7 percent. Table 5 presents the rate of increase and hatchery contribution for the sea-run cutthroat. The present program is one of an annual release of 20,000 smolts at a size of 3.0 fish per pound, released in late March or early April. Returns have ranged between 2.1 and 14.5 percent. Fish planted in May do not migrate to saltwater and contribute only to the early summer trout fishery.

Table 5
Sea-Run Cutthroat Counts
at
Winchester Dam, 1946 - 1971

Period	Average Run	Averages for Hatchery Contribution: Number of Fish	Percent of Run
1946-50	716	-	-
1951-55	1,090	-	-
1956-60	437	-	-
1961-65	256	70	27.3
1966-70	1,467	895	61.0
1971	1,880	1,190	62.7

Not only have hatchery produced anadromous fish increased spawning runs into the North Umpqua but sports fisheries on the various fish have also increased. Table 6 illustrates angler harvest for salmon and steelhead as reported on the Oregon punch card and the projected angler trips. The salmon harvest, although down from the record year of 1969, shows an increase from 508 salmon for 5,080 angler trips in 1961 up to 2,318 fish for 7,506 angler trips in 1970. The figures for steelhead are even more outstanding, showing an increase from 688 fish for 3,621 angler trips in 1961 up to 8,905 fish for 51,665 angler trips in 1970. The increase in salmon and steelhead production and harvest in the North Umpqua is also reflected in the overall harvest in the Umpqua River system. The total harvest for the Umpqua system in 1961 was 5,629 steelhead and 13,449 salmon compared to 21,748 steelhead and 22,429 salmon in 1970.

Table 6
Harvest and Angler-Use Statistics
for
North Umpqua Salmon and Steelhead, 1961-1970

Year	Salmon Harvest	Angler Trips	Steelhead Harvest	Angler Trips
1961	508	5,080	688	3,631
1962	306	1,700	945	4,974
1963	759	3,994	1,799	9,468
1964	575	3,594	1,140	6,000
1965	699	4,112	2,235	22,350
1966	745	4,382	4,069	29,064
1967	802	4,717	3,297	23,550
1968	1,083	3,495	4,335	30,964
1969	5,714	12,986	6,986	42,113
1970	2,318	7,506	8,905	51,665

In summary, hatchery programs utilizing an annual release of 800,000 smolts (350,000 full term ChS. - Sts. - StW. - CtS.) (450,000, 100-day CHF.) have demonstrated increases in anadromous fish in the North Umpqua from 14,468 fish in 1949 up to 38,809 fish in 1971. Hatchery produced fish totaled 20,794 in 1971 and made up 53.6 percent of the returns. Salmon and steelhead sports fisheries in the North Umpqua during the last ten years have increased from 1,196 fish caught in 8,701 angler trips up to 11,223 fish caught in 59,171 angler trips.

HATCHERY PRODUCTION OF SALMON SMOLTS IN ALASKA

Joe Wallis

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Fire Lake Hatchery
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Rearing salmon smolts in Alaska is a very recent program, and until now has been largely experimental. We have worked with both local and imported stocks of chinook and coho.

Local Stock Chinook

Adult chinook enter freshwater in May, June, July and spawn in July and August. Juveniles emerge during winter and spend a little over one full year in freshwater before migrating to sea in May and June. A few adults return to spawn a 3-year fish (jacks), but most return as 4, 5, and 6-year-olds.

In our rearing program, fish begin to feed in October. Growth is rapid due to warm water temperatures, and the fish are planted as smolts at about 15 to 20 per pound in May of their first year.

Returns to date have been very preliminary, but we have had enough adults return to be encouraging. The adults from hatchery-reared smolts are comparable in size to natural adults one year older, as a result of our eliminating one full year of freshwater life.

Local Stock Coho

Approximately 60 to 80 per cent of the adult coho in Southcentral Alaska originate from 2-year-old smolts. Our rearing program for coho has been to produce smolts in one year, and release them during May at about 10 to 15 fish per pound.

We had our first adult returns of local stock coho in 1971. Fish were of Bear Lake (Seward) origin, and smolts were planted into Ship Creek (Anchorage) and Seward Lagoon (Seward) at about 10 fish per pound.

There was incomplete recovery of fish in Ship Creek and in the commercial fishery in Cook Inlet, but we know the escapement was in excess of one per cent.

At Seward, a total of 45,000 smolts were planted. A very intensive creel census was conducted on the sport fishery in Ressurection Bay, and we had reasonably reliable estimates of escapement. The estimated survival of this lot was approximately 15 per cent.

Import Stocks of Chinook and Coho

We have planted fall chinook of Green River, Washington stock, and coho from three sources in Oregon. A few adults from these groups returned, but there were so few they were of no practical significance. In addition, they returned so late in the year they would be of questionable value in our management programs.

PROGRESS IN ORAL IMMUNITY FOR *Vibrio anguillarum*[1]

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and

Robert L. Garrison
Oregon State Game Commission

Previous work in our laboratory indicated that a formalin-killed sonicate of *Vibrio anguillarum*, when fed at a level of 1,000 micrograms per fish over a 30 day period, reduced mortality in experimental fish exposed to the causative agent of vibriosis. In recent experiments our objective was to determine if variations of this preparation would also provide protection. Vaccines prepared by altering cell sonication were examined. The variations in preparation of vaccine included: (1) sonication for 2 minutes after treatment in 0.3% formalin, (2) sonication for 5 minutes after treatment with 0.3% formalin, (3) sonication for 5 minutes with no formalin treatment and (4) whole cell preparation treated with 0.3% formalin and not sonicated. These vaccine preparations were incorporated into Oregon test diet at a level of 2 milligrams vaccine/gram of diet and fed to fall and spring chinook salmon over a 30 day period. Groups of fish were also vaccinated by intraperitoneal injection with formalin-killed cells in Freund's complete adjuvant. Following the 30 day vaccination period, all groups of fish including unvaccinated control lots were exposed to a natural challenge of *V. anguillarum*. In the unvaccinated control groups there was high mortality with 70% loss in the spring chinook and 87% in the fall chinook group. Vaccinated groups experienced much lower mortality ranging from 3 to 17%, indicating immune protection by all vaccine preparations tested. Results of these tests reveal that the whole cell preparation was effective in protecting fish from vibriosis. This indicates that the sonication step in vaccine preparation can be eliminated. This will reduce both the cost of the vaccine and the time necessary for its preparation. At the present time studies are in progress to test the whole cell preparation in a production experiment.

1 This work is supported by the Oregon State Game Commission.

SOME RECENT OBSERVATIONS ON *Ceratomyxa shasta*[1]

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Ceratomyxa shasta infections were first obtained in the upper Willamette River at Albany, Oregon in coho salmon and cutthroat trout. The exposures for these infections began about April 10, 1970. Liveboxing of rainbow trout established the presence of the infection through October 16, 1970. In 1971, infections, which were obtained by weekly liveboxing of rainbow trout, occurred on May 23, in mid-June, and again on July 15 after which the river was positive for *C. shasta* until October 27 and possibly beyond that date.

Studies have established that the source of the infection is located near Corvallis, Oregon slightly upstream from the confluence of the Marys River. The percentage of infection decreases and the mean day of mortality increases from a point near the north city limits of Corvallis to above the Marys River confluence. This was determined for liveboxed fish in several intermediate localities. The source is probably a portion of the mainstream river rather than a side channel as previously suspected.

The susceptibility to *C. shasta* was investigated for several species of juvenile salmonids. Four hatchery groups of fall chinook were tested and three had low susceptibility. All of these were from Columbia River basin hatcheries. The fourth group, from Trask Hatchery (OFC), had extremely high susceptibility. Since the Columbia River contains *Ceratomyxa* and the Trask River does not, the differences in susceptibility are possibly genetic. The remaining salmonids tested fell into three susceptibility categories:

- high susceptibility: rainbow, cutthroat and brook trout; also coho salmon
- moderate susceptibility: Atlantic salmon
- low susceptibility: kokanee and spring chinook salmon

The low susceptibility of spring chinook salmon was different than previous data but the other groups agree well with previous work on these species.

Filtration experiments with Willamette River water have shown that 14.0, 8.0, 1.2 and 0.45^{u} pore diameter membranes remove the infection when infectious water is run through them. Successful exposures have been obtained with rainbow trout by adding 14 and 8^{u} filter membranes, which had been used previously to filter infectious water, to uninfectious filtered water. Metal screens of 43^{u} pore size did not remove the infection from the water. Thus the size of the infectious agent of *Ceratomyxa shasta* must be between 43 and 14^{u}.

1 This study is supported by the Oregon State Game Commission.

PROGRESS WITH THE ABERNATHY DIET

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Diet experiments with fall chinook slamon fingerlings reared in constant 53° F. water indicated an increased growth response due to an adjustment of the dried whey to wheat germ meal ratio. Substitution of cottonseed meal for a portion of the herring meal did not reduce fish growth as long as the whey and wheat germ were maintained at a 1:1 ratio (Tables 1 and 2).

A 45 percent protein level appeared to be close to optimum when caloric levels were maintained isocaloric. Increased growth was not obtained by feeding 50 and 55 percent protein levels. Increasing the caloric level of the 50 percent protein diet and thereby changing the protein calorie to energy calorie ratio increased fish growth. A further caloric increase to the 50 percent protein diet produced no response (Tables 3 and 4).

Table 1,--1970 Feeding Trials, Salmon-Cultural Laboratory

	Diet 1	Diet 2	Diet 7
Herring Meal	39	48	50
Dried Whey	24	28	19
Cottonseed Meal	15	--	--
Wheat Germ Meal	15	17	19
Vitamin Premix	1	1	1
Soybean Oil	6	5	5
Corn Starch	--	1	6
Average Weight Per Fish (Grams)	2.14	20.4	25.5

Table 2,--1971 Feeding Trials, Salmon-Cultural Laboratory

	Diet 1	Diet 2
Herring Meal	47	39
Dried Whey	19	19
Cottonseed Meal	--	15
Wheat Germ Meal	19	19
Wheat Middlings	12	4
Vitamin Premix	1	1
Soybean Oil	2	3
Percent Fish Meal Protein	78	63
Average Weight Per Fish (Grams)	21.4	21.2

Table 3,--1970 Feeding Trials, Salmon-Cultural Laboratory

	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Herring Meal	29	40	50	60	71
Dried Whey	29	24	19	14	8
Wheat Germ Meal	29	24	19	14	8
Vitamin Premix	1	1	1	1	1
Soybean Oil	9	7	5	3	1
Corn Starch	3	4	6	8	11
Percent Protein	35	40	45	50	55
Calories	3,250	3,250	3,250	3,250	3,250
Average Weight Per Fish (Grams)	19.4	22.2	25.5	25.0	24.8

Table 4,--1971 Feeding Trials, Salmon-Cultural Laboratory

	Diet 1	Diet 5	Diet 6	Diet 7
Herring Meal	47	49	58	58
Dried Whey	19	19	15	15
Wheat Germ Meal	19	19	15	15
Wheat Middlings	12	6	7	5
Vitamin Premix	1	1	1	1
Soybean Oil	2	6	4	6
Percent Protein	45	45	50	50
Calories	3,050	3,350	3,350	3,500
Average Weight Per Fish (Grams)	21.4	22.6	25.4	24.4

PRODUCTION TRIAL OF ABERNATHY DRY DIET FOR COHO

Dwain E. Mills

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Clackamas Laboratory
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In 1970 we fed the Abernathy Dry Diet to coho and spring chinook at the Clackamas Laboratory. We fed the coho using two feeding methods similar to that used in our hatcheries to regulate growth. One group was programmed to a liberation size of 15/lb. and the other group 22/lb. The spring chinook were scheduled to produce near maximum growth under Clackamas conditions as estimated from results of previous experiments.

In our coho hatcheries we program the fish to achieve the liberation size we desire (15/lb. on April 15). To accomplish this we program the fish size by month, starting in April or May. When the desired monthly fish sizes have been determined, we use the conversion history of the hatchery to calculate the amount of food to feed each month.

We were able to regulate the coho growth in the lab and produce fish of the desired size. The Abernathy fed fish had a lower conversion rate and required about 19% less food.

With the spring chinook we were able to produce as much growth with the Abernathy diet as the Oregon Pellet. The Abernathy fish had a slightly lower conversion rate but it took two to three times as much feeding effort to get less food into the fish.

Based on these laboratory results with coho, we are now conducting a production feeding trial with coho at Big Creek Hatchery. We started from first feeding and will continue through liberation. One pond of fish on each diet will receive a single fin mark to determine returns to the hatchery for the purposes of evaluating survival.

We started the experiment of February 8 with fish averaging 1,178/lb. By the end of the starter diet period, the Abernathy fed fish had fallen behind those started on Oregon Mash. They continued behind through the end of March. The Oregon Pellet fish were put on the feeding schedule the first of April, but because the Abernathy fed fish were behind we did not put them on the feeding schedule until the first of May when they caught up to the Oregon Pellet fish.

Our only previous coho feeding experience with the Abernathy diet was in the lab study so we used that as a guide for the production feeding trial.

We feel it is important to liberate these groups at approximately the same size so any differences in returns will be due only to diet. We have had difficulties keeping the fish on the two diets the same size. This is mainly due to our inexperience in feeding the Abernathy diet under production conditions. Although this is not too critical at this time, it will be after the first of the year when it becomes increasingly difficult to make adjustments in fish size.

This table gives the results through the end of November.

There doesn't appear to be any appreciable difference in mortality levels between the two diets.

Results of Production Comparison of
Abernathy and Oregon Pellets Through November 1971

Diet	Fish/lb.	Conversion	Food Cost/Lb. of Fish Raised ¢/Lb.	Fork Length	Hematocrit
Abernathy	21.7	1.28	14.8	115.1	31.9
Oregon Pellet	19.9	1.47	22.1	119.9	31.2

GROWTH OF PINK, CHUM, AND FALL CHINOOK SALMON IN HEATED SEA WATER

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Pink, chum, and fall chinook salmon were raised in sea water (35%) at four temperatures (50°, 55°, 60°, and 65°F). Water flows and oxygen levels (7.2 - 7.8 ppm) were controlled. Food conversion and food consumption rates were determined.

GROWTH

Growth rate was expressed as % gain in body weight/day. The relative growth rate of pink salmon in relation to temperature was according to the following temperature sequence: 60° 55° 65° 50° F. (see Table 1). In like manner, the relative growth rate of chum salmon was according to the following temperature sequence: 55° 60° 50° 65° F. The slow growth observed at 65° F was possibly due to the expenditure of energy for high temperature acclimation.

Chinook salmon growth was very slow at 50°F and a weight loss occurred at 55, 60 and 65°F. The chinook salmon were acclimated to sea water at an average weight of 14g. The expenditure of energy to maintain osmotic balance may partially account for the poor growth of chinook salmon. Elevation of water temperature above 50°F may impose an additional stress as evidenced by weight loss and high mortality. Chinook salmon raised at 50°F experienced low mortality, but they grew slowly.

FOOD CONVERSION AND FOOD CONSUMPTION RATES

For pink and chum salmon, the best food conversion (grams of food needed to produce a gram of fish flesh) occurred at the temperatures associated with the highest growth rates (see Table 1). Poor conversion at 65°F possible reflected the use of food energy for temperature acclimation. Food conversion and cunsumption rates were not examined at 50°F.

The food consumption rage (g consumed/100g of fish/day) increased as temperature increased for pink and chum salmon (see Table 1). As water temperature increases, the metabolic rate of the fish increases. The increase in food consumption rate was probably necessary, therefore, to meet the higher energy requirement of increased metabolism.

In the near future, pink, chum, and chinook salmon fry will be raised at temperatures ranging from 55° to 70°F.

Table 1. The growth rate, food conversion ratio, and food consumption rate of pink and chum salmon reared in sea water at four temperatures (50°, 55°, 60°, and 65°F).

Temperature (°F.)	Pink Salmon		
	Growth rate	Food conversion	Food consumption rate
50	1.26	----	----
55	1.65	2.32	3.12
60	1.78	1.80	3.21
65	1.59	2.63	3.37

	Chum Salmon		
	Growth rate	Food conversion	Food consumption rate
	1.26	----	----
	1.43	1.59	2.09
	1.27	1.88	2.18
	1.03	5.50	2.97

SMOLT CHARACTERISTICS DEPENDENT UPON WATER TEMPERATURE

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Steelhead trout reared at 6.5° or 10°C showed an increase during smolt season (mid-March through mid-June) of Na+, K+ stimulated Mg++ dependent ATPase from base level of 17 units (micromoles of ATP hydrolysed per hour per mg protein) to 32, or was increased nearly two-fold (slide 1 top). Fish from the same lot reared at 15° or 20°C did not show any indication of a rise in the activity of this enzyme during the same period. This suggests that the parr-smolt transformation will not occur for juvenile steelhead in water near 15°C or above. The data also indicates that the warmer the holding water, the lower the non-smolt activity will be.

The co-efficient of condition of the 6.5° and 10°C held fish was depressed during the months of April and May and most of June, whereas in neither the 15° nor the 20°C held fish was there any depression in this factor. Slide 1, bottom shows the results from the 6.5° and 20°C held fish.

Salt water survival tests also indicated that the smolt form is restricted to fish with increased Na+, K+-ATPase, which required a water temperature near 10°C or lower. In mid-smolt season when the ATPase acitivity was above 30 units, four fish were taken from each of the different temperatures and placed directly into full strength sea water at 12.5°C. All of those from the 6.5° and 10°C water survived, but only one from the 15° and none from the 20°C water survived longer than three days in sea water. After the ATPase activity returned to the non-smolt level (below 20 units) in fish held at 6.5°C another three tests were made involving 24 of these fish, none of which survived full strength sea water.

Our date indicates, however, that fish reared at 15°C could be transferred to colder water (preferably below 10°C) for six to eight weeks before the smolt season and would then make the transformation successfully. On the other hand, smolts transferred into warm water showed a rapid decrease of ATPase activity, suggesting a loss of sea water adaptability.

USING GILL ATPase ACTIVITY TO DETERMINE THE INFLUENCE OF PHOTOPERIOD ON PARR-SMOLT TRANSFORMATION IN STEELHEAD

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Previous studies have shown that sodium-potassium stimulated adenosinetriphosphatase (Na^+, K^+-ATPase or sodium pump) activity in gill microsomes of coho and spring chinook salmon, and steelhead trout, increases during transformation from parr to smolt. This appears to be a physiological adjustment which facilitates adaption to sea water, and measurement of the ATPase activity provides an excellent means of detecting the onset of parr-smolt transformation.

During this past year Dr. Harry Wagner of the Oregon State Game Commission generously provided us with an opportunity to study gill ATPase activities in steelhead held under a variety of artificially controlled photoperiod and temperature regimens. Previous experiments by Dr. Wagner had shown that accelerated or advanced photoperiods resulted in early physical signs of parr-smolt transformation. Decelerated photoperiods resulted in evidence of delayed transformation. These physical manifestations were supported by migratory movements of planted fish. ATPase measurements conducted during the winter and spring of 1971 confirmed the earlier observations.

The accompanying figure summarizes our findings. Four temperature and four photoperiod variations are indicated. Included tables show water temperature variations and the number of hours of daylight per day under each of the regimens.

The symbols are defined as follows:

SL = normal photoperiod
ADL = photoperiod advanced three months
AL = accelerated photoperiod
DL = decelerated photoperiod
NT = normal temperature
CT = constant temperature (12.2°C)
ADT = temperature cycle advanced three months
AT = accelerated temperature

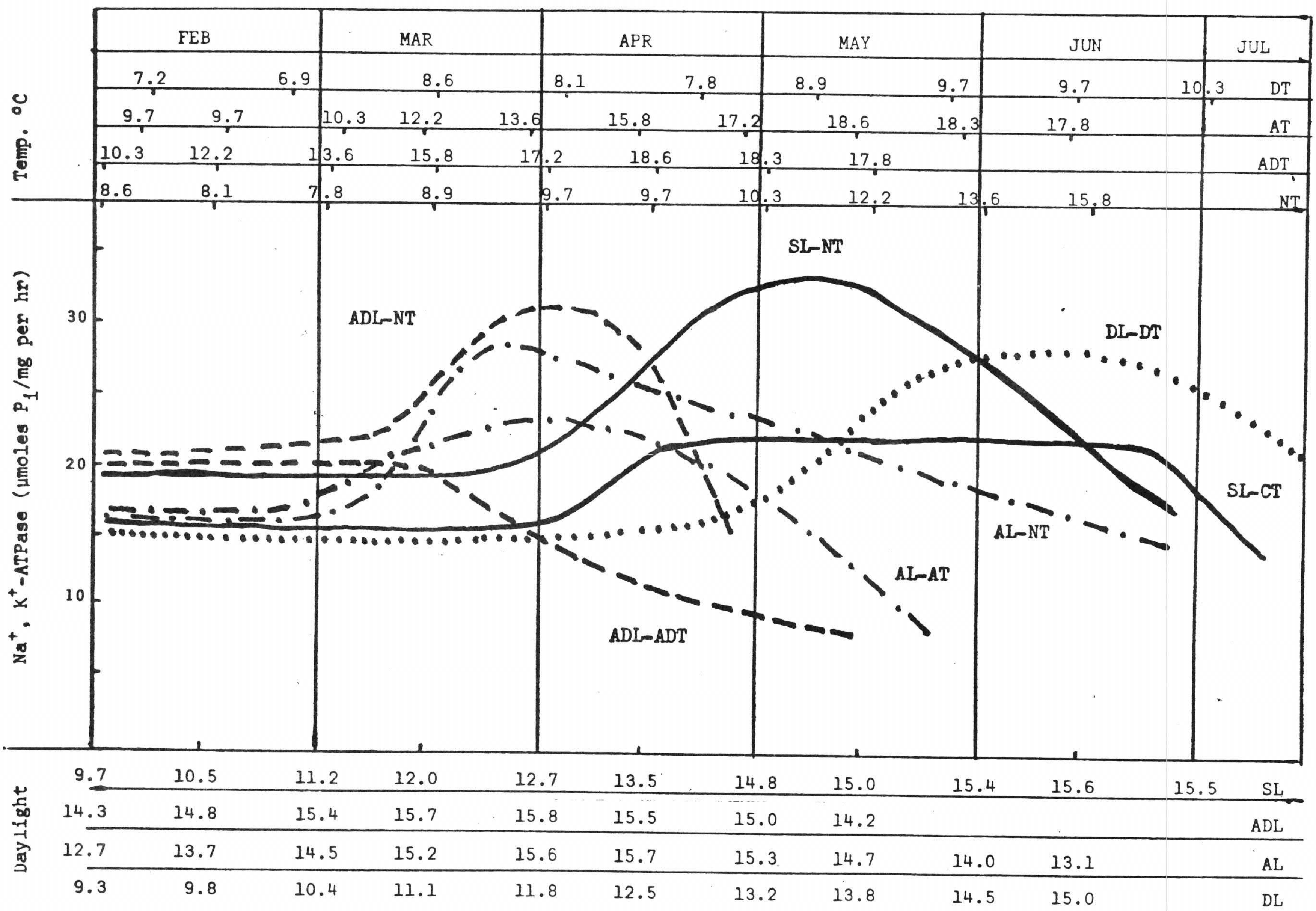
Sodium pump activity began to increase during the first of April in control steelhead under a normal photoperiod, normal temperature cycle (SL - NT), then showed a decline from mid-May through June. The onset of declining activity, or reversion to "parr" may have been initiated prematurely by increasing temperatures since other experiments on steelhead held at a constant 6.5 or $10^{o}C$ showed no decrease in activity until mid-June. ATPase activity in controls under normal photoperiod but constant temperature (SL - CT) increased at the same time as in the SL - NT controls but failed to reach the same level. There was no decline, however, until the latter part of June.

A three-month advance in photoperiod resulted in early development of elevated ATPase activity when normal temperatures were used (ADL - NT), whereas an advance in temperature cycle resulted in a drop in activity (ADL - ADT). High temperatures undoubtedly inhibited the developemnt of ATPase activity. Accelerated photoperiod also induced an early rise in activity (AL - NT and AL - AT) which again was influenced by temperature (AL - AT).

The decline in ATPase activity under advanced (ADL) and accelerated (AL) photoperiods with normal temperature cycle (NT) may have resulted from the influence of a daylength comparable to that which occurs at the summer solstice, June 22. Normal reversion of smolts occurs at this time of the year.

A delay in the elevation of ATPase activity resulted from decelerated photoperiod and temperature cycles (DL - DT).

Measurements of Na+, K+-stimulated ATPase activity indicate that parr-smolt transformation can be induced approximately one month early by accelerating or advancing the photoperiod. A one-month delay in transformation occurs under the influence of a decelerated photoperiod.



FEB
MAR
APR
MAY
JUN
JUL
7.2 6.9 8.6 8.1 7.8 8.9 9.7 9.7 10.3 DT
9.7 9.7 10.3 12.2 13.6 15.8 17.2 18.6 18.3 17.8 AT
10.3 12.2 13.6 15.8 17.2 18.6 18.3 17.8 ADT
8.6 8.1 7.8 8.9 9.7 9.7 10.3 12.2 13.6 15.8 NT
Temp. °C
Na+, K+-ATPase (µmoles P1/mg per hr)
30
20
10
SL-NT
ADL-NT
DL-DT
SL-CT
AL-NT
AL-AT
ADL-ADT
Daylight
9.7 10.5 11.2 12.0 12.7 13.5 14.8 15.0 15.4 15.6 15.5 SL
14.3 14.8 15.4 15.7 15.8 15.5 15.0 14.2 ADL
12.7 13.7 14.5 15.2 15.6 15.7 15.3 14.7 14.0 13.1 AL
9.3 9.8 10.4 11.1 11.8 12.5 13.2 13.8 14.5 15.0 DL

PARR-SMOLT TRANSFORMATION IN WINTER STEELHEAD TROUT AS AFFECTED BY PHOTOPERIOD AND TEMPERATURE

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From June 1967 through July 1971, five experiments were conducted to determine the relation of seasonal changes in photoperiod and temperature to parr-smolt transformation.

Smolting was assayed by examination of changes in migratory behavior, co-efficient of condition, thyroid activity, sea-water tolerance, and Na+ K+-stimulated gill ATPase activity.

Experimental photoperiods were of constant duration, or had an accelerated or decelerated rate of change (phase and frequency altered) or were advanced (phase altered only) in comparison to the natural photoperiod. Fish were reared under constant temperature (12.3°C) or variable temperature cycles. The simulated natural temperature cycle or variations of it ranged from 6.9 ot 18.6°C.

Photoperiod was the main environmental factor controlling the onset of transformation but did not determine whether or not the event occurred. Fish reared under an accelerated or advanced annual photoperiod were migratory earlier than control fish regardless of the temperature cycle. Those receiving a decelerated annual photoperiod had a delayed and extended migratory period.

The data suggests that the rate at which the length of the daily photoperiod increases is the information most utilized by the fish for synchronizing the metamorphic response, rather than length of the daily light or dark period per se or accumulated hours of exposure. Migratory behavior and smolt characteristics were observed in some fish under constant photoperiod and temperature regimes. Therefore transformation appears to have an endogenous mechanism.

Temperature had two measureable effects on smolting. Fish reared in a variable temperature cycle moved downstream in greater numbers and in fewer days than those reared at constant temperature (12.3°C), regardless of photoperiod. Temperature also influences the duration of the migratory period. For example, when the temperature cycle was out of phase but behind the photoperiod cycle, the migratory period was extended.

The results of this study have provided insight into the role of certain environmental factors in regulating the onset and duration of parr-smolt transformation in winter steelhead trout. Knowledge obtained from this study suggests that fishery managers can control, to a degree, the time of seaward migration of hatchery-reared stocks by photoperiod manipulation. The results also provide a basis for predicting changes in migration patterns where temperatures are held constant or are increased during the smolt period.

WINTER-RUN STEELHEAD TROUT RETURNS TO THE UNIVERSITY CF WASHINGTON

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The College of Fisheries, University of Washington, maintains a small winter steelhead run, which originated from the South Tacoma Hatchery, Washington State Department of Game, on Chambers Creek. Adult fish were transported to the campus and a portion of their eggs and sperm was used for hybridization experiments with our select rainbow stock. Others were used to produce steelhead trout migrants to establish the winter run of steelheads.

The fish used in this study were spawned during the early spring of 1968. They were reared in the hatchery and ponds until their release into Lake Union. The first plant of 6,083 on December 2, 1968, averaged 72.7 grams, or 6.2 fish per pound (Table 1). An additional 5,023 large fingerlings, which weighed an average of 102.3 grams, or 4.4 fish per pound, were released on December 20.

Steelhead fingerlings are usually released from hatcheries at a later date, but the limited salmon rearing facilities in the experimental hatchery at the College forced us to release the fish at an earlier date. The need to "sneak" the fish out to sea during the inclement winter weather also entered the decision for an early release. Lake Union is open to year-round fishing, so the migrants did not have the protection usually afforded hatchery releases. Prior to their release, all the young steelheads were marked with a cold-branded letter "S" on the left side, anterior to the dorsal fin and above the lateral line.

During the late winter and early spring of 1970, a total of 62 "S" branded two-year-old steelhead trout returned to the campus pond. The number included 61 males and 1 female "jack." They averaged about 2 pounds in weight, and provided a sport fishery along the route from salt water to the entrance of the pond.

An additional 166 adult "S" branded steelhead returned the following year in late winter and spring, 1971. The 63 adult males averaged 25.1 inches in length and 6.12 pounds in weight. The condition factor was 1.07 for the males. The 103 females, that were measured and weighed, averaged 24.8 inches and 6.06 pounds. The females were more robust than the males, with a condition factor of 1.11.

Fifty-nine of the females were spawned the eggs kept in separate trays so that size and number of eggs could be recorded for each female. The eggs averaged 174 per ounce, with the range from 163 to 193. The average production was 4,918, with the outstanding female producing 7,664 eggs.

The total return to the campus pond of 228 fish, or 2.05% of the smolts released, is not outstanding. However, it must be considered as a good return from a release in the center of a metropolitan area, where the juveniles and adults were subjected to an intense sport fishery on outmigration and return.

Table 1. 1968 brood year steelhead, University of Washington hatchery.

Releases

Date	Mark	Number	Average Weight (g)	Number per pound
1968				
Dec. 2	"S" left	6,083	72.7	6.2
20	"	5,023	102.3	4.4

Returns

Date	Sex	Mark	Fork length (cm) Mean	Fork length (cm) Range	Weight (g) Mean	Weight (g) Range	Weight (lb) Mean	Weight (lb) Range	Number return	Number return
1970	M	S-left	44.0	26.0-57.2	940	650-1,250	2.07	1.43-2.75	61	0.55
	F	S-left	44.0		850		1.87		1	0.01
									62	0.56
1971	M	S-left	63.5	52.8-70.4	2,780	1,650-3,980	6.12	3.63-8.77	63	0.57
	F	S-left	62.3	49.0-80.0	2,756	1,420-4,800	6.07	3.13-10.57	103	0.93
									166	1.50
							Total		228	2.05

WHIRLING DISEASE AT LAHONTAN NATIONAL FISH HATCHERY IN NEVADA

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Whirling disease caused by Myxosoma cerebralis, a myxosporidian protozoan, was first described in Europe in 1903. In 1956 the disease was first diagnosed in the United States at a Pennsylvania trout hatchery. The first record of it in Western United States was at a small private trout hatchery near Carmel, California, in January, 1966. In June of 1966 it was diagnosed in rainbow and cutthroat at Lahontan National Fish Hatchery, which is located 50 miles south of Reno.

The disease is named for the erratic, tail-chasing, whirling behavior in the infected fish. Infected young fish often have black tail, and spinal deformities and misshapen heads usually develop in some of the survivors. Mortalities may be insignificant, but can be severe in highly infected waters. The survivors of an outbreak may appear normal, but they likely carry the spores for the remainder of their lives. Upon death, the fish decompose and the spores are released to infect the waters.

Fish may become infected from the day they hatch until 8-10 months old, and possible older. Whirling disease has naturally infected rainbow, brook, brown and cutthroat trout. Coho and chinook salmon and lake trout have been infected experimentally. The exact mechanism of the fish becoming infected is not known. The immature stages of the parasite develope in the cartilage, primarily the head, of the young, infected fish. Approximately four months after the initial infection occurs, the mature spore can be found in the survivors. It is only after finding the spores that the definite whirling disease diagnosis can be made.

After the disease was found at the Lahontan hatchery in 1969, all fish on the station were buried. The rearing facilities were then thoroughly cleaned and disinfected with 800 p.p.m. cholorine. The source of the infection was assumed to be the Carson River, which had been used for rearing, and from which positive whirling disease fish were recovered. In May, 1970, rainbow and cutthroat eggs were brought into the station where they were incubated and reared on only well water. In November, 1970, the spores were again found in both groups of fish. The fish were buried and the facilities were disinfected with 1600 p.p.m. chlorine.

In May, 1971, an elaborate experiment was set up to determine the source of the second infection. The following possible sources of infection were considered:

1. Contamination through the wells.
2. Contamined lines from the wells to the hatchery.
3. Raceways or aeration tower infected by air borne source.
   - birds, mud-carrying insects, dust blowing, etc.
4. Seepage through raceway cracks.
5. Eggborne infection.
6. Contamination by personnel,-boots, equipment, etc.
7. Incomplete disinfection after the first outbreak.

Test tanks or live boxes were set up to bioassay the complete station to determine the source of the infection. Rainbow eggs were hatched at the various well and hatchery test sites and on the Carson River water. The eggs hatched on May 12, 1971, and to date the only positive whirling disease was found in the fish on river water. Spores were found there on November 9, which was almost six months after hatch. This indicates that the river water was not infective until July as the spores develope approximately four months after infection occurs. If the spores are not found in any of the other test units it will indicate that the wells are disease free this year, but we will not know what the source of last year's infection was.

PROGRESS IN THE STUDY OF ANTIBIOTIC EFFIACACY AND TERATOGENICITY IN ADULT CHINOOK SALMON (ONCORHYNCHUS TSCHAWYTSCHA)

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Washington Department of Fisheries
Cowlitz Salmon Hatchery Laboratory
Salkum Washington

Adult spring chinook salmon (*Oncorhynchus tschawytscha*) arrive at Cowlitz Salmon Hatchery in the spring and must be held 4-5 months until they become sexually mature in September. During this holding period these adults are attacked by bacterial kidney disease (*Corynebacterium sp.*) and furunculosis disease (*Aeromonas salmonicida*). A study on the control of these diseases was initiated in 1968. In this test adult spring chinook were injected subcutaneously with a mixture of penicillin G procaine, dihydrostreptomycin sulfate and oxytetracycline - HCl (PSO). Similar tests of PSO were conducted in 1969 and 1970.

PSO therapy increased adult survival as well as the production of viable eggs by these adults, but it also caused deformities among some of the progeny. Production of viable eggs was increased by 50% in 1968, 30% in 1969 and 240% in 1970. Deformities first occurred in the 1968 brood juveniles. In 15% of these fish the mandible and frequently the caudal and anal fins were deformed. By 1970 the incidence of deformities had been reduced, through the proper scheduling of the injections, to 3.6% in one lot and 0.1% in another lot.

Studies in 1969 and 1970 showed that the incidence of deformities was related to the length of the interval that occurs between the last PSO injection and the start of the spawning period. The lowest incidence of deformities was associated with the longest interval. In 1970 one of the lots receiving a sequence of three PSO injections had a 32 day interval between the last injection and the start of spawning. This lot had only 0.1% incidence of deformities. It also produced 3.5 times more viable eggs than were produced by the untreated control.

The occurrence of deformities was almost eliminated and juveniles produced by the treated adults had normal survival and growth rates; however, it is conceivable that PSO could cause other damage to the progeny that has not been detected. A mark - return study should be conducted to indicate whether juveniles produced by the treated and untreated adult lots have equivalent survival rates throughout their entire life cycle.

A subsequent study was conducted to determine which component in PSO is the teratogenic agent. This was attempted by injecting adult fall chinook salmon with injectable preparations of each antibiotic component as well as combinations of these components. These preparations frequently contained carriers and preservatives as well as the antibiotic. The penincillin G procaine preparations either alone or in combination with other antibiotics caused a high incidence of the typical mandible and fin anomolies. Dihydro-streptomycin sulfate and oxytetracycline - HCl did not produce these deformities. Although one of the components has been identified as the teratogenic agent, further tests will be conducted before altering the PSO formulation, to assure that a new formulation would provide adequate therapy without adverse effects.

Current recommendations for the use of PSO are: (1) PSO therapy should be used only in those cases where the need is essential; (2) the sequence of three PSO injections should be scheduled so that there is a 32 day interval between the last injection and the first day of spawning; (3) carcasses of PSO treated adults should not be used as human or animal food and (4) the total effect of PSO therapy on the progeny of the treated adults should be evaluated by adult mark - return studies.

Table 4. Antibiotic therapy, adult survival, egg mortality, viable eggs per original female and deformed fry. Adult spring chinook injected with PSO in 1968.

Lot	Number of injections	Percent adult survival	Percent egg mortality1/	Number viable eggs per original female	Percent deformed fingerlings
1	0	56	12.3	1,833	0
2	2 1/	66	-	-	-
3	3 1/	80	8.1	2,720	15

1/ Dead eggs were enumerated at about 30 days after fertilization.

STUDENT PROJECTS AS A SOURCE OF INTERESTING AND USEFUL INFORMATION

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Spearfish, South Dakota

Student projects are the source of much new and interesting information at the Spearfish Fisheries Center. Each student at the Bureau's Cold-Water In-Service Training School is required to carry out an investigative project. The basic purpose of the project is training, but they are selected such that the results should have application in fish husbandry. Several examples are shown below:

INVESTIGATORS	SUBJECT OF INVESTIGATION	FINDINGS
Herbert Rice	Pressure O_2 atmosphere for distribution tanks.	3.5 pounds of 7-inch rainbow trout per gallon of water were held in a static test of four hours with a pure O_2 atmosphere of 15 p.s.i.
Steve Leek Jack Manning Jim Hammer	Proximate analysis of four stream organisms: *Limnephilus Sp* (tricoptera), *Baetis Sp* (ephemeroptera), *Hydropsche Sp* (tricoptera), and *Simulium Sp* (diptera).	Dry wt. basis-Crude protein 42, 64, 44 and 56%. Lipid- 18, 25, 26, and 33%. Ash- 24, 13, 17, and 15%. K Cal per pound- 1907, 2390, 2400 and 2212.
Henn Gruenthal	Nature of surface water film retained by fish removed from water.	The weight of the water film varies as to the size of the fish and it is proportionally larger for the smaller fish.
James Lutey	Starvation of rainbow trout vs. overfeeding and subsequent weight gain.	Rainbow trout starved for 3 days and 7 days respectively, would catch up with controls when fed 150% of normal for 3 times starvation period. Proximate analysis indicated body composition similar to controls. Conversion and cost for 3 day trial equalled controls.

Harry Shaw	Various levels of trace-mineralized salt in the diet.	There was a steady increase in conversion from 1.36 with no supplementary salt 2.09 with 15% of the diet as salt. Growth rates were inversely proportional to salt levels.
Richard Ivarie	Vegetable protein as a replacement for herring meal in trout diets.	Replacement of 50% of the herring meal from diet PR4-70 with a 50-50 mixture of soybean oil meal and cotton-seed oil meal provided the best results.
Larry Sisk	Substituting bulk into trout diets to retard growth rate.	Ground whole oats and wheat bran were substituted into a control diet in place of protein and oil sources. Growth was reduced as much as 33% without apparent harmful effects.
Lawrence Wirtanen	Substituting bulk into trout diets to retard growth.	Wheat middling were substituted for protein sources. A 1% reduction in protein resulted in a 0.61% growth reduction.
John Shrable	Various protein levels in Rainbow Trout Diets.	Diets with protein levels from 23-51% were tested. A 1% increase in dietary protein produced a daily increase in growth of o.6% All factors considered, 43% appeared optimum.

THE POSSIBILITIES FOR CULTURING CRAYFISH

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Presented by: Robert Coykendall

When explaining our crayfish research project to visitors at our new facilities of the Department of Fisheries and Wildlife at Oregon State University, the question most often asked is why are we trying to develop culture methods for the Pacific Northwest crayfish, Genus Pacifistacus. The answer; to develop a more reliable commercial crayfish supply for existing and potential markets.

Historically, our crayfish was probably first marketed for use by early tavern owners as part of their free lunch cuisine. As that era came to its regretable end it was replaced by individuals and their families who continued to capture these miniature lobsters because they enjoyed both the recreation and eating.

Present marketing of crayfish locally is pitifully limited as very few, if any, reach our neighborhood grocers even during peak crayfish harvesting. Recently a significant export market for our crayfish has developed in the Scandinavian countries. They have, reportedly, offered to buy as much as 1,000 pounds per day from this region. This, without question, is beyond the productive capacity of our native local stocks.

How did this market come about? A crayfish disease, presumed to have been introduced into Europe over 100 years ago has decimated their natural crayfish populations from Norway to Siberia. This disease is so deadly to their own stocks that they have all but disappered in most of Europe. The western Scandinavian stocks have only recently begun to be affected by the disease. Since the people of these countries are such crayfish eaters, and our local crayfish so closely resembles their own species, they have been more than willing to purchase all that we can supply. It has been reported to us that our crayfish bring the United States equivalent of $6.00 per processed pound on their markets. This would give some indication of how they value crayfish. Hopefully, our own meager domestic consumption will be increased through vigorous promotional methods to the American housewife.

Commercial crayfishing has created unfortunate problems, however. Since this overseas market has been developed, local crayfishermen have, under the present scanty regulations, overharvested prime producing areas, thus cutting their own economic throats, so to speak. This probably wouldn't have happened if there had been some control over their harvest based upon sound biological knowledge.

Thus, the need for culture methods was seen. By supplementing the native catch with cheaply cultured crayfish, there would be a more stable supply for the market. With the understanding gained through successful cultural practices, native stocks could perhaps be manipulated for the better natural production. With all these problems in mind, our research program, funded through the Sea Grant Aquaculture program, was initiated in September 1970.

Unfortunately, very little information can be found by searching the literature. Present culture methodology for crayfish consits of stocking and trapping a Gulf coast crayfish species in flooded agricultural land. The last year, therefore, was spent accumulating as much basic information as possible about the biology of our crayfish by actually working with the animals under a variety of conditions. My specific graduate research is to investigate the basic parameters needed for the successful commerical rearing of Pacifistacus crayfish.

My experimental design, now in operation, is concerned with the measurement of growth, survival, and the molting characteristics of two age classes of crayfish under fresh and brackish water conditions, incorporating three temperature regimes (12, 16, and 20°C) and two widely differing diets. One diet is rabbit pellets (the rabbit food variety) and the other, marine euphausiids. The latter is a small shrimp-like animal that crayfish relish greatly most likely because of their cannibalistic nature.

Final results of our growth experimants are not available as they are still in progress. However, we can say that crayfish of the year are widely adaptable to various water conditions and temperature regimes. They survive and grow in salinities of 8 parts per thousand. Molting frequency and growth are stimulated by temperature increases up to 20°C and there is indication they may do well at even higher temperatures. Post-yearling crayfish, in our experiments, have not benefited from these same types of stimuli as we had hoped they would and seem to be much slower growing under all three temperatures.

We are hopeful that Pacifistacus will adapt itself to inexpensive culture methods. Brackish water coolant ponds at nuclear power plants may be well suited to intensive crayfish culture activities. We have found, as a result of earlier experiments conducted last year, several specific problems that must be solved before we can successfully culture these animals. The development of a brood stock to provide a continous supply of young will be necessary. Thus far we have formulated roughly the necessities of a hatchery operation and the holding facilities required for the rearing and breeding of adult animals.

Cannibalism is another difficulty that has arisen in the rearing of the young hatchlings. A 'clumping' phenomenon occurs shortly after the young leave the mother that results in aggressive contacts that will reduce large numbers of young to a few survivors. Current flow, substrate preference, shelter formation, and dietary experiments may help to solve these problems of aggressiveness and overt cannibalism.

As can be seen by the aforementioned problems, continuing research will be required in order that a workable crayfish culture program can be fully developed.

PRELIMINARY STUDIES USING SYNTHETIC POLYMERS TO REDUCE TURBIDITY IN A HATCHERY WATER SUPPLY

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Water supplying the Alchesay National Fish Hatchery in Arizona flows extremely turbid during certain periods of the year. This paper reports on preliminary testing using anionic and cationic synthetic polymers for clarifying water during actual storm conditions. Instruments recorded turbidity levels of water diverted from the main hatchery supply and furnished to three test groups of rainbow trout (Salmo gairdneri); one untreated and two treated flows were monitored. Polymer was automatically metered into the water when muddy conditions reached 70 Jackson Turbidity Units (J.T.U.) or higher; the level at which fish stopped feeding. Over 1,000 hours of turbidity occurred during 1971 where treatment of water was necessary. It was shown that heavy silt loads could be removed and normal fish cultural activities resumed without interruption. Turbidities approaching 7,000 J.T.U. were reduced to below 35 with no adverse effects on the fish.

The Alchesay-Williams Creek National Fish Hatchery is operated by the Bureau of Sport Fisheries and Wildlife of the U.S. Department of Interior. The Alchesay Unit of this two hatchery complex is located on the North Fork of White River eight miles north of Whiteriver, Arizona, Alchesay Spring, primarily a natural underground aqueduct of the White River, can supply up to 9,000 gpm water flow to hatchery operations. Turbid water caused by runoff in the upper watershed is thus channeled through the hillside and into the rearing facilities. It is this occasional turbidity which causes considerable problems in the hatchery.

Fish cultural operations at Alchesay have shown that when turbidity (measured with a Hellige Turbidimeter) reaches 70 Jackson Turbidity Units (J.T.U.) or greater the fish's feeding activity drops sharply. They are unable to see feed thrown into the water under these conditions and feeding stops. Under normal conditions the feed conversion ratio (lb. of feed fed/lb. of weight gain) approaches one. However, when water is turbid the conversion ratio increases and 2.5 or more pounds of feed may be required for each pound of fish produced.

Many man-hours have been spent since hatchery operation began in 1963 on cleaning raceways and ponds of silt. A single storm may deposit as much as two or three inches on raceway floor. Removal of silt before reaching production facilities would be invaluable in terms of increased production and reduce labor and operating costs.

A model water clarification system was tested at Alchesay using synthetic polymers to flocculate suspended materials from the water. Dow Chemical Company U.S.A., was issued a contract to design and maintain this system. Although initially planned as a one-year study it was extended to the second year so that a more detailed study might be made. This paper is a summary of those two years.

METHODS

To support a pilot study the hatchery holding house was chosen for the experiment. The building holds 12 concrete tanks; each 12 feet long. 2.5 feet wide and three feet deep. A 25 gallon per minute water flow is available to each tank from the main hatchery supply.

Water treated with synthetic polymer must have a settling basin for the flocculant formed by the process. This was achieved by extending the sides of four hatchery tanks with plywood to make them six feet deep. Plumbing was arranged so that water could be diverted through one clarifier, two clarifiers in parallel, or two clarifiers in series. Water was gravity fed from the settling basins into the tanks of fish. The system was designed so that three separate water environments were tested. Each treatment contained two tanks of fish. Those treated with polymer had two clarifiers for settling purposes. Tanks used as controls (untreated water) did not have clarifiers but silt removal from untreated water flowing through the settling basin was shown to be minimal.

Water for the control tanks was taken directly from the main hatchery supply, whereas, water for the treated tanks was diverted through separate lines to facilitate polymer mixing. Polymers need sufficient time to mix with turbid water to obtain good flocculation and clarification. To achieve complete mixing the following system was constructed. Two inch plastic lines from the main supply were adjusted to a flow of 50 gpm each. Water then flowed into funnels where the polymer was added. The combination of polymer and water flash mixed in two 3-inch plastic lines for 120 feet before gentle mixing in 200 feet of six-inch corrugated aluminum pipes. This entire process was designed for six minutes of resident mixing time prior to the water reaching the clarifiers.

Polymer, in concentrated form, was prepared for dispensing by mixing with water in four 55 gallon drums (two for each set of clarifiers). One drum would supply 24 hours running time at the desired polymer concentration. Pumping was achieved by use of two Masterflex Tubing Pumps (Cole-Parmer Co.), while the flow rate was adjusted by use of Predictability Flowmeters (Manostat Corp.). Automatic controls were installed to start and stop pumping operations. Two Hach Surface Scatter Turbidimeters were used to monitor water turbidity. These were in turn connected to two chart recorders that contained switches to turn the polymer pumps on or off. One turbidimeter monitored control water only. The second turbidimeter was connected to all three test units and monitored each unit's turbidity in the course of a 40-minute cycle. Recorders operated with interlocks so that both had to agree when excess turbidity was encountered before polymer was dispensed. One recorder falling below prescribed limits could turn the system off. This safety interlock prevented the possibility of a cationic polymer being dispensed in clear water. Cationic polymers may be harmful to fish in the absence of suspended particles (Watershed Research Group, Dow Chemical Company, personal communication).

Initial tests were conducted to determine the most suitable polymer for Alchesay water and to determine its effects, if any, on growth and condition of fish. Four polymers, products of Dow Chemical Company and supplied by them, were tested: Separan MGL,(R) non-ionic; Separan AP-30,(R) and Purifloc A-23,(R) anionic; and Purifloc C-31,(R) cationic.

Studies conducted in 1970 determined difference between cationic Purifloc C-31 and other polymers tested. Tests during 1971 used anionic Purifloc A-23 as a standard. All systems remained the same in the second year studies with these exceptions:

1. Purifloc A-23 dispensed at 0.5 ppm was selected as the treated control to be used throughout the test period for comparison with other polymers.
2. An adjustable bottom was installed in one set of clarifiers to determine the effect of depth on clarifier efficiency.
3. Weirs at clarifier outlets were modified to increase water stability.

Rainbow trout were moved into the tanks prior to flocculant testing. During 1970 these fish were allowed to reach a maximum of 100 pounds per tank before thinning. Control tanks on untreated water were fed regardless of turbidity. The 1971 study was changed using a loading factor (0.4 times length of fish times gallon per minute water flow) to standardize the metabolic rate in each tank. Tanks were taken off feed when turbidity reached 70 J.T.U. or higher. This point was determined from recent years of recorded turbidity data indicating the level at which production fish went off feed.

RESULTS

Physical Aspects

Results of tests conducted in 1970 were very encouraging. Polymer dispensing equipment operated for over 375 hours during the year. Maximum turbidity reached 2,920 J.T.U. The longest single treatment for one storm was 65 hours.

(R) Registered trade mark

Preliminary tests of the four polymers revealed that Separan MGL and Separan AP-30 did not clarify water as well as others. These were later discontinued and more extensive testing was done using Purifloc A-23 and Purifloc C-31. Regardless of turbidity, C-31 would normally settle out all but 20-40 J.T.U. It appeared to work better on higher turbidity ranges and decrease in effectiveness as lower ranges were encountered. This cannot be stated in all cases as synthetic polymers were found to react differently to individual storms or to various parts of the same storm. The extensive watershed above Alchesay hatchery has a variety of material which contributes turbidity when runoff causes erosion on particular sections of the stream. Several colors may be encountered in a single storm and distinct layers can be seen upon examination of flocculated mud. Nature of the suspended material determines the effectiveness of each polymer. Anionic polymer reacted in a reverse fashion to the cationic C-31. Purifloc A-23 did well on low turbidities and its effectiveness appeared to decline as high suspended matter concentrations were reached.

A second year study was added to provide further data on polymer use. Procedures for collecting and recording of data were revised to give better results. Additional changes in equipment design were made to enhance data collection and further experimentation. Heavy rainfall during late July, August and early September gave ideal conditions for extensive testing.

In July 1971, 7750 fish at 32.4 per pound were divided among six tanks. Water flow into the two untreated "C" tanks was adjusted at 20-25 gpm each to match the flow in "A" and "B" tanks. Equipment and concentrations were adjusted to dispense 0.5 ppm of the anionic polymer, Purifloc A-23, into the treated "B" tanks. Depth of the clarifier remained at six feet to allow 1300 gallons storage capacity. Detention time for settling the treated suspended material was approximately 26 minutes for a 50 gpm flow. This method was maintained throughout all tests as a control on "A" treatment. Treated "A" tanks were designed to test various combinations of flow pattern, water depth, baffle placement and polymer concentration. Varying the water depth in clarifiers adjoining "A" tanks allowed 15 minutes detention at 3.25 foot depth and 10 minutes at 2.4 feet for a 50 gpm water flow. When using two clarifiers in series the settling times were increased to 30 minutes and 20. A storm by storm account of turbidity, although desired, was not achieved. High turbidity levels throughout August required that equipment operate constantly. Various tests were run whenever good stopping-starting points could be determined. The following is a breakdown of tests and resulting turbidities between treated tanks "A" and "B" and untreated water in "C". Average turbidities were obtained from the recorders at three hour intervals.

Date		Average Turbidity In Tanks "A"	"B"	"C"
7/20-22	A-23 polymer dispensed @ 0.5 ppm. Water depth @ 3.25' using single clarifier	20	20	114
7/22-8/2	A-23 polymer dispensed @ 0.25 ppm. Water depth @ 3.25' using single clarifier	26	29	236
8/2-10	A-23 polymer dispensed @ 0.25 ppm. Water depth @ 2.4' using single clarifier	29	27	257
8/10-13	C-31 polymer dispensed @ 5.0 ppm. Water depth @ 2.4' using single clarifier	30	30	905
8/13-24	A-23 polymer dispensed @ 0.5 ppm. Water depth @2.4' using single clarifier	15	13	241
8/24-9/5	A-23 polymer dispensed @ 0.5 ppm. Water depth @ 3.25' using single clarifier	14	12	154
9/5-6	A-23 polymer dispensed @ 0.25 ppm. Water depth @ 2.4' Water flow through two clarifiers in series	10	11	74
9/6-11	A-23 polymer dispensed @ 0.125 ppm. Water depth @ 2.4'. Water flow through two clarifiers in series	14	15	74
9/11-13	A-23 polymer dispensed @ 0.25 ppm. Water depth @ 2.4' Water flow through two clarifiers in series	13	12	58

Average turbidities from "A" and "B" tanks showed little differences by changing polymer concentration, water depth, and flow pattern. A-23 dispensed at 0.25 ppm worked as well as A-23 at 0.5 ppm. Although A-23 at 0.125 ppm gave good results on 74 J.T.U. it is doubtful higher turbidities could be reduced as well. The application of A-23 at a recommended level of 0.5 ppm gave better rsults than C-31 polymer at 5.0 ppm recommended treatment. Lower turbidities during the latter part of 1971 were attributed to improved techniques in polymer preparation.

Synthetic polymers are made of extremely long chains of molecules. These chains are responsible for the conglomerate known as floc. The longer the chain the better the floc. Throughout 1970 and early studies in 1971, polymer was prepared by adding a predetermined amount to the 55 gallon barrel of water and stirring with a mechanical mixer for periods of an hour or more. According to Dow Chemical consultants the polymer was being sheared (i.e. breaking the long chains into shorter, less effective ones). By using a special dispensing devise and avoiding long periods of stirring, station personnel were able to prepare a better polymer concentrate and lower the turbidity in treated water.

Turbidities recorded during July, August and September are averaged and comparable results between "A", "B" and "C" groups shown (table 3). The highest recorded turbidity was 7,000 J.T.U. in August 1971. Pumping equipment operated in excess of 1,050 hours during the three months of testing with 714 hours recorded in August when turbidity continued to exceed 70 J.T.U.

Polymer was prepared in highly concentrated form and added to the total water supply from Alchesay Spring to determine the effects a treatment would have on high volume flows. The main pipeline with its own sedimentation basin was used for mixing and settling. The first application was for short duration and results were inconclusive. The second and third applications consisted of several hours flocculation time and results were encouraging. Purifloc A-23 at 0.5 ppm was added to 3,000 gpm flow at Alchesay Spring when turbidity measured 1,800 J.T.U. Within 50 minutes turbidity of inflowing water at the sediment basin was 15 J.T.U. and showed well formed floc which settled out immediately. Water in production facilities began to clear even though residual turbidity made the progress slow. Later, Purifloc C-31 at 5.0 ppm was added to the spring flow when turbidity was 2,300 J.T.U. Success was limited and turbidity was reduced to only 680 J.T.U. at the control tanks. Addition of 10.0 ppm Purifloc C-31 did not improve results. As previously mentioned, polymers react differently to different types of parent material. This particular storm encountered was not greatly affected by polymer. Similar situations have been experienced with other storms although they were of short duration and did not present a problem. Turbidities were much lower, averaging 140 J.T.U., when a treatment using both Purifloc A-23 @ 0.25 ppm and Purifloc C-31 @ 2.5 ppm was tried with success. The lowest turbidity was 8 J.T.U. in the sedimentation basin. Earlier in the day 0.5 ppm Purifloc A-23 was used alone and depressed turbidity to only 31 J.T.U. Dual treatment appears to be a distinct possiblility especially when storms are nonamenable to one polymer.

Table 3. Average turbidities during July, August and September 1971 at three hour intervals when control exceeded 50 J.T.U.

Test Tanks	7/20-31/71	8/1-31/71	9/1-13/71
"A" Treated Testing	23	19	11
"B" Treated Control	25	18	12
"C" Untreated Control	190	319	80

Biological Aspects

Effects of polymer treated water versus effects of untreated turbid water were of main concern throughout the study. Test fish were closely watched to determine any biological differences that might arise between the three groups.

Gill damage from abrasion by suspended particles in water was confirmed for the first year studies by the Fish Cultural Development Center, Bozeman, Montana. Gills were examined from fish before, during and after the rainy season. Results showed that fish held in water treated with Purifloc C-31 and Purifloc A-23 had healthier gills than those fish subjected to untreated water. Purifloc A-23 appeared to be the better of the two polymers from comparison of gill damage. Gill samples from this year's studies have been forwarded to the Development Center at Bozeman and results are pending examination.

Growth rates of test fish were closely watched. Since hatchery production experienced a sharp drop in feeding activity during periods of high turbidity, it was anticipated that a similar situation would occur in test facilities. Conversion ratios in 1970, however, remained about the same for all three groups which may have indicated that confinement in aquarium-like conditions allowed for feeding though fish in outside facilities went off feed. Feeding trials in 1971 were changed to conform closely to the outside production units. Fish in "A" and "B" (treated) groups appeared in excellent condition. They were healthy and agressive feeders throughout the study. Fish in "c" tanks (untreated) were noticeably smaller and in poor condition by the end of August.

DISCUSSION

The extensive watershed above Alchesay is typical of terrain found in southwestern United States above 5,000 feet elevation. Alghough heavily wooded, the ground cover is generally sparce. Extended periods of drought and occasional heavy rains are condusive to soil erosion. Portions of the area have been clear cut by logging operations which increases the amount of top soil washed into the drainage.

Management plans are disrupted, planting schedules delayed and production costs increase when muddy water is received. Loss of 0.754 inches growth during a two month period can effect overall hatchery planning and take months to correct. Mortalities in production units to IPN virus in 1971 precluded plans to calculate lost weight during the muddy season. Weight gain in treated tanks and weight loss in untreated tanks were projected and applied to normal hatchery production for August. Considering all things equal between test fish and hatchery production, hatchery loss would have been 9,200 pounds for the month. The gain for this same period would have been 15,000 pounds assuming a full scale treatment plant had been in operation.

Accumulated mud in "A" and "B" settling basins was studied to determine the extent of suspended solids that came into production facilities during a one week period in August 1971. Dow Chemical researches calculated that 6,600 cubic feet of sediment entered the hatchery. Not all this material settled out in raceways and ponds but liberal quantities remained to be removed from the hatchery. Mud samples, taken at different locations within the settling basins, indicated that nearly 45% was less than four microns in size as measured by Dow Chemical personnel. Considering the silty-clay classification and the amount of suspended material entering water, it must be assumed that chemical flocculation, as opposed to mechanical removal of turbidity, is the most efficient and economical approach to the problem. Aside from any effect (physical or biological) high turbidity and heavy silt may have on fish, the aesthetic value of clean water to hatchery operation would be invaluable.

Cost of treating the entire hatchery supply, based on 1971's study, has been calculated and projected for a maximum 9,000 gpm water flow. Assuming treatment of 1,050 hours using Purifloc A-23 at 0.25 ppm, the cost for the polymer would be approximately $2,500.00. Plans for a full scale treatment plant have been drawn up by Dow Chemical consultants. By utilizing existing water lines and constructing a large settling basin ahead of the production facilities, a treatment system for the total water flow can be placed into operation without major changes in hatchery design.

SUMMARY

It has been demonstrated through a pilot treatment system that synthetic polymers worked effectively on reducing turbidity in the hatchery water supply. Two years of monitoring the water and recording turbidity levels of treated and untreated flows were completed. Growth differences between test fish were measured as well as histological changes in gill structure. No adverse effects were noted in fish reared within treated water while those raised in untreated water of high turbidity lost weight, showed gill damages and appeared inactive throughout the study. A full scale treatment plant using synthetic polymers to reduce turbidity has been designed for use on the main water supply. A change in water quality as a result of less turbidity would allow the hatchery to operate on a daily feeding schedule without interruption and provide a more efficient operation in terms of production, man power utilization and total costs.

Figure 4 - Diagram of model water clarification system

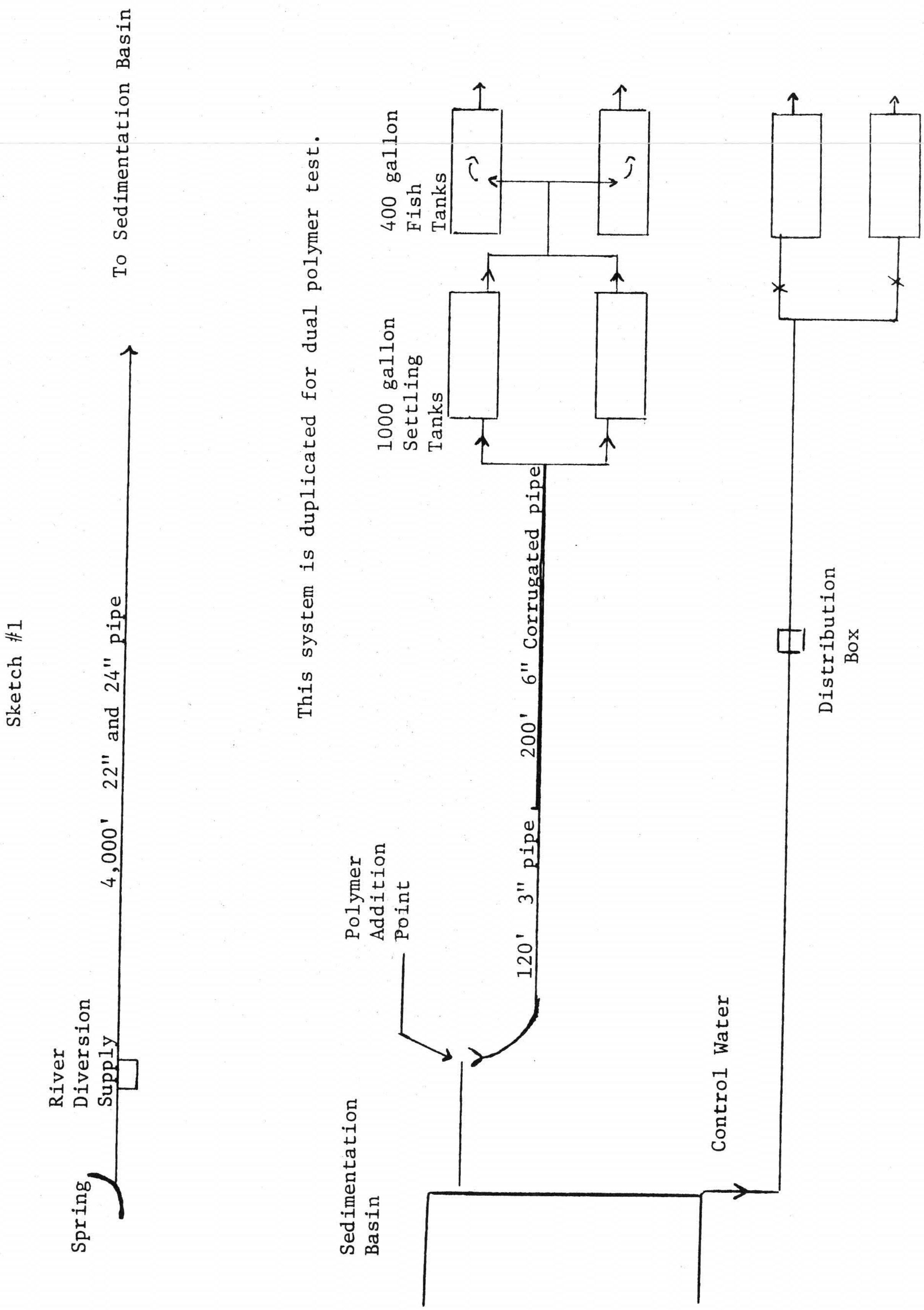

Table 4. Growth data of rainbow trout in experimantal tanks for the period of July 22 to September 30, 1971.

July 22, 1971

Beginning number of fish in each test group:
2,592 @ 32.4 per pound weighing 80 pounds.

August 31, 1971

Fish weighed and production calculated for past month.

Tanks	Food Fed (lbs.)	Gain in Weight (lbs.)	Length Increase (in.)	Number per lb.
"A"	60	29.9	0.504	21.7
"B"	60	32.5	0.667	20.9
"C"	16	-18.3	0.000	40.0

September 1, 1971

Excess fish were removed from "A" and "B" tanks to reduce weight to 40 pounds each tank or 80 pounds per group.

September 30, 1971

Fish were inventoried and production calculated for past month.

Tanks	Food Fed (lbs.)	Gain in Weight (lbs.)	Length Increase (in.)	Number per lb.
"A"	58	28.6	0.530	15.9
"B"	58	31.0	0.585	14.9
"C"	46	34.3	0.389	24.9

Growth Summary

Tanks	Food Fed (lbs.)	Gain in Weight (lbs.)	Length Increase (in.)
"A" & "B" (treated)	236	122	1.143
"C" (untreated)	62	16	0.389

ACKNOWLEDGMENTS

Acknowledgement is extended to Dow Chemical Company for their cooperation in this study; also, to the Fish Cultural Development Center, at Bozeman, Montana for their histological examination of gill samples.

ASCORBATE IN RAINBOW TROUT

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Recent studies have shown that ascorbic acid is an essential nutrient for juvenile rainbow trout, coho salmon, carp and guppies (Bull. Japan. Soc. Sci. Fish. 31:818, 1965; Trans. Amer. Fish. Soc. 98:762, 1969). However, little is known about the metabolism of ascorbate in fish. Ascorbic acid ^{14}C-1 and ^{3}H-4 were intubated in a single dose into 400 g rainbow trout catheterized and confined in metabolism chambers. Total urinary, branchial and fecal wastes were collected for 72 hours post insult. Approximately 0.3% of ingested dose was eliminated in the feces, 0.8% via the gills and nearly 3% in the urine. Raw urine samples revealed no free ascorbic acid or reduced ascorbate. Urinary metabolites were fractionated with lead acetate at pH 4 and pH 8. Nearly half of radioactivity remained in soluable fraction. Co-chromatography of the soluable fraction showed the major component migrated identical with ascorbate-3-sulfate.

Radioautograms prepared from sagittal sections of the fish revealed high concentrations of material in the liver, skin, gill support cartilage with a $^{14}C/^{3}H$ ratio identical to the intubated dose. Fractionation of the liver tissue revealed that three-fourths of the labeled material was present in the soluable fraction. Co-chromatography and subsequent radioautography showed that 90-95% of this fraction was ascorbate-3-sulfate.

VITAMIN C_3 FOR FISH

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Trout and salmon require vitamin C for normal growth and development. Dietary deficiency results in lordosis, scoliosis; impaired collagen, cartilage and bone formation; and in death. Intubation of labeled L-ascorbic acid (C_1) results in tissue fixation of active material wherever collagen, cartilage and bone formation occurs, but only 3-5% of intubated dose is excreted.

Co-chromatography of excreted material indicates most is eliminated as ascorbate-3-sulfate. This stable metabolite is designated vitamin C_3.

Vitamin C deficient rainbow trout and coho salmon were fed vitamin C_3 as sole source of ascorbate to attempt reduction of deficiency symptoms. After four weeks on test, C_3 fed fish had no further symptoms of deficiency and were beginning to grow again; whereas, fish continued on low ascorbate diets became worse and many died. After 12 weeks on treatment, C_3 fed fish were growing and no new deficiency symptoms had appeared. Terminal assay of blood and tissues disclosed no indication of acute toxicity from ascorbate-3-sulfate feeding. Vitamin C_3 appears biologically active and reduced vitamin C deficiency symptoms in both rainbow trout and coho salmon.

This compound is chemically stable to mild heat, to ultraviolet radiation, and to atmospheric oxidation, in direct contrast to L-ascorbic acid; thereby offering several advantages to fish diet formulation and feed storage stability.

CHINOOK SALMON PEN-REARING PROJECT IN PUGET SOUND

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Chinook salmon, Oncorhynchus tshawytscha (Walbaum), are currently being raised in floating pens in Puget Sound. Four 8-ft x 8-ft x 8-ft 1/4 inch mesh nylon pens are suspended from a wooden frame. The wooden frame measures 20 ft x 20 ft inside diameter and 26 ft x 26 ft outside diameter, and has eight sections bolted together. It is kept afloat by styrofoam bars.

The water at one site (Pond 4 at the Big Beef Creek Research Station) is slightly brackish. Generally, salinities in the pens are less than 0.5 o/oo, but on flood tides, they may reach 2 or 3 o/oo at the surface and 9 or 10 o/oo at the bottom (approximately a depth of 2 meters). The other sites are entirely marine. At Squaxin Island, in southern Puget Sound, salinities have ranged from 28 to 29 o/oo between July and November 1971. At Manchester, at the R/V Brown Bear on Clam Bay, salinities have ranged from 27 to 30.9 o/oo. At Kiket Island, near LaConner, salinities were from 19 to 30 o/oo between July and October 1971. The large fluctuation at the last site was due to tidal action and the influence of the nearby Skagit River. Other hydrological data have been taken.

Over 40,000 chinook salmon were obtained from the Hoodsport Hatchery of the Washington State Department of Fisheries in early June 1971. They were transported to Big Beef Creek Pond 4. The remained at this site until the first week in July. The fish were divided into four groups of approximately 10,000 fish each and marked by embedding a color-coded wire tag in the head and clipping the adipose fin. While at Big Beef Creek, a Vibrio outbreak between June 14 and 27 killed 5,499 (13.7%) of the fish. Before improvements were made on the pens, approximately 3,300 fish escaped into Pond 4. Some of these remained in the pond, but many migrated down Big Beef Creek to the sea.

During the first week in July, three of the four groups of fish were transported to the Kiket Island, Manchester, and Squaxin Island sites. The fourth group remained at Big Beef Creek. Of the original 40,000 fish, 30,000 remained for rearing at the four sites, and as of October 12, the survival was 95%.

The fish averaged 5.4 g (80/lb) when brought from Hoodsport Hatchery on June 3. On July 6, at the time of the transfer, the average size was 12.4 g (37/lb). In the interim, the fish were not fed a standard amount as the exact population numbers in the pens were not known. Since the transfer on July 6, growth rate has varied depending on the site. The fish at Kiket Island showed the greatest growth through August, but between August and November, the fish at Big Beef Creek have surpassed them. As of October 12, the Kiket fish averaged 75.8 g (6/lb) and the Big Beef fish averaged 79.8 g (6/lb). Squaxin Island fish averaged 57.7 g on September 25, but were of the same size as those at Kiket by mid-October. The Manchester fish have grown at a lower rate than those at the other sites. As of October 6, they averaged 65.2 g (7/lb). Growth per week has increased from 1.2 g/week to 8.2 g/week at Manchester, but from 3.9 g/week to 9.6 g/week at Kiket and Big Beef Creek. Until late September, growth among Squaxin fish averaged only between 3.8 and 5.4 g/week. Rough weather and logistical difficulties have hampered recent sampling.

Since late October, growth rates at all sites have decreased. In early November, Big Beef fish averaged slightly over 100 g, while Squaxin fish averaged slightly under 100 g (4.5/lb.). Manchester fish have continued to grow at a lower rate. As of October 31, fish at Manchester averaged 81 g (5.6/lb). One of the four pens at Kiket Island was broken apart during a storm the night of October 13. Approximately 1,892 fish escaped. Only three pens of fish were reared until October 26. Storms the nights of October 26 and 27 made the remaining three pens unusuable. An estimated 7,406 fish were released from the four pens during the two storms. As a result, the Kiket site is now no longer in operation.

The fish have been kept on a diet of Oregon Moist Pellets throughout their pen-rearing life. After the fish had been moved and counted in early July, they were fed at 3% of the body weight. The feeding rate was established weekly on the basis of growth rate data from bi-weekly sampling. The feeding percentage was increased to 3-1/2% on August 6, and to 4% on September 4. Fish at several sites failed to consume all food as winter months approached, so the feeding percentage was decreased to 3-1/2% on September 27, to 3% on November 1, and to 2-1/2% on November 22. A feeding percentage of 3-1/2% appears to be optimum for late summer and early fall. A higher rate might be advisable for early summer. Conversion rates have averaged approximately 1.7 at all the marine sites, and 2.1 at Big Beef Creek. The role of supplemental food at the marine sites is not known.

Prevention and control of *Vibrio* appears to be important to the further success of this and any other salmonid pen-rearing projects. *Vibrio* outbreaks may occur at virtually any time, not just summer. The latest significant outbreak occurred from October 9 to 11 at Kiket Island, Manchester, and Big Beef Creek. At Kiket Island, 140 fish died. Water temperatures at the sites were down to 9.9 C, and circulation seemed adequate, so warm water and limited circulation apparently are not the only predisposing conditions for the disease. Individual deaths attributable to Vibrio have been noticed at Big Beef Creek and Manchester well into November.

Myxobacterial infections, primarily of caudal fins, have also been a problem. Infection, resulting in complete degeneration of the caudal fins, has been responsible for a number of deaths. The problem is particularly bad at Squaxin Island, but myxobacterial infections of the caudal fins are relatively common at all the other sites.

Many agencies and organizations are co-operating in this project. Financial support is provided principally under the Sea Grant Act (Project R/A-2), and supplementally by Seattle City Light and Snohomish County P.U.D. The Washington State Department of Fisheries contributed the chinook salmon fingerlings. The reared salmon will be released at each of the remaining three sites in mid-January 1972 to become part of the State's sport fishery tag-and-recapture program in Puget Sound. The Small Tribes Organization of Western Washington (STOWW) has provided rearing pens as well as fish food and fish feeders at Squaxin Island. Biologists at the National Marine Fisheries Service vessel R/V Brown Bear have made the benefits of their research, as well as their services, available to project personnel.

On April 5, 1971, 583 chinook salmon reared in pens at Manchester for approximately 8 months and weighing approximately 1/2 lb (263 grams) at sampling on March 15, were released after being tagged with a Carlin-type tag. The summary of tag returns in the following six months is given.

March to November 1971

Point of Release	Number Released
Manchester (central Puget Sound)	583
Case Inlet (southern Puget Sound)	202
Total	785

Area of Return	Manchester	Case Inlet	Combined
Southern Puget Sound	5	13	
Central Puget Sound	34	4	
Northern Puget Sound	10	0	
Hood Canal	1	0	
Strait of Juan de Fuca	2	1	
Unknown	2	0	
Totals	54	18	72
% Return	9.26%	8.91%	9.17%

STEELHEAD REARING IN LAKE QUINAULT

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In the spring of 1971 the Quinault Indian Tribe initiated a prototype fish rearing program funded by the Office of Economic Opportunity. The objectives of the program are:

1) develop inexpensive fish rearing facilities to augment the natural runs of salmon and/or steelhead on the Quinault Indian Reservation
2) initiate interest in fish rearing
3) train interested persons in rearing techniques.

Because of the high value of steelhead trout to the Indian commercial fishery and Indian guide sport fishery steelhead were selected for rearing.

With the assistance of Bureau of Sport fish and Wildlife floating pen enclosements were designed for rearing fingerlings. A sheltered bay on Lake Quinault was selected as the site. The floats, twelve feet by sixteen feet square, enclose 192 square feet of surface area each. A total of sixteen floats are planned.

Small mesh nylon holding boxes, twelve by sixteen feet square and eight, ten, or twelve feet deep, hang from these floats to enclose 1,400 to 2,100 cubic feet of water. The carrying capacity of these pens have yet to be determined.

In this first year 60,000 steelhead fingerlings from Washington Game Department, South Tacoma hatchery are being reared in a co-operative effort to determine if pen-rearing of steelhead in a lake environment is biologically and economically feasible.

This group of fish starting in mid-July at 3 grams (150 fish/lb) have grown to 35 grams (13 fish/lb) by mid-November. Water temperatures fluctuated around 58° and 60°F until mid-October when fall cooling trend started, except for high temperatures of 65°F in the last half of August. During this time columnaris became a problem and approximately 1,000 fish died. Conversion factors range from .8 to 1.5 over the summer and fall for the Abernathy dry diet.

The many problems of handling, treating, and transferring fish reared in floating pens have yet to be completely solved. With the ingenuity of the staff and others interested in this type of rearing it is hoped that the technology can be worked out.

PROGRESS REPORT ON CONTRIBUTION OF HATCHERY PRODUCED SUMMER STEELHEAD TO SILETZ RIVER

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Three years of study have been completed on returns of hatchery reared summer steelhead to Siletz River. The study objectives were to evaluate the stocking program on the Siletz in terms of Sustaining the run, producing highest rate of return, and greatest contribution to the fishery.

The fish are Siletz strain summer steelhead. Brood fish are trapped from Siletz River, then held and spawned at Roaring River Hatchery in the Willamette Valley. Rearing is done at Oak Springs Hatchery near Maupin. The yearling smolts are stocked at 6 or 7 per pound in April or May.

Three stocking sites have been evaluated. They are: Sam Creek, RM 45; Buck Creek, RM 59; and North Fork, RM 72.

Returning fish were monitored at Siletz Falls trap (RM 65), by personal creek census, and with voluntary census stations at both ends of the major fishery reach.

In the past three years, hatchery produced fish have made up from 72 to 83% of the run to Siletz Falls (Table 1). They have contributed 85 to 98% of the angler catch (Table 2).

Table 1
Trap Counts of Summer Steelhead at Siletz Falls

Year	Marked Fish	Wild Fish	Total Fish	Percent Marked
1969	2081	822	2903	71.6
1970	1568	562	2130	73.7
1971	2915	605	3520	82.8

Table 2
Observed angler catch of summer steelhead from Siletz River

Year	Marked Fish	Wild Fish	Total Fish	Percent Marked
1969	133	23	156	85.0
1970	98	8	106	92.3
1971	467	10	477	98.3

In the first two years of study, fish stocked at Buck Creek (6 miles below Siletz Falls) returned to the falls at a higher rate than those stocked in the North Fork (7 miles above Siletz Falls) and at Sam Creek (20 miles below Siletz Falls). That relationship indicated a higher survival by the Buck Creek release group. In the past year, the returns to the falls were in line with what would be expected, with the North Fork group returning at the highest rate (Table 3).

Table 3
Percent return of summer steelhead to Siletz Falls trap by release group

Stocking site	Year of major return		
	1969	1970	1971
North Fork	2.98	1.89	4.84
Buck Creek	3.93	2.38	3.96
Sam Creek	2.52	1.47	2.27

Fish from the Buck Creek release group have consistantly been caught by anglers at the highest rate (Table 4). Fish released at the Sam Creek site have made the next highest contribution followed by the North Fork group as a poor third.

Table 4
Percent return of summer steelhead to angler by release group, Siletz River

Stocking site	Year of major return		
	1969	1970	1971
North Fork	0.19	0.23	0.95
Buck Creek	0.61	0.77	2.51
Sam Creek	0.51	0.64	1.82

When observed returns to the falls and angler are combined, the Buck Creek group has consistently shown the highest rate of return, even in 1971 when they were outnumbered at the falls by the North Fork group (Table 5).

Table 5
Observed percent return of 1968 brood summer steelhead to Siletz River, 1970 and 1971

Return type	age	Stocking Site			
		North Fork	Buck Creek	Sam Creek	All
Return to angler	1 Salt	0.10	0.25	0.21	0.19
	2 Salt	0.85	2.26	1.61	1.58
	Total	0.95	2.51	1.82	1.77
Return to falls	1 Salt	0.68	0.39	0.20	0.45
	2 Salt	4.16	3.57	2.07	3.39
	Total	4.84	3.96	2.27	3.84
Total return	1 Salt	0.78	0.64	0.41	0.64
	2 Salt	5.01	5.83	3.68	4.97
	Total	5.79	6.47	4.09	5.61

A tagging program in 1970 confirmed what we suspected, that the majority of fish stocked below the falls remained there through late fall while at least half of the North Fork fish passed up stream. Though the number of tags applied probably was not sufficient for a statistical conclusion, it did re-inforce our overall findings that the lower river release groups returned best.

Management goals for these fish are to ensure adequate spawning escapement to the upper river while providing the highest return to the angler. Since fish stocked at lower river sites pass to the upper river in sufficient numbers for spawning stock and are caught at greater rates by anglers, all smolts are now being released at the lower sites. This distribution should provide for more efficient use of the hatchery product.

NEW USES FOR OLD FISH TREATMENT CHEMICALS

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Potassium permanganate has been returned to practical usage by the Washington State Game Department in its steelhead and searun cutthroat rearing ponds to control external protozooan parasites. At 2 ppm, Trichodina, Trichophrya, Gyrodactylus, and Epistylis are efficiently and economically controlled. Single treatments at the same level did not control *Ichthyopnthirius multifilis*.

Dilute concentrations of formaldehyde were used in repeated flush treatments to control "Ich" at the Tucannon Hatchery. Every three days, 24 hour flush treatments at the 15 ppm (1:66,666) level were administered to 5 c.f.s. of inflow. After the third treatment (9 days), "Ich" could be found only on the moribund fish; after 5 treatments (15 days), the "Ich" was absent on all fish examined.

HANDLING STRESS AND ITS PHYSIOLOGICAL CONSEQUENCES

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Handling stress is an inescapable part of the life of hatchery fishes, whether it occurs during cultural operations or during experimental work in laboratories. Depending on the severity of such stress, immediate or delayed mortalities can follow ("hauling" or "handling" loss) and disease epizootics, particularly those due to faculative pathogens, can occur. Unfortunately, even a mild, sublethal, handling stress may disturb homeostasis and thus weaken disease resistance. In such cases, there may be no behavioral changes, and thus little visible evidence that stress has even occurred. Accordingly, in the absence of death as an indicator, the actual severity of handling stress and the length of time a fish needs for recovery are frequently unclear.

To help resolve this probelm, the blood chemistry fluctuations caused by a mild, standardized, handling stress were investigated using the juvenile chinook salmon and steelhead trout as test species. Fluctuations in plasma glucose, chloride, calcium and cholesterol levels indicated that significant osmoregulatory and metabolic dysfunctions occurred after handling.

Due to the sublethal stress used in this study, survival of the handling was assured and normalization of metabolic and osmoregulatory function was usually complete within about 24 hours. Since the laboratory water supply is quite soft, it was possible to show that increasing the NaCl level to about 100 mOsm (0.3 %) and the Ca^{++} content to 75 or 120 ppm partially or completely alleviated some of the osmoregulatory fluctuations (hyperglycemia and hypochloremia) caused by this type of stress. Thus, these results help to explain past empirical findings that salt additions can reduce the "hauling loss" mortality of certain species.

Considerably more work should be done to optimize environmental conditions so that the adverse physiological effects of handling stress in fish culture operations can be reduced to the minimum practical level.

WILLAMETTE RIVER SPRING CHINOOK SURVIVAL STUDIES

Don Swartz

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In 1968 the Fish Commission of Oregon began a study of the Willamette River spring chiook. The object of the study was to determine the influence of smolt size and time of release on survival. The rearing phase of the study was conducted at Willamette River Salmon Hatchery using 130,000 juveniles from the 1967 brood production stock. Growth and condition were monitored regularly during rearing. By late summer the study fish had developed a bimodal length distribution with distinct subgroups having mean fork lengths of 135 and 180 mm. The small subgroup (58,000) were finclipped left ventral (LV) and the large fish (70,000) received a right ventral (RV) clip.

In early January 1969 one half of each subgroup was released with a single oxytetracycline (OTC) mark. At release the small fish (LV) were 13.5 per pound and the large fish (RV) were 4.6 per pound. The remaining fish were released in mid March 1969 with 2 OTC marks. Average fish sizes were 10.9 and 3.9 per pound for the LV and RV subgroups, respectively.

The first known adult recoveries were made early in 1971 when 4-year fish were taken in the lower Columbia River gill-net and sport fisheries, and in the Willamette River sport fishery. Based on sampling data from the various fisheries it was estimated that a total of 785 RV+OTC and 247 LV+OTC marked adults were harvested in the 1971 fisheries between salt water and Willamette Falls. An escapement of 649 RV and 190 LV marked fish were calculated to have passed through the fish ladder at Willamette Falls. Combined harvest and escapement figures gave a total estimated return of 1,434 RV and 437 LV marked 4-year fish.

Examination of OTC marks in vertebra from 366 RV and 71 LV clipped fish showed 71% and 68% respectively were from the March release groups. Applying these percentages to the total estimated return gave return estimates for each of the four release groups. Per cent returns were 1.2 and 0.5% of the RV and LV clipped fish released in January, and 3.0 and 1.0% of the RV and LV clipped fish released in March. Returning 5-year fish in 1972 are expected to provide further study data.

HATCHERY WATER QUALITY MONITORING

Warren Shanks

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A monitoring program to characterize the effluent from salmonid hatcheries was initiated in July 1971. Monthly water samples were taken at 3-5 locations at 6 hatcheries. A total of 19 physical, chemical, and biological parameters were measured either by Bureau personnel or under contract with a private laboratory.

Waste loading factors (pounds given parameter/100 pounds fish/day) calculated on basis of 4 sets of samples analyzed to date correlate well with similar studies. Fecal coliforms were absent in all samples but non-fecal coliform enrichment was observed in hatchery discharge and receiving water immediately below discharge. Suspended solids discharge averaged 19.4 ppm, equivalent to 5.8# suspended solids/100 pounds fish/day.

Table 1 summarizes Waste Loading Factors for 7 additional parameters as reported by other authors and in current study.

Table 1

Fish Hatchery Water Quality Study
Waste Loading Factors

(Pounds/100 pounds fish/day)

Reference	B.O.D.	TKN	NH_3-N	NO_3-N	NO_2-N	T-PO_4	O-PO_4
Bodine	1.3*	0.20	0.058	-	-	0.036	0.015
Liao	1.342	-	0.138	0.089	-	0.011	-
Bozeman FCDC	1.10	0.093	0.077	0.009	0.004	0.041	0.012
Coleman NFH	1.31	0.300	0.28	-	0.029	0.031	0.006
Ennis NFH	1.61	0.181	0.141	0.013	0.015	0.028	0.020
Kooskia NFH	1.64	0.241	0.171	0.057	0.039	0.055	0.025
Quilcene NFH	0.47	0.096	0.076	0.006	0.015	0.014	0.004
Winthrop NFH	1.06	0.107	0.078	0.030	0.002	0.015	0.001
Ave. W.L.F.	1.20	0.170	0.137	0.019	0.017	0.031	0.012

*Calculated value

ADULT STEELHEAD RETURNS FROM RELATED PLANTS

Marvin Hull

Washington State Department of Game
Skamania Hatchery
Washougal, Washington

The Washington Game Department's Skamania Steelhead Hatchery was located on the West Fork of the Washougal River because of the spring-run steelhead existing there. The hatchery water supply is taken from the West Fork and returned below the hatchery through the fish ladder. Beside the ladder in the river is a low lava falls. The returning steelhead may go either way.

With the start of operations in September of '56 two factors became apparent. There were fewer adults than expected in the run and the adults migrated longer than anticipated. Thirty five were trapped in the first three months. For the next four years the total stream reared, no marked adults was 153,114,81 and 166. Some fingerling were transported in from Goldendale Hatchery as soon as the race-ways were in condition plus 100 adults. None moved in were from the Washougal.

These would mix with the native strain upon spawning as adults. With 100% marking of hatchery plants into the brood stream the adults of hatchery reared steelhead could be positively separated but they would still be blended toward one strain in the wild and at the hatchery while spawning.

Assuming two year wild fresh water cycle, as in only ideal conditions are the smolts migrating in one year from the hatchery with unlimited feed and a one and two year salt water cycle which occurs in winter steelhead (1), then from the 1958 spawning the 1961 adults returning would be the last full return of native fish. These could be identified with a full dorsal and no fin clipped. This could be projected another year assuming no escape of fingerling into the river from the hatchery. However there was a problem of unknown losses and fish escaping into the river for several years.

The upstream migration of our first smolt plant on 5-22-57 clearly demonstrated the biological deadline for release of smolts under that years related factors. Most of the plant was caught above the hatchery all summer as trout with two fins missing.

Production wise smolts of 10-11 per pound have been marginal size for returns. We have found no break off point numerically where larger smolts do not give a better return. In the selection of smolts we have preferred the largest yearling smolt which corresponds to the earliest eggs taken which stretches the biological years backwards and more growing time to planting deadline. The much larger two year old have been second choice as they have a slower rate of growth with poorer food conversion.

There were many years before there really was a choice for planting yearling smolts. For five years with two minor exceptions all smolts were planted 1 1/2 or 2 years old. The fall plant always returned along with the subsequent spring plant. Thus the school apparently stayed in the Columbia River as they did not stay in the Washougal River. Other reports have shown the restricted period for salt water entry. The nitrogen problem today adds at least one new factor to the habitat. Before, all the fall plants returned comparable to the companion spring plant but markedly less in two.

1962 was a pivotal year in operations. It was the last year of our fall plants and the end of 100% marking of smolts with two fins clipped for the home stream. For this year the cleared marks and the requested marks did not corelate. All were still marked but the returns were not clearly identifiable for reference. The total plant weight of 20,640 pounds was our heaviest till 1970. 1962 was also the last year of commercial dry diet which had replaced the hatchery fresh frozen or wet diet.

Since the rearing program started, with one exception, no return total exceeded .9% and most were well under .5%. The return from plants through 1962 or adults through 1964 when compared with the one full cycle return of native fish in 1961 formed a similiar nearly balanced or equal bimodal graph. However the jacks or half year salt water cycle had ceased and there was a hint of a trend to longer salt water of one to two years.

The 1963 plant was the first made exclusively of yearling smolts and was partly reared in a warmer spring water hatchery as others were on three other years with less success. The 104,000 smolts weighed 17,137 pounds and were on moist pellet for about half the year. The 1965 adult return showed better than a three fold increase over any previous year and better than double any previous plant percentage. The marked smolts with the 1963 plant dropped to 17% of the total and had a confused return. Through 1969 the marking dropped to zero with two single fin exceptions. Using "no marks" for identification of the balance of the spring yearling plant it totaled 88,000 and 15,500 pounds and brought out a higher survival percentage and a definite shift from one year salt to two year salt water period with five to one in the formerly balanced bi-modal graph. This would include stream reared returns incidental in numbers as already mentioned. There is no previous yearling plant to compare this result with.

The 1964 migrant plant was the first all moist fed smolts. It was and is the largest number with the most weight for two year old smolts or 79,000 and 15,365 pounds. The yearling moist fed plant was 32,000 fish weighing 4,500 pounds with one fin clip mark. Half these yearling smolts were raised from egg to plant at the Goldendale Hatchery which has a constant temperature of 53 degrees. These counted about 6 1/2 per pound while the local marked were 8. There was no significant difference in the returns from the two stations not relatable to size. Including the few returning in 1967 as 1/3 cycle the total percent was 3.1 for local and 3.4 for Goldendale. The total return for 1966 was approximately 7060:2583 were tagged with plastic tags and hauled to other streams, some 956 were counted moving around the closed trap and 3521 were held for spawning.

The 1965 plant was 54,000 2 year smolts weighing 9555 pounds and yearling smolts of 45,130 or 6635 pounds each with adipose clipped off. 88 were checked in 1966 and 990 in 67 or 2.4%. The total return for 67 of 3177 was 3.1%.

Then thru 1970 all plants were yearling smolts in the home stream with no marks. In 70-71 there was a percentage 2 year smolt plants with some marking and liquid nitrogen branding of both year groups.

A closer look at the components of the 61 adult return shows this to be of smaller size total because of a better percentage return of a specific marked plant. The spring plant of 38,000 in 1960 returned so much better as 2/1 than the fall plant 58 of 34,000 and the spring plant of 59 of 22,000 that the total returns showed an undesirable size average.

To further compare this dominant year return against itself as 2/1 and 2/2, Ad-Rv mark, they are about equal and compare to the 1961 native bimodal return.

The reason the 62 total return size compares favorable with the native 61 bimodal return is because the 60,000 spring 61 plant compares favorable as 2/1 with the 38,750 spring 60 plant returning as 2/2. Numerically the annual return was only about half as good. With a similar percentage return the 62 total size picture would also have shown an undesirable average. Comparing the two year annual return it is the same bimodal graph of 61 wild.

A different look shows the total weights of the 62 plant at 20,640 pounds exceeds the planting weight for 64 and 65 by 15% and 20% with far less returns. Even the 61 plant compares in weight with 64 and 65 and only 10% less by count but was 33% and 82% less in returning adults. This grouping involves a change to OMP feed, stopping fall plant a decrease in fin amputation and a continuing selection for the most desirable progeny into the brood stream. Adaptation never is static. The progeny is always changing and with crossed strains there would be a greater divergency potential for a few generations.

This may explain some of the results. In 58-59-60 there was a jack return or 2 1/2 cycle. This has not re-occurred since. In 1961 there was a Do-Rv plant mark which returned in 63-64-65. This mark was used before in 58 on 15 per pound smolts with no returns. The sizes from the 61 group do not correspond to the salt water period for growth. This explains in part the unfavorable total size for 64.

Now we continue with the possible 1965 returns from a second "no mark" plant in 64 of 78,000 two year smolts weighing 15,400 pounds. With one exception the 2/1 cycle has been indicative of the success of the 2/2 return while averaging 23+" in size. Here of the 755 measured in spawning 126 grouped under 25" or a 630 projected total of 3699 adults in 1965. Still the 1966 returns were nearly double any previous year total and sized out as 2/2 or around 28". Where was the normal return of 2/1 adults the previous year?

The measured adults for 65 was a weak percentage and for 66 adults the percentage and especially details are the worst for the station. No attempt is made to establish from this that a change took place. Instead in tracing back all the following years total returns with a size shift to the two year salt cycle from an equal one and two we end up looking at the 1964 plant and 65 and 66 returns. If this is from the new feed the results are not common. If from selective breeding it was the continual use of the largest males. Here rather than size slow maturing would be the key. This would not hold if the largest males were repeat spawners. Using a slit anal for identification we have few repeaters and only one has been a male.

The three marked plant of yearling in 64 and 65 also show a shift in the salt water cycle favoring the larger size. This in comparison to the only previous all yearling plant in 1963. The lower percentage total return of the 65 adipose mark suggests there may have been a good 1/3 return. How to acquire this information without crippling the smolts using fin clips is another problem. Nitrogen brands are due back for 72 spawn. Preliminary check of several dozen single fin clipped adults reveals no trace of the brand.

THE SUCCESSFUL USE OF CO_2 ANAESTHESIA FOR SPAWNING FALL CHINOOK SALMON

Elmo B. Barney

Bureau of Sport Fisheries and Wildlife
Spring Creek National Fish Hatchery
Underwood, Washington

Fall Chinook spawning was successfully accomplished with CO_2 as an anaesthetic. Although CO_2 is more expensive than Quinaldine, fish recovery time is shorter when using CO_2.

The projected diagram shows a method of obtaining an even CO_2 distribution in anesthetic tanks. Less CO_2 is required if distributed in the manner described.

A PROGRAM FOR THE STUDY OF FISH HATCHERY WATER TREATMENT SYSTEMS AT THE BOZEMAN FISH CULTURE DEVELOPMENT CENTER IN MONTANA

Ronald D. Mayo

of

Kramer, Chin & Mayo
Consulting Engineers
Seattle, Washington

In late 1970 the firm of Kramer, Chin & Mayo was retained by the Walla Walla District of the Corps of Engineers to conduct a program for the study of fish hatchery water treatment systems at the Bozeman Fish Culture Development Center in Montana and to relate this study to work being done at the Dworshak National Fish Hatchery in Idaho and the Abernathy Salmon Cultural Laboratory in Washington.

Our services and the construction of the test program facilities were funded by the Walla Walla District of the Corps of Engineers under the value engineering program. While the results of this program will hopefully have wide application they are intended to relate specifically to the proposed expansion of the Dworshak National Fish Hatchery.

The purpose of this paper, which has been authorized by the Corps of Engineers, is to describe the program developed at Bozeman in terms of the physical facilities constructed there and to explain the results of the study.

Succeeding papers in this publication will describe the nitrification process which was an important factor in the water treatment systems developed at Bozeman; the occurrence of toxic effects in the various water reuse systems; and the effects of nitrite on the blood and tissues of salmonids.

In August 1970 Kramer, Chin & Mayo prepared a report for the Corps of Engineers titled "A Process Design for Effluent Treatment Facilities at Spring Creek and Bonneville Salmonid Hatcheries". This process design was based on the assumption that reconditioning systems would be installed at each of these two hatcheries similar in nature to that now in service at the Dworshak National Fish Hatchery in Idaho. For this reason the unit at Dworshak was studied intensively to determine the character of the water at various points in the system.

In general the Dworshak reconditioning system operates on a total inflow of 1500 GPM and a constant discharge at the same rate. On the basis of a 10 pass system, this means a total flow through the raceways of 15,000 GPM. In terms of treatment this unit has performed fairly well and several cycles of steelhead have been raised for release into the Clearwater River.

The effluent from this process, however, was of special concern because of heavy organic loading. This was especially true during the backwashing of the filters when quantities of organic materials were flushed out of the system into the river. This backwashing process occurred every other day for each individual filter and was of considerable importance in its effect on the design of effluent treatment facilities.

The study at the Dworshak Hatchery was completed and the data obtained is being used as the basis for the construction of the effluent treatment facilities at the Spring Creek unit. However, during the development of the process design we came to realize that it might be possible to reduce or eliminate the need for effluent treatment if the reconditioning process itself were designed to serve the dual purpose of reconditioning the water and providing adequate effluent treatment. It was this concept that provided the basis for the study program developed at the Bozeman Hatchery.

Our specific assignment at Bozeman is stated in the following excerpt from our contract with the Corps of Engineers.

"It is the general intent of this contract to conduct certain studies which will result in improved and more economical hatchery reconditioning systems and waste treatment processes. The following general items of work are considered necessary to perform these studies.

A. Construct prototypes of alternate water treatment systems at the Bozeman National Fish Hatchery. These prototypes include the following 4 systems:

An upflow submerged filter using plastic media.
A downflow open trickling filter utilizing plastic media.
An activated sludge system.
And an extended aeration system.

B. Operate these prototypes at various rates and loadings and collect date through water sampling and analysis. Fish cultural conditions will be evaluated at various points through the system.

C. Monitor the gathering of similar data from Dworshak and the Abernathy Stations.

D. Summarize and evaluate the data collected.

E. Develop engineering criteria for the design of alternate systems which will meet both fish culture and water pollution control requirements.

F. Report all data is usable report form."

Individuals providing technical assistance were Jack Larmoyeux, Robert Piper and Charlie E. Smith from the Bozeman facility; Einar Wold and John Parvin from the Federal Bureau of Sports Fisheries and Wildlife of the Dworshak Hatchery; and Bob Combs and Joe Elliot of the Abernathy Hatchery.

In order to conduct the program at Bozeman, a test facility was constructed on the lower level of raceways. These test facilities consisted of 4 separate units, each with a 12 ft. diameter rearing tank, an 8 ft. diameter treatment tank, and a recirculating pump. All of the rearing and treatment tanks were set on a timber deck as shown on the photo page. These units were serviced by air compressors mounted together in a small house. Water to the units was supplied from the hatchery system. Bozeman has an unusual water system in that two springs a short distance apart are available; one with a constant water temperature of approximately 49^{o}, and the other with a constant water temperature of approximately 70^{o}. A small pipe from each of these two sources was directed into the rearing raceways and through modulating the valves a total flow of 5 to 10 GPM of water was available. Normally the rearing units were operated on 5 GPM of water and through a 10 pass reuse system an effective flow of 50 GPM was provided.

Once the test systems began operating hydraulically, fish were gradually loaded into the rearing tanks to increase the biological load on the treatment system. This loading process started at approximately 50 lbs. of fish in each rearing unit. During certain periods, fish loads as high as 600 lbs. per tank were reached. This resulted in an effective water use of 120 lbs. of fish per GPM.

This study was divided into three phases. Phase 1 consisted of the actual construction of these tanks and the establishment of uniform operating conditions. To determine when uniform operating conditions were achieved, periodic water samples were taken from several points in the process and analyzed for various chemical parameters. In these tests (and all tests throughout the program) effort was concentrated on those tests which related ammonia and solids removal to hydraulic and fish loading. However, in order that the mechanism involved in the removal of metabolic by-products and the treatment of the process effluent be fully defined, other tests were necessary. During the period prior to achieving steady state, and then on a 24-hour cycle when steady state had been achieved, the following tests were made - pH, NH_3, PO_4, NO_2, NO_3, DO, COD, BOD, SS. These tests were conducted by Warren Williams of our firm in the Bozeman laboratory facilities. In addition, histopathological tests were conducted by the Bureau of Sport Fish and Wildlife. The 24-hour test series were run on all the pilot plants several times during the Phase 1 work. Finally as the units became more or less stabilized, the project entered Phase 2.

Phase 2 consisted of the continued operation of the units at various fish and hydraulic loadings, with 24-hour test series run on each unit at 2 - 5 week intervals. At the completion of each test series, the operation of the units was modified and then monitored until once again a steady state had been achieved; then another 24-hour test cycle was undertaken. This procedure was repeated throughout the 24 weeks of Phase 2.

Phase 3, which is now in progress, consists of analyzing data obtained, and developing necessary design criteria. However, since Phase 3 is not completed we have not reached any final conclusions relative to the various treatment processes described. These conclusions will be reached after a thorough analysis of the data. This will probably take place in 2 to 3 months. However, several tentative conclusions and comments have been reached. They are as follows:

1. Reconditioning filters can be built to accept a higher hydraulic loading rate than has been assumed in the past.

2. Reconditioning filters can be operated on a continuous flow basis without the need for periodic backflushing. The solids generated in the systems can be removed by sedimentation.

3. The effectiveness of the reuse system is principally a function of retention time; the specific surface area of the biological filter media; the hydraulic loading; and the organic loading.

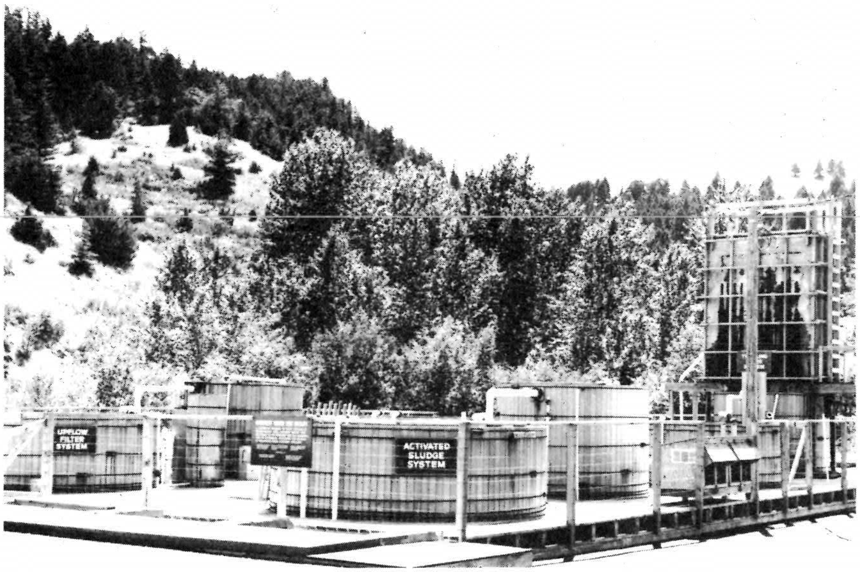
4. Of the several systems that were evaluated at Bozeman, the two most likely to be appropriate to 10 pass water reconditioning are a submerged upflow filter with solids removal in a clarification zone below the filter, and an open downflow trickling filter with a clarification zone following the filter.

5. The systems evaluated here were based on 10 reuses of the water. Other levels of reuse from 2 to infinity are perhaps appropriate to other situations and should not be ignored.

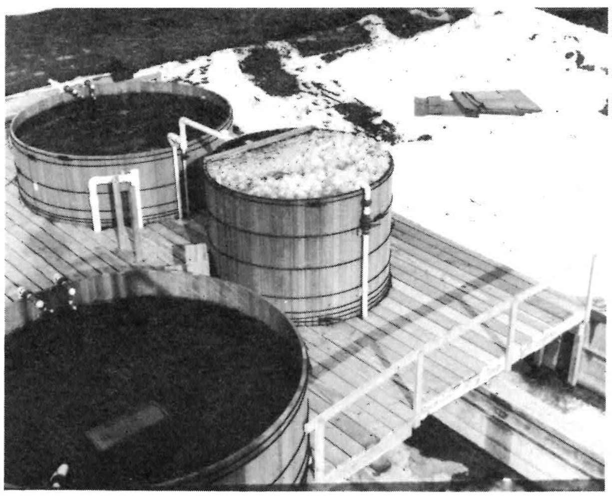
6. The start-up water reconditioning system, depending as it does on the nitrification process, must be accomplished in gradual steps. This confirms earlier findings.

7. Differences in findings of researchers in this field almost inevitably disappear when real communication is established and common methods of measurement and expression are utilized.

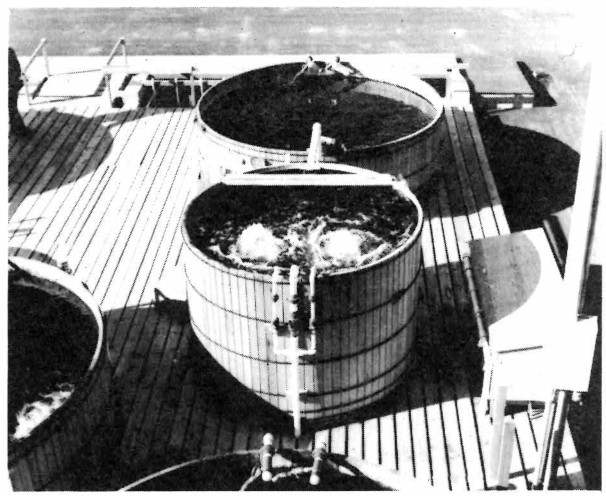
BOZEMAN TEST FACILITY



BOZEMAN TEST FACILITY
OVERALL VIEW OF THE R&D PILOT PLANTS DESIGNED BY KRAMER, CHIN & MAYO, CONSULTING ENGINEERS, SEATTLE, WASHINGTON AT THE BOZEMAN FISH CULTURAL DEVELOPMENT CENTER IN MONTANA FOR FISH HATCHERY WATER TREATMENT STUDIES.

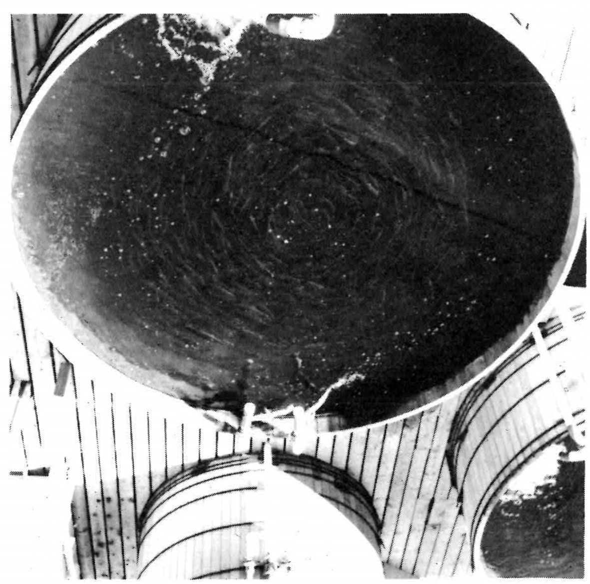


UPFLOW FILTER WITH MEDIA SHOWING



ACTIVATED SLUDGE SYSTEM

TRICKLING FILTER



REARING TANK FOR TRICKLING FILTER

THE OCCURRENCE OF NITRITE TOXICITY IN WATER REUSE SYSTEMS

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During a series of pilot plant studies on water reuse conducted by Kramer, Chin & Mayo at the Bozeman Fish Culture Development Center in Montana, fish mortalities from an unknown cause pointed to nitrite as a possible toxicant.

During this study we had expected a short period of higher nitrite levels than would be present after the system had reached equilibrium. However, literature values of nitrite toxicity indicated that the levels anticipated would not be toxic.*

Oxygen was used as the limiting variable during the start-up phase to determine the fish-loading. This provided a large metabolic waste load (ammonia) for the filters.

Evidence that the nitrifying culture in the upflow filter had begun to develop was provided when the ammonia began to decrease and the nitrite began to increase. Several weeks into this phase, fish mortalities began to occur. Fish mortalities increased and on April 9, 1971 the rearing pond was taken off reuse for one day. The fish improved immediately and the filter was then reconnected. The next morning, however, a greater fish kill was discovered and the remaining live fish were removed from the system. Since the fish had been in high ammonias since the beginning of the study it was assumed that this was the contributing factor.

When new fish were put in the filter on April 15, substantial mortalities again occurred. The rearing pond was then taken off the reuse filter and the filter was flushed with spring water. On April 19, the reuse filter was reconnected and substantial mortalities still occurred. The fish were removed and the filter was flushed again. A very light fish loading was then introduced into the system and mortalities ceased to occur.

*Klingler, K. "Natriumnitrit, ein langsamwirkendes Fischgift", Schweizerische Zeitschrift fur Hydrologic, 19 (2): 565-578. (1957)

Saeki, Aritsune, "Studies on Fish Culture in Filtered Closed Circulating Aquaria 11-on The Carp Culture Experiments in The Systems," Bulletin of the Japanese Society of Scientific Fisheries, Vol. 31, No. 11, 1965.

During this time period the cause of the mortalities was not known. There was considerable speculation about various causes but the evidence eventually pointed to nitrite as the cause. Our resultant literature survey, however, did not confirm nitrite as toxic to fish at the levels encountered in the reuse system.

During the latter part of April, nitrification in the trickling filter was discovered and monitored. During the week of May 4, mortalities in the trickling filter started to occur. Concurrently the levels of nitrite began to increase. Mortalities counted through May 12 strengthened our suspicions that an increase of nitrite resulted in fish mortalities. The suspected nitrite toxicity problem was gradually overcome by increasing the fresh water make-up from 1/10 to approximately 1/3. The mortalities began to decline and were eventually eliminated.

Confirmation of nitrite as the toxicant was provided by running a series of bioassay tests. To determine if nitrite was the specific problem or if there was a synergistic effect with some of the other metabolites, the following bioassay tests on 20 fish in each trough were conducted.

(1) Water that had been used for fish culture in the hatchery building was aerated to re-oxygenate it and then was run into 2 troughs. One trough was used as a "control" trough and one as an "experiment" trough with sodium nitrite dripped into the experimental trough to supply the nitrite level found in the reuse system.

(2) Spring water was run through two troughs - one "control" and one "experiment", with $NaNO_2$ and NH_4Cl added to the appropriate levels found in the reuse system.

(3) Spring water was run through two troughs - one "control" and one "experiment", with $NaNO_2$ added to the level found in the reuse system.

Table 1 shows the results of the bioassay tests in terms of mortalities. There were mortalities in all three "experiment" troughs.

TABLE 1. BIOASSAYS - MORTALITIES*

	Experiment	Control
$NaNO_2$ + natural metabolites	+	-
$NaNO_2$ + NH_4Cl	+	-
$NaNO_2$	+	-

Examination of the experiment fish in the bioassay showed the same conditions as those found in the reuse system. These conditions were gross necrotic and hemmorhagic lesions on the tongues, gill arches, roof of the mouth and the under surface of the opercles. The gills were dark reddish brown rather than the typical bright red of the control fish. Fish hemorrhaged readily from the gills when handled.

* "+" indicates mortalities, "-" indicates no mortalities

Since the experiment fish evidenced the same symptons as those found in the pilot plants during the high nitrites, nitrite was thus confirmed as the toxic agent in the pilot plants.

The problem experienced at Bozeman during the start-up phase of the study was brought about by the excessively high metabolic (ammonia) loadings. There are a variety of start-up techniques that can be employed to avoid the temporary toxicity due to high nitrites. These include chemical start-up with no fish in the system; using a light fish loading to provide the metabolic (ammonia) load; and using a reduced recycling rate during start-up.

More extensive work was conducted on nitrite toxicity and a paper is being prepared for publication at this time.

ACKNOWLEDGMENTS

This research is being funded by the Walla Walla District Corps of Engineers. The assistance rendered by the Federal Bureau of Sport Fisheries and Wildlife and the National Marine Fisheries Service is gratefully acknowledged.

THE NITRIFICATION PROCESS FOR RECONDITIONING FISH HATCHERY WATER

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Treatment methods for reconditioning fish hatchery water may include biological, physical, and chemical processes and their various combinations. Biological processes include the use of a filter system, an activated sludge process, and stabilization ponds. Major physical-chemical processes involve air stripping, ion exchange, aeration, sedimentation, screening and chemical coagulation.

For reconditioning hatchery water, the most important treatment functions include the removal of metabolities (such as feces, ammonia, CO_2 and organic solids) and the proper use of aeration and pH control. The removal of ammonia and organic solids from hatchery water is considered essential in providing the proper environment for fish propagation since the ammonia is highly soluble and is toxic to fish even at a very low level (Ellis, 1937, Wahrmann, 1948 and Burrows, 1970). Coventionally, ammonia in water can be efficiently removed through biological oxidation (nitrification), air stripping, ion exchange and chlorination followed by dechlorination and carbon absorption. Biological nitrification when compared to physical-chemical methods, is more economical, efficient, and reliable. It also requires less operating skill. The simplicity of this process fits the hatchery operation pattern very well. Therefore, it is the most commonly used method for hatchery water reconditioning.

On the other hand, the physical-chemical methods are not normally recommended in hatcheries, even though they are efficient, because they are more expensive; require special operating skills; and under certain conditions can be harmful to fish i.e., ion exchange bed exhaustion, failure in the pH adjustment of air stripping, or failure in removing residual chlorine in the chlorination-absorption method.

The existing prototype operation for reconditioning hatchery water has been discussed by Mayo (1970) and is not repeated here; but in order to properly apply the nitrification process to hatchery water treatment, an understanding of the following mechanisms involved in ammonia oxidation is necessary.

THE NITRIFICATION PROCESS

The nitrification process is a water treatment method through which ammonia is biologically oxidized to nitrite and then nitrate. The nitrates may form salts with cations in water or may be reduced to nitrite and then to free nitrogen gas through a biological dentrification process.

THE MECHANISMS OF AMMONIA REMOVAL THROUGH NITRIFICATION

Ammonia, produced by the breakdown of nitrogeneous matter, is highly soluble in water. At one atmosphere of pressure and 20°C about 525 grams of ammonia can be dissolved in 1 liter of water (Hodgman et al, 1958). However, the ammonia dissolved in water normally acts as a weak base in water. Therefore, most of the ammonia in water is in an ionized form, which is considered non-toxic to fish (Ellis, 1937 and Wahrmann et al, 1947). The per cent of ionized - unionized ammonia in water depends upon the pH and temperature as shown in Figure 1. Since only the unionized ammonia is toxic to fish, the control of the pH and temperature may be a practical method for controlling ammonia toxicity. This possible application, however, has not yet been tried.

Biochemically, ammonia removal through nitrification is a two-step process. The ammonia is normally oxidized to nitrite by Nitrosomonas. The nitrites are then converted to nitrates by Nitrobacter as follows:

1. $NH_4^+ + 1.5O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^- + 2H^+ + H_2O$

2. $NO_2^- + 0.5O_2 \xrightarrow{\text{Nitrobacter}} NO_3^-$

When the reactions proceed a significant amount of energy is released simultaneously. This energy supports the growth of the nitrifying bacteria. During this growth some of the nitrogen is assimilated into the bacteria protoplasm, with carbon dioxide providing a source of cell carbon when the organic is absent. The empirical cell formula of $C_5H_7NO_2$ has been proposed by Oswald (1960). On this basis, biochemical equations describing the overall reactions of nitrification and assimilation may be expressed as follows:

3. $55NH_4^+ + 5\ CO_2 + 76O_2 \xrightarrow{\text{Nitrosomonas}} C_5H_7NO_2 + 54\ NO_2^- + 52H_2O + 109H^+$

4. $400\ NO_2^- + 5\ CO_2 + NH_4^+ + 195O_2 \xrightarrow{\text{Nitrobacter}} C_5H_7NO_2 + 400\ NO_3^- + H^+$

If an organic carbon is present in the water, such as glucose $C_6H_{12}O_6$, it may constitute a source for cell carbon. In this case, the overall reactions of nitrification and assimilation may be expressed as follows:

5. $C_6H_{12}O_6 + 3NH_4^+ + 4O_2 \xrightarrow{\text{Nitrosomonas}} C_5H_7NO_2 + 2\ NO_2^- + CO_2 + 6H_2O + 5H^+$

6. $C_6H_{12}O_6 + 2NO_2^- + HN_4^+ + 2O_2 \xrightarrow{\text{Nitrobacter}} C_5H_7NO_2 + 2NO_3^- + CO_2 + 4H_2O + H^+$

FACTORS AFFECTING THE NITRIFICATION PROCESS

The major factors affecting the nitrification process are temperature, pH, the dissolved oxygen concentration, the nature of the environment, the nitrifying bacterial population, the retention time, and the ammonia concentration or loading. The realtionships of these factors and ammonia oxidation are discussed as follows:

A. Water temperature

According to Downing and Knowles (1966) the relationship of water temperature and rate of nitrification can be expressed as

7. $$K = 0.18^{0.12\,(T-12)}$$

where K = rate constant nitrification
T = water temperature

From this equation the effect of temperature on nitrification is obvious. The higher the water temperature the higher the nitrification rate, and vice versa.

B. pH

Meyerhof (1916) found that nitrification was optimal with a pH value of 8.6 and zero activity at pH 7.6 and 9.6, respectively. However, Lees (1952) reported that when the pH was 7.7 nitrification was optimal, and that the rate constant K, decreased when the pH was lower than 7.0 Simpson (1964) indicated that nitrification might be inhibited if bicarbonate ion (HCO_3-) built up and when the pH was less than 5.5 Haug and McCarty (1971) found that optimal nitrification occurred at pH 6.8 to 8 and that the rate of ammonia oxidation decreased dramatically when the pH was less than 6.4. The rate of nitrification was almost zero at pH around 5.5 (Figure 2).

C. Dissolved oxygen concentration

Nitrification occurs at dissolved oxygen level as low as 2 m/l. However, most investigators claimed that for efficient nitrification the dissolved oxygen must be maintained above 4 mg/l (Eikum 1967). When the oxygen is less than that required for nitrification, the rate of ammonia oxidation decreased significantly (Haug and McCarty 1971).

D. The nature of the environment and nitrifying bacterial population

The nature of the environment must be in favor of the nitrifying bacteria development. Since the nitrifying bacteria are autotrophic, low organic levels must be maintained for *Nitrosomonas* and *Nitrobacter* to predominate. Otherwise, the process will be retarded.

E. Retention time

The efficiency of nitrification was found to be a function of retention time and temperature. The detention time required for a given degree of treatment increased as the temperature decreased and vice versa (Haug and McCarty, 1971). These authors found that at a given pH and temperature the rate of ammonia oxidation increased with time.

F. Ammonia concentration

Liao (1971), through field monitoring tests conducted at various nitrification facilities in North America found that the rate of nitrification was a function of initial ammonia loading. Similar phenomena was also observed by Haug and McCarty (1971) and Speece (1971). The relationship is almost linear when either the initial ammonia concentration or the loading is plotted against the ammonia removal rate as shown in Figure 3. According to Haug and McCarty (1971) the relationship between the ammonia oxidation rate and the initial ammonia concentration can be expressed as

$$8.\quad \frac{ds}{dt} = 2.59 \left(\frac{S}{10}\right)^{1.48}$$

where $\frac{ds}{dt}$ = rate of ammonia oxidation in mg/l/min at 25°C

S = initial ammonia concentration, mg/l

Assuming other factors affecting nitrification are satisfactorily maintained, the relationships of the nitrification rate, temperature, and the initial ammonia concentration may be expressed as follows (Haug and McCarty 1971):

$$9.\quad \frac{ds}{dt} = (0.11\ T - 0.20) \left(\frac{S}{10}\right)^{1.2}$$

where $\frac{ds}{dt}$ = rate of nitrification in mg/l/min

T = temp. in °C

S = initial ammonia concentration in mg/l

However, the relationships established by Haug and McCarty (1971) were based on a small scale pilot plant using a pure supply of oxygen and synthetic ammonia waste. Oxygen levels in the system were reported to be at least 300% higher than the saturation point in natural waters. In order to control environment so that autotrophic nitrifying bacteria could predominate, the synthetic ammonia wastes were devoid of organics. These situations are far from realistic. Therefore, the application of these relationships to the treatment of hatchery waste water that is low in ammonia with organic present needs further investigation.

THE DESIGN AND OPERATION OF THE NITRIFICATION FACILITY

The major factors affecting nitrification, discussed earlier, must be considered prior to the design and operation of a nitrification facility for treating hatchery water. Factors relative to the design and operation of the nitrification process may vary with different systems. The results of the pilot plant performance study conducted at the Bozeman Fish Culture Development Center in Montana suggest that the filter process is more efficient and more reliable when compared to other biological nitrification processes such as activated sludge and detention aeration. Therefore, discussion here is limited to the filter process. Because of the limited scope of this paper, a detailed discussion of the design and operation of the nitrification process for reconditioning hatchery water can not be covered here. Instead, the necessary information for a hatchery nitrification filter design is listed below.

1. The ammonia production rate and total ammonia load (Liao, 1970).

2. Acceptable ammonia level versus time, temperature and pH.

3. Hydraulic and ammonia loading rates of the filter greater than 2 gpm/ft^2 and 10×10^{-5} lb NH_4-N/ft^2-day have been found acceptable.

4. The retention time required varies with temperature.

5. The total specific media surface area required.

6. Solid removal and aeration - Solid removal is desirable prior to filtration; a higher oxygen level should be maintained.

7. pH control is dependent on the buffering capacity of the water.

8. Temperature control - A system with minimum heat gain or loss is desirable.

Once the filter facilities are designed and installed the operation follows. Based on experience gained during the study at the Bozeman Fish Culture Development Center, a period of several months is necessary for the nitrification process to reach a steady state after the system is started. Because ammonia oxidation is a two-step process, the level of intermediate ammonia oxidation product (nitrite) may build up if the nitrobacter population is not adequate for converting nitrite to nitrate as shown in Figure 4. Nitrite has been found to be very toxic to fish (Smith and Williams 1971) because it reacts with hemogloblin and converts hemagloblin, an oxygen carrier, to methemoglobin, a non-oxygen carrier, and results in fish mortality if the nitrite level is high. The details of nitrite toxicity to fish is discussed by Warren Williams and Charlie Smith elsewhere in this publication. To prevent the nitrite level from building up, the fish must be loaded gradually after the nitrification process is activated. Dilution, by increasing make-up water, may be used as an alternative for controlling nitrite toxicity, since a nitrite level of less than 0.2 mg/l has been found to be non-toxic to fish.

SUMMARY

1. The biological nitrification process is an economical, efficient, and simple treatment method for reconditioning fish hatchery water.

2. To properly apply the nitrification process an understanding of the mechanisms of ammonia oxidation and the factors affecting the nitrification process is necessary.

3. Biological filters have been found to be the most feasible for hatchery water treatment.

4. Various design and operation factors were discussed briefly due to the limited scope of this paper.

5. Data obtained from the pilot plant operations at the Bozeman Fish Culture Development Center and other stations in North America is being processed. Based on the information derived from this data, rational design criteria, equations, and detail design calculations

will be developed. This design information will be available during the early part of 1972.

ACKNOWLEDGEMENTS

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EFFECTS OF NITRITE ON THE BLOOD AND TISSUES OF SALMON AND TROUT

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Yearling rainbow trout were exposed to sodium nitrite to give nitrite (NO_2) concentrations of 0.15 and 0.55 ppm for 48 and 24 hours respectively. Trout exposed to 0.55 ppm for 24 hours suffered a 55% mortality. No mortality occurred in trout exposed to .15 ppm NO_2 for 48 hours.

Total hemoglobin and methemoglobin determinations revealed that fish suffered from methemoglobinemia. Symptoms were: loss of orientation, lethargy, coma and death.

Grossly, necrotic lesions and petechial hemorrhages were consistently found in the thymi of trout exposed to nitrite. Blood was light chocolate brown and internal organs pale to light brown. Histologically, thymi from test trout showed generalized edema, scattered focal hemorrhages and granulomatous lesions which varied from one to several in number.

Fingerling trout were exposed to NO_2 and found to be less sensitive than yearlings ince mortality did not occur at 0.55 ppm for 24 hours. However, a concentration of 1.6 ppm resulted in a 50% mortality.

Chinook salmon exposed to .5 ppm NO_2 for 24 hours suffered a 40% mortality. Symptomatology, gross pathological changes as well as hematological and histopathological changes were similar to those observed in yearling rainbow trout.

PROGRESS IN WATER RECLAMATION STUDIES

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The water reconditioning experiments conducted at the Salmon-Cultural Laboratory during 1971 were directed toward exploring upflow filtration and the discovery of filter media more efficient than crushed rock. When compared to the downflow filters we have been using, the upflow filter removed ammonia more efficiently and required less frequent cleaning. Cleaning was reduced due to digestion of sludge in the settling area beneath the filter.

Artificial media tested included Koroseal, alternating corrugated and flat fiberglass sheets, 3/4 inch PVC tubes, and 11/32 inch styrofoam balls proved inefficient for ammonia removal, due we believe, to the laminar water flow through the media. The laminar flow allowed much of the water to pass through without contacting the media surface on which the nitrifying bacterial culture grew. The small styrofoam ball media was several times more efficient in ammonia removal than crushed rock, but after two and one-half months of operation the filter became so badly clogged with organic debris that cleaning became extremely difficult. It appeared that the void space in the media was too small for continuous operation unless a better method of cleaning was developed.

Several drugs were tested for compatability with the nitrifying bacterial culture in biological filters. Sodium chlorite, $NaClO_2$, a bleaching agent was found to be effective against the filamentous bacteria Sphaerotilus which causes filter clogging. At the effective treatment level, 1.0 ppm, much of the nitrifying bacterial culture was destroyed; however a 3-day pre-treatment at 0.5 ppm apparently conditioned the bacteria so that subsequent treatments at 1.0 ppm were tolerated. Roccal at 0.67 ppm for 3 consecutive days did not harm nitrifying bacteria and controlled bacterial gill disease in fingerling chinook salmon. The nitrifying bacteria also tolerated Hyamine 3500 at 1.0 ppm but this drug level was not tested against bacterial gill disease.

EVALUATION OF ADULT STEELHEAD SORTING EQUIPMENT AND AIR SPAWNING AT DWORSHAK NATIONAL FISH HATCHERY

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A study was conducted at Dworshak National Fish Hatchery to determine the effect of the mechanical sorting apparatus on the quantity and quality of the incubated egg, and the feasibility of live spawning steelhead.

The mechanical sorting apparatus is made up of a series of crowders, lifts, anaesthetic tanks, and sorting tables. During the normal spawning operation the fish are crowded into a fish collection chamber, dumped into anaesthetic tanks, elevated and poured onto a sorting table to be segregated for spawning. The unripe females are returned to the ponds and the ripe females are killed. As males are used several times over a period of several weeks they are returned to the ponds.

The steelhead for the trial were divided into three groups and handled in the following manner. Fish in group one were processed through the sorting machinery and killed as described above. Group two fish were processed through the machinery and air spawned. Group three fish were maintained in a pond throughout the spawning season and were air spawned.

Eggs obtained were handled in the same manner for all three groups. The eggs were hatched in vertical incubators supplied with six GPM incubator water, and treated twice a week with a 15 minute 1:600 Formalin treatment. Eggs from two females, fertilized by two males, were incubated in each tray. All mortalities were recorded separately for each pair of females.

Some of the air spawned females were sacrificed to determine the quantity and quality of the remaining eggs. The eggs expelled by air and those left in the body cavity were fertilized by the same male and incubated in adjoining incubator trays. The eyed and dead eggs were counted to determine the percentage of eggs left in the body cavity and the quality of the eggs.

Two hundred fifty tagged, spawned out adults were released after the spawning season.

RESULTS:

Females from group one averaged 5,710 eggs per spawned fish as compared to 5,076 and 5,075 per spawned fish in the groups air spawned.

When taking into account the mortalities due to handling and the killing of green females, an adjusted figure of eggs per female is derived. This figure is more appropriate when comparing handling methods. The adjusted average was 5,434 eggs in group one, 5,039 eggs in group two and 4,839 eggs in group three.

The following table shows the numbers and percent of eye of all steelhead eggs obtained during the trial.

Group	Green Eggs per Female	Eyed Eggs per Female	Percent Eyed Eggs	Number of Females	Average Length of Females
1	5,434	4,357	80.18	439	30.97"
2	5,039	4,108	81.53	276	30.48"
3	4,839	3,766	77.82	346	31.18"

Group 1 = Killed
Group 2 = Air spawned in building
Group 3 = Air spawned in pond

Sixteen females were sacrificed in each of air spawned groups.

Data regarding these fish are listed below:

Group	Number of Green Eggs Spawned	Number of Green Eggs Remaining	Percent of Eggs Left	Number of Eyed Eggs Spawned	Percent Eyed	Number of Eyed Eggs Remaining	Percent Eyed
2	85,580	13,060	13.24	76,176	89.00	12,265	93.91
3	82,278	15,967	16.25	70,135	85.20	12,538	78.50

In addition to keeping records on individual females, all males were numbered and matings were recorded. After studying the results of the many matings, it became apparent that some of the females in all three groups produced non-fertile eggs as the percent eye from individual females varied from 20 to 95% when mated with common males.

CONCLUSIONS:

1. Sorting equipment at Dworshak National Fish Hatchery does not reduce the quantity or quality of sex products of adult steelhead.
2. Thirteen percent of the available eggs were left in the body cavity after air spawning.
3. The eggs left in the body cavity after air spawning and those removed were of the same quality.
4. Poor overall egg development was due to poor individual females and not the quality of the sperm.
5. The practice of live spawning and release of spawned out steelhead is justified when enough adults are available to produce the required amount of eggs at the lower egg per female obtained via air spawning.

HIGH VOLUME, ECONOMIC, ULTRA-VIOLET WATER PURIFICATION AND FILTRATION UNITS FOR THE HATCHERIES

Robert E. Flatow

R. E. Flatow and Company, Inc.
Berkeley, California

Filter and ultra-violet systems have been installed all over the U.S.A., Canada, Mexico and Chile during the past year, with even more and larger installations scheduled for 1972. Considerable engineering advances have been made: Larger, more economic ultra-violet purifiers up to 1000 GPM and more, with built in sampling points and in-place cleaning. Filters with eight times the capacity of 1½ years ago, requiring no more space, and even tighter filtration are already in use. 99% plus 10 micron removal is now standard, with 5 or 1 micron possible in the same units.

Parts replacements costs in the new untra-violet purifiers have been reduced more than 50%.

As, in some area, water quality presented major ultra-violet transmission problesms, testing has been improved and successful pre ultra-violet treatments have been perfected where required. Ph correction of some waters has been achieved.

Improved specifications, fair to all and easy to compare, have been developed in co-operation with governmental agencies.

New improved ultra-violet lamps have been developed. Improved water quality monitors are in production.

All equipment is available in laboratory sizes which will scale up exactly to production units.

A NEW PROBLEM - DISPOSAL OF ADULT SALMON RETURNING TO HATCHERIES

Ernest R. Jeffries

Fish Commission of Oregon
Portland, Oregon

About ten years ago hatchery problems were generally related to getting sufficient adults back for egg collection, combating serious diseases, and providing an adequate diet. Work was underway to learn more about the correct size and time to release fish and to improve other fish cultural techniques.

Because of better techniques and expanding hatchery capabilities, we now have other problems. One of these is how to handle the increased numbers of adult salmon returning to the hatcheries in order to keep both sport and commercial fishermen happy.

Since 1964, the numbers of adult salmon returning have increased making it necessary to develop several different uses for adult coho. We started transporting adults to stream areas above obstructions and since that time have transported 150,000 adult coho. Unfed fingerlings are released into lakes, reservoirs, and stream areas above obstructions. To date, about 91 million have been released. Other state agencies and federal agencies were provided over 70 million coho eggs since 1964.

Prior to 1963, we used all the adults that returned for egg taking. We gave the carcasses to state and county institutions, Indians, and some to private concerns.

In 1964, we continued to give adult salmon to state and county institutions and the Indians, but started a bid procedure for the sale of the fish. None could be used for human consumption. As numbers of fish to the hatcheries increased, many were too good for animal food or fertilizer and in 1967 the restriction for use was removed.

During the last two years we have received complaints from commercial fishermen to the effect that too many fish are returning to the hatcheries; we are in direct competition with them; this is not a state agency function; our selling salmon was the cause of the price reduction in 1971; and, that our fish are of poorer quality than commercial caught fish.

As a result of these comments we held meetings with people in many state and federal agencies who were interested in the problem and have further changed our program. The Game Commission will liberalize sport fishing regulations in selected areas. Commercial regulations will be eased if hatchery stocks can be harvested at a greater rate without endangering wild stocks. Study programs have been started to move smolts to other areas for release. We plan to move slowly in this area to make sure we maintain or increase the harvest rather than just transfer the problem to a natural stream area. Bid procedures were also modified and fish were placed in three categories with fish in the third category not to be used for human consumption.

Number of Adults By Species and Year
Handled at FCO Hatcheries, 1960-71

Year	Chinook Fall	Chinook Spring	Chum	Coho	Steelhead	Total
1960	7,945	2,227	189	30,321	700	41,382
1961	7,548	2,052	296	49,178	552	59,626
1962	8,135	4,304	249	95,675	1,641	110,004
1963	17,198	9,463	202	76,302	806	103,971
1964	15,879	8,274	134	163,606	4,202	192,095
1965	8,571	8,701	228	158,026	2,981	178,507
1966	20,430	6,229	485	145,242	5,449	177,835
1967	16,904	13,283	121	157,732	10,828	198,868
1968	11,965	13,587	50	126,798	8,815	161,215
1969	19,689	12,481	16	101,482	7,155	140,823
1970	25,474	10,969	152	159,948	3,881	200,424
1971 1/	23,705	10,404	544	98,751	5,152	138,556

1/ Incomplete

Numbers of Salmon Sold
FCO Hatcheries, 1964-71

Year	Chinook Fall	Chinook Spring	Coho	$-Received
1964	4,917	0	58,724	$ 5,072
1965	3,016	3,682	93,391	10,031
1966	17,056	3,753	85,272	20,818
1967	12,848	6,960	91,725	42,422
1968	9,262	6,479	79,094	26,266
1969	16,769	6,416	66,850	23,892
1970	22,945	4,899	136,592	65,454
1971 1/	23,274	5,423	72,896	64,940

1/ Data through November, 1971.

Pounds of Salmon Landed in Oregon/
Pounds Sold From FCO Hatcheries, 1968-70

Year	Lbs. Landed Commercial	Lbs. Sold Hatcheries 1/	%
1968	9,990,635	647,448	6.5
1969	10,932,020	625,645	5.7
1970	19,624,008	1,218,746	6.2
1971	17,330,000	819,219	4.7

1/ Estimated only

THE STATE OF WASHINGTONS'S SURPLUS SALMON PROBLEM

C. H. Ellis

Washington State Department of Fisheries
Grays River, Washington

Washington, for the past 20 years, has been increasing its salmon hatchery production.

In 1950, only 180,000 lbs. of salmon were released.

In 1960, 410,000 lbs. were released, or a little more than double the 1950 plants.

In 1971, over 3,200,000 lbs. have been, or will be, planted. Washington State Department of Fisheries, has become the largest poundage producer of artificially reared salmon in the world! This production indicates that present plants are about 18 times the 1950 plant and 8 times the 1960 plant.

This has led to problems of excess escapement to hatchery streams. In 1970, an all time high of 600,000 adult salmon returned to the Department's hatchery racks.

Less than 20% of this number, or approximately 100,000 fish were needed for the Departmental hatchery program, plus another 100,000 for stream escapement and thereby a large surplus of salmon existed.

In 1970 the Department, through bid calls, contracted with commercial fish companies to sell surplus salmon and as a result over 3,800,000 lbs. of salmon were sold and another 216,000 lbs. donated to Indian Tribes and welfare agencies. Sales of the 1970 surplus amounted to more than $364,000.00.

This large number of surplus salmon entering the commercial trade created objections from the fishery trades people. They contended that such large sales impacted their market prices.

As a result of the objections of the trades people, meetings were held in 1971 with representatives of fishermen, fish canneries, and other agencies such as the State of Oregon, U.S. Food and Drug, Department of Agriculture, etc. to determine what would be the best use of surplus salmon and what standards were to be observed.

In discussions, it was pointed out that the surplus factor should not be as impactive on the market as many contended. Of a representative population of salmon reaching maturity, 84% were caught in the various fisheries, and of the remaining 16%, only approximately 3% reached the market in the category of being fit for human consumption.

Objections against sale of carcasses still persisted. In May of 1971, the Washington Legislature passed a resolution that surplus salmon from the State of Washington sockeye run be distributed to welfare agencies, state institutions and disadvantaged peoples.

Following the spirit of the Legislative action, the Department proceeded to negotiate with the Washington State Department of Social and Health Services, private enterprise and the Washington National Guard to effect the hauling and canning of surplus salmon. These were to be eventually distributed to welfare agencies throughout the State.

On September 15, 1971 a contract was issued by the Department of Social and Health Services to a canning company to pick up and can surplus salmon for welfare purposes. As a part of the contract, it was stipulated that all eggs would be removed from females before leaving the hatchery. The hatcheries' personnel removed and bagged excess eggs which were marketed separately at prices in excess of $1.00 per pound.

Results of the 1971 approach had a considerable difference in the disbursement of excess carcasses. As of November 27, 1971 a total of 1,379,075 lbs. of salmon have been donated and sold. In addition, 66,324 lbs. of eggs have been bagged and sold.

Of the 1,379,075 lbs. involved to November 27, 1971 there were:
821,986 lbs. consigned to the canned fish welfare program
334,998 lbs. were allotted to Indian people
129,445 lbs. were allotted to prisons, schools, training schools, etc.
92,646 lbs. were sold to dealers prior to execution of the canning contract.

The sales realized from such procedures were drastically below the $364,000 of 1970. Sales to November 27, 1971 will probably not exceed $85,000.

With emphasis on added hatchery production and a continuing increase in survivals of those salmon released, the problem of excess salmon arriving at hatchery racks will be a problem that will require continuous resolution in the future.

Recap - Two Years of Salmon Carcass Distribution - 1970 & 1971

Washington Department of Fisheries

Year 1970

Carcasses sold:

For human consumption	1,373,663
For animal food	2,498,808
Total sold	3,872,471 lbs.

Carcasses donated:

To Indians	124,586
Schools and Institutions	91,415
Total donated	216,001
Grand total carcasses (1970)	4,088,472 lbs.

Year 1971 (to November 27 only)

Carcasses sold:

For human consumption	92,646 lbs.

Carcasses donated:

To Indians	334,998
Schools and institutions	129,445
Welfare canning program	821,986
Total donations	1,286,429 lbs.
Eggs sold:	66,324 lbs.
Grand total carcasses* (1971)	1,379,075 lbs.
Grand total eggs - 1971	66,324 lbs.

* To November 27, 1971 only

ANADROMOUS FISH ARE RETURNING

Paul Handy

Bureau of Sport Fisheries and Wildlife
Division of Hatcheries
Portland, Oregon

Thirteen of the twenty-one production hatcheries operated by the Fish and Wildlife Service in the Pacific Northwest Region have anadromous fish returning. In fiscal year 1971 more than one million pounds of salmon and steelhead returned to these thirteen facilities. Approximately 70 percent of these fish were either given to local Indian Tribes for their use or, as in the case of steelhead, were returned to the water. The remaining fish, 375,000 pounds, were sold as dog and cat food at not more than 2¢ per pound.

We in the Division of Fish Hatcheries feel that to sell these fish as dog and cat food, is a waste of a high quality protein. In addition, we believe that by selling these carcasses for human consumption a greater revenue would be realized. This revenue could then in turn go toward hatchery operation or be returned to the Federal General Fund. Regardless of where it would be funneled it would be to the advantage of the taxpayer.

In an effort to accomplish this we have requested a policy change within the Department of the Interior and as of this date the request is still under review. Secondly guide lines have been obtained from the Food and Drug Administration as to how these fish must be handled to meet their regulations concerning products which are to be sold for human consumption. These regulations can be met with no significant change at our facilities.

The progress to date has been zero. The Department is reluctant to change the existing policy as there are those who feel we would be in direct competition with the commercial fishing interests. We do not show this feeling as we do not believe the poundage sold by these hatcheries would adversely affect the market. We will continue our efforts along the present line until advised officially.

JOB ACCOUNTING AT A SALMON HATCHERY

John G. Clayton

Washington Department of Fisheries
Klickitat State Salmon Hatchery
Glenwood, Washington

One of the major costs of hatchery operation is for labor yet, in most instances, the cost for fish culture versus other hatchery work is unknown. Acceleration of fish culture activities, economies in hatchery operation and the limited manpower, recent evaluation of runs of fish, and specific species of fish have made the demand for efficient labor utilization important. Labor costs have, in general, been considered much less carefully than other records of the hatchery's operation. Efficient labor utilization can only be achieved by a comprehensive coverage of all phases of the manpower expended or by job accounting.

In 1967, the personnel at Klickitat Salmon Hatchery initiated a job accounting program to study labor costs to improve utilization of labor. The study was to: (1) indicate areas of non-productive labor; (2) reduce or eliminate such labor by improved methods; and (3) provide data that could be used for cost studies.

To initiate job accounting, a list of the many different activities was placed on a report form. Basic requirements of this form were simplicity and accuracy so that a minimum of time would be involved for each man in recording his day's activities, and the resulting data would be factual and usable.

The report was divided into three main areas of activity - Fish Culture, Maintenance, and Leave (annual, sick and compensatory) with 49 work categories. Each eight-hour day was divided into 32 units of 15 minutes each.

The results of this study, after completing four years, has met all of the original objectives. There are areas of labor that do not relate directly to rearing fish but are essential to the overall operation of the station. These could not be eliminated; however, man hours to do these jobs were reduced by better planning, better equipment, or improved methods.

In the first year of the study, only 45.8 percent of labor was categorized as fish culture. Station maintenance required 41.7 percent, and leave time accounted for 12.5 percent of the total man hours. These percentages have varied over the four years with an average of 51.2 percent for fish culture, 38.6 percent for maintenance, and 10.2 percent for leave.

The study has been an aid in meeting the demand for increased production. The 1971 poundage produced is some 95,000 pounds or 106.9 percent more than the 1967 poundage. Consideration for an increase in production must be weighed by the records of past pond loadings, waterflows, and monthly poundage on hand to determine the hatchery's capacity to handle any increase. By referring also to the job account record, and calculating the labor hours involved, one can estimate the labor capabilities, then estimate the total increase in production. In 1971, based on the time spent feeding and picking loss, spring chinook average 71 pounds of fish produced per man hour expended, 72 pounds for coho, and 28 pounds for fall chinook.

The 1971 production summary illustrates the difficulty encountered for the evaluator of a group of fish when more than one species is reared on a station. Varying numbers and pounds of fish produced, time, and difficulty of rearing are all factors that contribute to labor hours spent.

In addition to the station benefits, Klickitat job accounting data has been used by the Fish and Wildlife Service and the Oregon Fish Commission in their studies.

With the demand for information, no evaluation of the future species can be complete without species costs from each hatchery.

Table 1

Percentage of Time For Fish Culture, Maintenance and Leave By Year

Year	Fish Culture	Maintenance	Leave
1967-68	45.8%	41.7%	12.5%
1968-69	46.7%	44.3%	9.0%
1969-70	52.1%	35.9%	12.0%
1970-71	60.2%	32.5%	7.3%

Table 2

Total Pounds of Fish Produced 1967 to 1971

Year	Total Pounds of Fish	Pounds Per Man
1967	89,244	17,848
1968	113,022	22,604
1969	145,909	29,181
1970	136,683	27,336
1971	184,664	30,777

Table 3

The 1970-71 Breakdown of Hours For Each Catagory			
Fish Culture Hours		Maintenance Hours	
Feed Spring Chinook	1,166.0	Clerical-Operations	440.50
Feed Coho	799.25	Repair Bldg.	415.50
Size Fish	716.0	Repair Equipment	389.25
Clean Ponds	622.75	Misc. Operations	381.0
Transfer Fish	538.0	Build Equipment	338.0
Mark Fish	429.0	Grounds Maintenance	262.25
Clerical-Fish Culture	349.50	Paint Equipment	260.50
Feed Fall Chinook	338.0	Snow Removal	213.75
Transfer Eggs	326.50	Paint Buildings	213.50
Pick Mortality-Sp. Chinook	288.25	Pickup Supplies	188.0
Pick Egg Loss	231.0	Road Maintenance	162.0
Pick Mortality-Coho	221.75	Lawn Care	157.75
Misc. Fish Culture	190.25	Clean Buildings	143.50
Spawn Fish	170.0	Training School	120.50
Sample Fish	159.25	Clean Equipment	66.0
Release Fish	129.0	Service Equipment	48.50
Clean Baskets-Trays	120.75	Repair Screens	38.50
Public Relations	99.75	Haul Garbage	37.0
Treat Sick Fish	71.50	Repair Ponds	28.0
Unload Feed	68.0		
Clean Fry	53.50	Leave Hours	
Fish Trap	47.50		
Pick Mortality-Fl. Chinook	38.50		
Treat Eggs	14.50	Annual	548.0
Disinfect Ponds	10.0	Sick	190.0
Check Intakes	5.0	Compensatory	129.50

Table 4

Klickitat Hatchery Production Summary
July 1, 1970 to June 30, 1971

Species	Lbs. of Fish	Per Cent	Man Hours	Per Cent	Total Released	Per Cent
Sp. Chinook	62,207	33.6	875	43.2	1,335,963	16.6
Coho	110,427	59.7	799	39.6	1,753,328	21.8
Fl. Chinook	12,030	6.7	348	17.2	4,945,924	6.15
Total	184,664		2,022		8,035,215	

LASER AND FREEZE MARKING OF SALMONIDS AND CRUSTACEANS FOR INDENTIFICATION

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In spite of efforts by many workers in the field of animal identification, the pressing need is still for an inexpensive and simple means of identification. On our ability to identify fish simply, effectively, and without influencing survival, will depend the future success of migration studies, fisheries management, and international fisheries agreements. The present report concerns itself with the use of laser beam marking, which has the potential of being developed into a highly automated marking system capable of operation at rates of three fish per second or more, and with the use of the freeze marking systems.

Recent detailed studies of the freeze marking process reveals that:

1. marks applied must be observed for periods of at least four months before end state resolution of the mark can be observed,
2. the use of severe freezing, such as liquid nitrogen or dry ice and alcohol marking, if not carefully controlled, will invariably result in excess scar formation and disappearance of the mark applied,
3. the use of wide symbols in marking prevents the complete disappearance of all but the most severely damaging freeze marks, and
4. the optimal marking system evaluated thus far is one which employs round edged symbols 1/8 inch wide, with at least 1/4 inch depth applied for approximately 1 and 1/2 seconds at a temperature of -40^{o}F (=s-40^{o}C).

The results of various freeze marking procedures have been observed for as long as one year and a half, and field trials of various methods have been undertaken.

The use of Freon 22 and Freon 12 for portable, field marking systems for both Salmonids and Crustaceans utilizing both conventional and sponge marking has been evaluated.

Experiments with the laser beam included studies of the effects of infrared, red, green and ultraviolet wave lengths on steelhead trout. Consistent marks were produced by a variety of methods; however, the most practical technique consists of using 5.3 joules of red laser in a beam one inch in diameter applied while the fish is submerged in water. The water-skin interface allowed penetration of the beam such that destruction of the major pigment cell layer occurred. Resolution of the mark thus applied over a four month period resulted in a highly visible mark with little or no disturbance of the overlaying epidermal layers. The system requires field testing, and projects are currently being undertaken.

SUMMARY OF COHO CONTRIBUTION FROM PUGET SOUND AND WASHINGTON COASTAL HATCHERIES

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Using the 1964, 1965 and 1966 brood coho, the Washington Department of Fisheries studied the contribution and return from eleven Puget Sound and three coastal salmon hatcheries.

Paired fin marking was used to identify 10% or more of the fish produced at each hatchery. Because of the shortage of paired fin marks, a common mark was often assigned to 3 or 4 hatcheries lying within close proximity.

The average production from each of the 14 stations approximated just under one million 14-month-reared coho smolts. The average smolt size was 20 fish, 1 pound or 23 grams per fish. The release site, except on special studies, was directly from the hatchery ponds and made approximately 25 days prior the peak migratory period.

A few of the highlights follow:

1. Distribution: The catch of Puget Sound hatchery coho occurred largely north of the Columbia River, south of the central coast of Vancouver Island and to a lesser degree in Puget Sound...coastal released coho were mainly caught in an area along the northern Oregon coast, Washington coast, and southern Vancouver Island.

2. Total Survival to Adult: The percentage of fish caught plus those escaping averaged 8 percent at five southern Puget Sound stations; approximately 4 to 6 percent at Hood Canal, northern Puget Sound, and Willapa Bay stations. Coho from a hatchery in the Grays Harbor drainage survived at a level approximating 2 percent. (Pollution problems are suspected).

3. Catch to Escapement: The catch to escapement ratio on Puget Sound coho varied between years from about 3:1 to 4:1. Generally on coastal coho a higher ratio (4:1) can be expected.

4. Harvest: Of the adults caught in the fishery 50 percent of the Puget Sound adult coho entered the troll fish while 60 percent of the coastal adult coho entered the troll catch; approximately 13 percent and 20 percent respectively entered the sport catch; while 37 percent and 20 percent respectively entered the gill net fisheries.

5. <u>Benefit: Cost</u> The benefit: cost ratio averaged 3;1 but varied between groups of hatcheries from less than 1:1 to greater than 4:1.

6. <u>Miscellaneous Findings</u>:

a) Fin marked coho were 10 percent smaller than non-marked hatchery coho.

b) The gill net fishery were selective to coho of a larger size allowing greater escapement of smaller fish.

c) The environment into which fish are released greatly effects their ocean survival. Southern Puget Sound hatcheries survive "50 percent" greater than Hood Canal or northern Puget Sound stations.

d) The marine environment appears to effect both survival and distribution from a year to year basis.

e) A direct salt water liberation of coho smolts did not enhance survivals; did not greatly concentrate adults in the release area; but appeared to change their marine distribution.

f) The transportation of "smolt" coho to nearby streams altered their survival and changed their ocean distribution.

g) The transportation of smolt coho around an environmental block can increase their contribution.

h) Hood Canal coho stocks reared and liberated in Puget Sound survival equally as well as local stocks; and Southern Puget Sound coho stocks when liberated in Hood Canal also survived similar to local stocks.

NOTE: Three progress reports have been published covering most of the above points along with many others.

COST ANALYSIS OF REARING FIRST EGG COLLECTION IN REUSE SYSTEM VERSUS RAW WATER

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The reuse system at the Dworshak National Fish Hatchery is the first large installation to be built. Twenty-five ponds are included. Ten percent makeup water is introduced after having passed through an electric grid, pressure sand filters, and U.V. filters. This water is heated or cooled as the case may be to achieve the desired temperature within the system. The source of all water at this hatchery is the North Fork of the Clearwater River. The temperature ranges down to 32°F in mid-winter to a high of 75°F in midsummer. All the water used is pumped. It will immediately become apparent that any data available would be applicable to only hatcheries with similar water supplies and climate. At this station, fish reared in the raw water take two years to reach smolting size and those reared in the reuse system require less than one year. Prior to November of each year, the entire group of fish are incubated and reared in controlled temperature environment because of the lethal temperature experienced during the first summer. The costs up to this time should be the same for both lots.

The first collection of steelhead trout eggs of the North Fork of the Clearwater strain occurred during late April and May, 1969. After complete rearing of this year class, approximately equal numbers of fish reared in the reuse system and those reared in raw water had been reared to smolting size. This provided some basis for a cost analysis for the two systems.

The attached table shows the calculated costs of those items which were most readily available from the production records of the Dworshak operations. The electrical energy consumption was based on the pumping required for the two systems over the time each was in operation calculated on electrical consumption and demand for the pumps in use. The oil was calculated as that of the oil used for heating the reuse system.

No accurate estimates were made of the labor involved in rearing the two groups of fish although a general conclusion can be drawn that labor costs are considerably more for rearing a given group of fish two years instead of one. No calculation has been made of the relative applicable costs of rearing space use. The one year rearing results in a more efficient use of space.

Table - Summary of Costs of Rearing First Year Egg Collection at Dworshak National Fish Hatchery

No. Fish at Start	1,437,148	1,901,448
No. of Fish at Release	1,371,543	1,340,366
No. of Fish/lb. at Start	60.1	81.2
No. of Fish/lb. at Release	7.22	5.62
Length of Fish at Release	7.4"	8.3"
Wt. of Fish at Start	23,893	23,430
Wt. of Fish at Release	189,871	238,209
Gain in Weight	165,978	214,779
Percent Mortality	4.5%	29.5%
Total Food Fed	270,425	461,768
Conversion	1.63	2.14
Cost of Fish Food at $ 0.12/lb.	$32,451.00	$55,451.00
Energy Costs		
Electrical (pumping)	$5,000.00	$18,000.00
Heating (oil)	$35,000.00	
Total Costs of Energy & Fish Food	$72,451.00	$73,412.00

PROGRESS IN EVALUATING FISH FEEDS ON THE BASIS OF DIGESTIBILITY AND METABOLIZABLE ENERGY CONTENT

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The purpose of this report is to present some typical data from tests to determine metabolizable energy and digestibility of feed materials and of complete feeds. The objectives are to identify those materials which can best be utilized by fish.

Some typical data are presented in the table. Feeding trials have shown a close correlation between growth of the fish and the digestibility and metabolizable energy of the diets.

	LAB ANALYSIS		DIGESTION COEFFICIENT			
	Crude Protein %	Gross Energy kcal/gm	Protein %	Energy %	Dig. Protein %	M. E. kcal/gm
Lab Test Diet	54.8	5.06	89	90	46	4.33
Fish Meal	70.1	4.64	85	84	59	4.54
Poultry By-Products	68.5	5.08	75	72	51	3.48
Dry Skim Milk	65.4	4.95	90	87	60	4.30
Corn Gluten	50.6	5.24	45	43	24	2.26
Soy Bean Meal	55.5	4.77	81	87	45	4.15
Production Diet #1 Sample A	49.9	4.96	68	64	34	2.85
Sample B	47.5	4.53	67	65	32	2.74
Production Diet #2						
Sample A	46.9	4.92	83	85	39	3.92
Sample B	50.1	5.04	82	82	41	3.93

STANDARD DESIGN LIBERATION TANK CUTS COST

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I General facts regarding design practices agreed on by State and Federal Governments.

A Tank core should be rectangular
1. Allows more bottom area for proper fish disbursement.
2. Allows more water surface area exposed to atmosphere for CO^2 disbursement.
3. Cuts depth of water per gallon to allow easier netting of fish during multiple stop liberation procedure.

B Duel suction and duel discharge lines the total length of the tank are desirable
1. Provides even pickup on suction side throughout the entire length of the tank on both sides.
2. Provides spray discharge both sides top to assist agitation and remove CO^2 build up.
3. When atmospheric injection provided in discharge provides oxygen build up.

C All tanks must contain baffles
1. Provides safe operating conditions.
2. Provides compartments where desirable.
3. Provides structural strength to metal cores.

D All tanks must contain suction screens
1. Provides low velocity entrance of return water.
2. Utilization of 1/8" diameter perforations provides complete flexibility of fish size being hauled.

E Discharge troughs in tank bottom desirable
1. Provides complete flexibility in handling fry or adults.
2. Utilized primarily to position adults entering discharge outlet.
3. Note of caution: Proper agitation must be maintained in this area to maintain oxygen level.

F Multiple hatches are desired
1. Accessibility into all compartments or areas for liberation and observation.

G Insulation in all cases
   1 Provides minimum heat gain.
   2 Provides minimum sound level.

G Exterior metal sheeting a must
   1 Provides insulation moisture barrier.
   2 Provides insulation protection from gouging and crushing.
   3 Provides air wipe barrier to cut heat transfer.
   4 Provides reflection barrier to cut heat transfer.

I Large discharge opening best
   1 Provides complete utilization of tanker regardless of fish size.
   2 Note: Reducer must be utilized in small fish handling due to liberation conduit for convenient handling size.

J Quick action outlet gates of smooth bore required
   1 Provides positive release.
   2 Provides minimum damage to fish.
   3 Note: Pneumatic gate desirable when air available from truck or tractor.

K Diesel powered mechanical equipment desired
   1 Provides low cost fuel.
   2 Low fuel consumption.
   3 Low maintenance.
   4 Minimum electrical wiring.

L Refrigeration desired
   1 Provides even temperature drop.
   2 Provides heating prior to liberation where needed.
   3 Eliminates contact shock, crushing and cube utilization caused by ice.

M Auxillary pumping system desired
   1 Back up system if main pumping system fails.
   2 Where atmospheric injection used provides oxygen.
   3 Keeps CO^2 build up from occuring.

N Oxygen injection system desired
   1 Used as main system provides all oxygen requirements.
   2 Used as back up system provides all oxygen required if mechanical failure develops during haul.
   3 Note: Liquid oxygen is proving more desirable due to limited refrigeration effect acquired and size of cylinder to capacity ratio.

O Tank capacities desired
   1 1,000 gallon-Truck
   2 1,250 gallon-Truck
   3 1,500 gallon-Truck
   4 3,500 gallon-Semi

II Facts concerning design, fabrication, application and cost

A Basic sizes are standard
1 1,000 gallon
2 1,250 gallon
3 1,500 gallon
4 3,500 gallon

B Standards should be utilized in all cases
1 Tank core sizes and shapes should remain unchanged.
2 Insulation thickness should remain the same so exterior configuration is not modified.
3 Power supply units (engines) should be of same manufacture if possible.
4 Standard forms and shapes (angles, channels, etc.) should be utilized.
5 Standard steps, latches and metal thickness should be utilized.
6 Unitized liberation tank assemblies for easy chassis exchange. (All equipment mounted to tanker frame rails).

C Variations in design acceptable in fabrication
1 Different combinations of equipment desired such as oxygen, refrigeration, pneumatic gates and valves, hatches or doors, auxillary pumping, etc.
2 Improvements in fabrication techniques or mechanical equipment and apparatus.

D Cost saving factors
1 Buy standard manufactured liberation trucks and semi units to eliminate engineering costs. A special unit normally incurs a minimum engineering cost to the State or Federal Government of $3,000.00 to $5,000.00 and a minimum cost to the manufacturer for working drawings and engineering of $5,000.00 to $8,000.00. This cost totals $8,000.00 to $13,000.00. These figures can be cut to $1,000.00 to $2,000.00 engineering cost if standard tanks are utilized and only equipment changes etc. are made.
2 Buy from experienced and reputable firms with at least 5 years minimum experience in design. This is, in many cases, hard to do. However, companies must have a working knowledge of the entire system so it will perform when delivered to the agency, and should it not it is the company's responsibility to make it work. It is a common occurrence for a not familiar company to take a contract and be unable to produce a working unit. This type activity creates ill will, customer dissatisfaction and even company failure along with a definite cost to the agency.

III Recap

A All liberation tanks perform the same function with basic mechanical components.

B It makes good sense to buy standard manufactured tankers and alter the mechanical apparatus to fit your needs prior to construction.

C Place the operational responsibility where it belongs - With the manufacturer.

D Save thousands of dollars in engineering costs being duplicated in a non-required variation of tank sizes. This applies both to the agency and the manufacturer.

E Give the manufacturer ample time to complete your project.

F If these guidelines can be followed we should all have a much better product, better ecological surroundings and more pleasant business relationships.