PROCEEDINGS

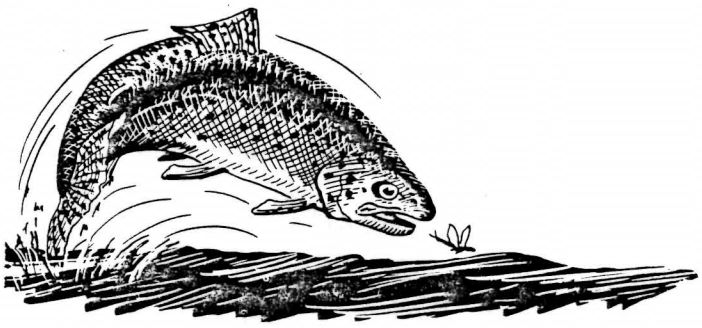
OF THE

THIRTY-FOURTH ANNUAL

NORTHWEST FISH CULTURE WORKSHOP

MOSCOW, IDAHO

DECEMBER 6-8, 1983



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THE NORTHWEST FISH CULTURE WORKSHOP

Northwest Fish Culture Workshops are informal meetings for exchange of information and ideas concerning all areas of fish culture. Current progress reports of managemant practiees and problems, new developments, and research studies are presented. Active discussion and constructive criticism are encouraged and furnish highlights of the conference. All persons interested in or associated with fish husbandry are invited to attend and to participate. Subject material is limited to topics that have direct application to fish culture.

The PROCEEDINGS contain unedited briefs or oral reports presented at each conference. Much of the material concerns progress of uncompleted studies or projects. THESE INFORMAL RECORDS ARE NOT TO BE INTERPRETED OR QUOTED AS A PUBLICATION.

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EFFECT OF SIZE AT RELEASE ON ADULT RETURNS OF COWLITZ HATCHERY SEA-RUN CUTTHROAT

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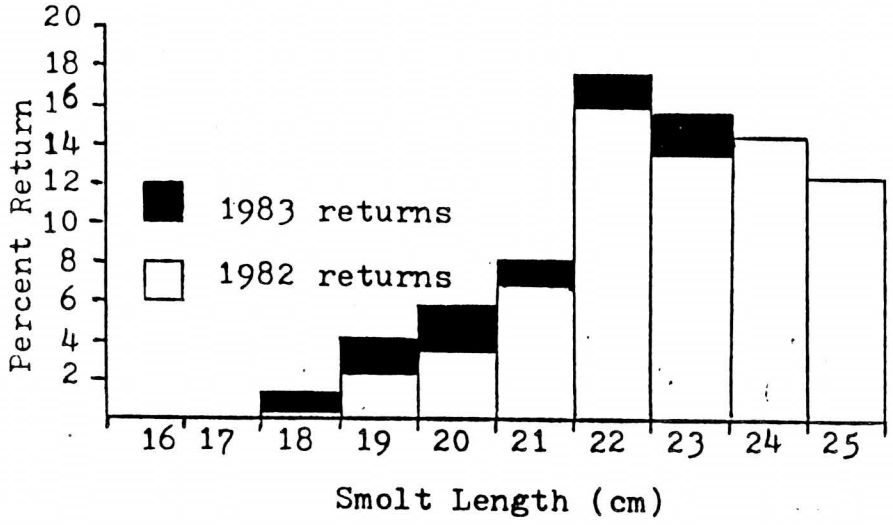
The size at release parameter was examined for Cowlitz hatchery sea-run cutthroat. In 1981 it was discovered cutthroat smolts averaging 5.5 and 4.5 fish per pound had 3.2 and 5.2 percent return, respectively, while smolts over 20 cm (fork length) which were marked with a small green Floy-anchor tag had 9.2 percent return.

In 1982 and 1983 an effort was made to determine optimum release size of hatchery cutthroat smolts. In 1982, approximately 200 fish at each centimeter length group from 16 to 25 centimeters (10 groups) were marked with numbered Floy tags about 3.5 cm in length. In 1983, 175 fish at each centimeter length group from 18 to 23 cm (six groups) were tagged at release. Smolts in each year were released about mid-April.

For those not familiar with the life history of sea-run cutthroat, fish are believed to return to freshwater each summer or fall and do not over-winter in the ocean. Not all returning fish are mature on initial migration and different stocks appear to have varying maturity rates. Males generally mature slightly sooner than females on the average. It takes two years to gather data after smolts are released.

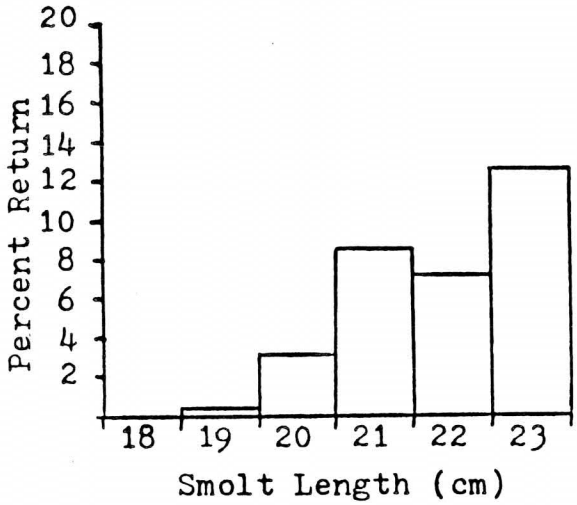
Return rates from the 1982 release, gained from sport and hatchery returns, show a definite advantage for smolts 22 cm and larger. Return for smolts greater than 22 cm was 14.0 percent on initial migration while only 2.2 percent for those smaller. Only two tagged fish in the 16 to 17 cm group were observed; residualizing near the release site several months later.

In the following year, 1983, return showed no large size related advantage although percent return was much diminished over initial migrant returns. On this basis, smolts 22 to 23 cm appear to be the best release size.



ADULT RETURNS FROM 1982 RELEASE

The 1983 initial migrant return, although not complete for the year, showed similar results as in 1982; a survival advantage was gained by smolts exceeding 22 cm. Return for smolts 22 cm and over was 10.3 percent and 3.4 percent for those smaller.



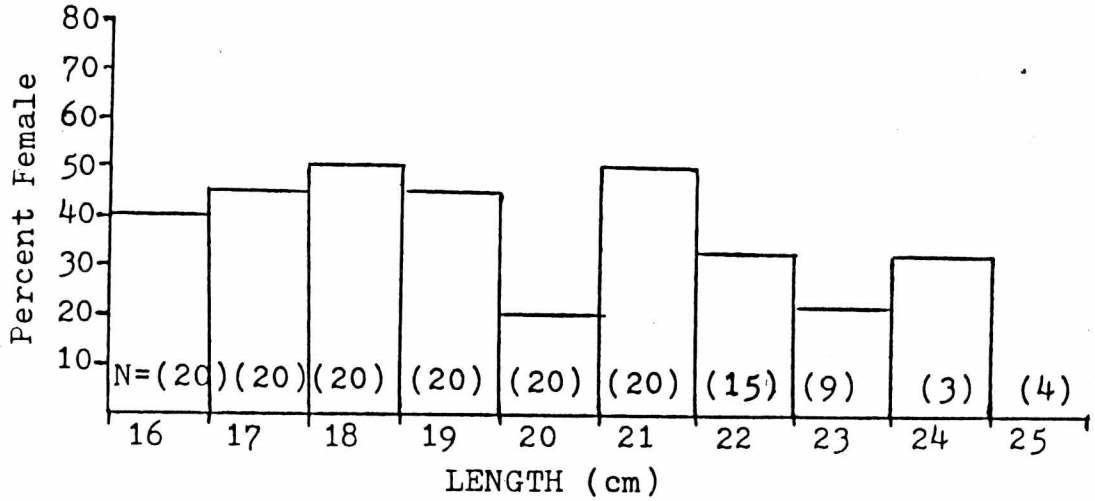
ADULT RETURN FROM 1983 RELEASE

Tag induced mortality is thought to be low because of the results observed and the study of Eames and Hino (1983) which found no effect of Floy tags on growth or survival of chinook salmon over 15 cm.

The Cowlitz hatchery cutthroat program nearly failed through the mid 1970s until smolts were reared in the 5-acre rearing ponds at the hatchery. Pond rearing of fish allowed smolts to reach a broad spectrum of sizes. It was thought rearing environment was responsible for improved hatchery returns but hatchery records prior to 1976 showed an average release size of 10/lb or 16.5 cm. The 1982 release of cutthroat had an average length of 21.7 cm, the largest in at least four years, and was accompanied with the best adult return ever observed since the hatchery began operation.

Inital migrant maturity rates based on tag returns from the 1981 release were 85.3 percent for males and 63.6 percent for females. At this time for the 1982 release, initial migrant maturity was 88.3 percent for males and 80.0 percent for females. Sport harvest accounted for a minimum of 17.6 percent of return from the 1981 release and 24.2 percent of return from the 1982 release.

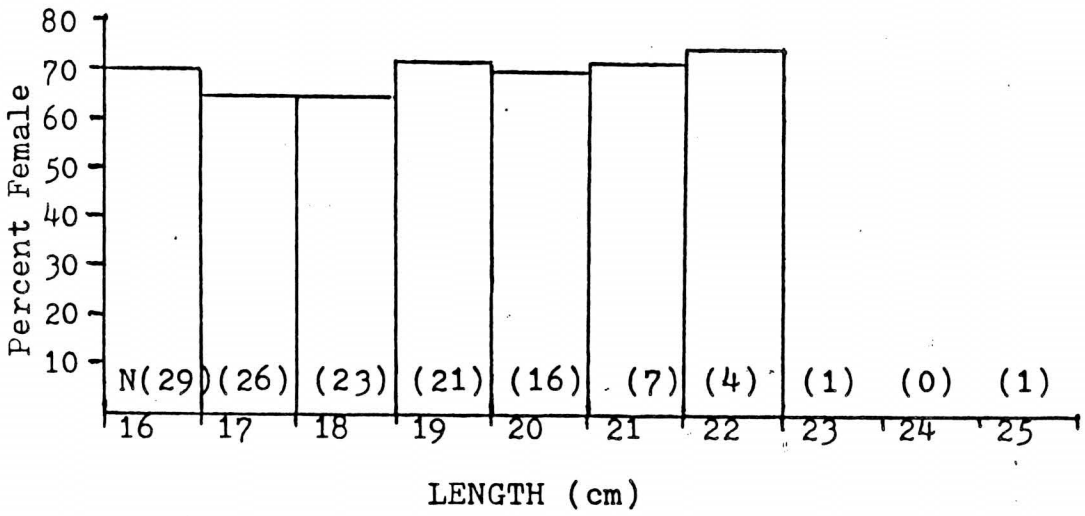
A phenomena observed with returns of Cowlitz hatchery cutthroat is males outnumber females about three to one every year. A total of 151 smolts with lengths varying from 16 to 25 cm were sacrificed to determine sex. Males accounted for 61.6 percent. There is a strong possibility males are larger smolts. However, an adequate sample size of larger smolts was not obtained in 1983. Washington (1982) found male coho smolts to be larger in many stocks he examined. Hager and Noble (1976) found males dominating in larger coho smolts.



Sex composition of smolts, 1983.

Mean length of residual cutthroat was examined in 1981, 1982, and 1983. Samples were gathered using hook and line about three months after release. As shown in other studies (Royal,1972, and Buchanan et al., 1981), residuals were significantly smaller in length than smolts released. In each year, mean length of residuals was about 19 cm. In 1983, sex of 127 residuals ranging form 16 to

25 cm were comprised of 67.6 percent females.



Sex composition of residuals, 1983.

So contributing to the sex ratio favoring males at the hatchery include: 1) larger smolts have better survival 2) mean length of male smolts may be larger 3) small smolts tend to residualize and 4) residuals are mostly females.

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OVERVIEW OF THE LOWER SNAKE RIVER FISH AND WILDLIFE COMPENSATION PLAN

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John S. Hanson

In 1945, Congress authorized construction of four projects on the Lower Snake River, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite locks and dams. The first dam was completed in 1961 and the fourth in 1975. While major salmon and steelhead losses were predicted, neither the Project's enabling Act, nor the general plans presented to Congress made mention of fish and wildlife resources. Nevertheless, initial efforts were made to maintain the anadromous fish resources at the Lower Snake River Projects, and some $52 million was spent for facility construction and research and development.

At the request of the Corps, a special report on the impact of the lower Snake River dams was prepared in 1972 by the Fish and Wildlife Service and the National Marine Fisheries Service, the report indicated that anadromous fish populations in the Snake River system had decreased by half in just ten years of operation of the dams. By 1977, direct dam-related losses to Northwest fisheries exceeded $35 million annually. Major summer and fall chinook salmon runs, spring chinook salmon runs, and summer steelhead runs were reduced to a fraction of their former abundance.

To compensate for the Project's fisheries losses, Congress authorized the Lower Snake River Fish and Wildlife Compensation Plan (LSRCP) as part of the Water Resources Development Act of 1976.

The essential elements of the Compensation Plan include: 1) authorization for construction and operation of hatcheries and other fishery facilities necessary to restore fall, spring, and summer chinook salmon and steelhead trout runs to "compensate for . . . losses" caused by the dams (these facilities are required to produce 9,160,000 fall chinook, 6,750,000 spring and summer chinook; and 11,020,000 steelhead smolts annually); 2) facilities to produce 93,000 pounds of trout annually to restore the resident fishery; and 3) acquisition and development of project and other lands for public access and habitat development. The Plan established that fishery mitigation facility construction, operation, and maintenance costs are made necessary by the power production feature of these projects and must be reimbursed to the treasury from power sales revenue. Bonneville Power Administration must adjust rates for sale of electric power from the Columbia River Power System to include the costs of planning, operating, and maintaining fishery resource compensation facilities.

Construction responsibility for the LSRCP was assigned to the Walla Walla District, U.S. Army Corps of Engineers (Corps), while responsibility for fisheries operation and maintenance funding (O & M) was to be accomplished by "one of the Federal fisheries agencies". (Responsibility for O & M for wildlife programs remains with the Corps). The question of O & M funding for fisheries was settled in 1977 with the signing of an interagency agreement by the Corps, National Marine Fisheries Service, and FWS, stating that the FWS would budget for and administer O & M for LSRCP fisheries programs.

The Corps estimated costs for development of the authorized Compensation Plan are $177 million for off-project features, while FWS estimated annual costs for fish facilities O & M are $8.4 million annually.

Operations and maintenance for LSRCP was administered by the FWS Boise Area Office from 1977 until that office closed on September 30, 1982. At that time, the LSRCP Office was established in Boise as a separate office. The Boise office is responsible for field administration of the program. The office exercises line and staff functions and other duties for FWS Compensation Plan activities in the field.

The LSRCP hatchery program requires expansion or construction of twelve hatcheries and numerous satellite facilities in Idaho, Oregon, and Washington. Idaho Department of Fish and Game will operate four hatcheries, Oregon Department of Fish & Wildlife three hatcheries, Washington Department of Fisheries one hatchery, Washington Department of Game two hatcheries, and Fish and Wildlife Service two hatcheries.

The program is expected to return 18,300 fall chinook adults, 58,700 spring and summer chinook adults, and 55,100 steelhead adults back to the project area, and to produce 93,000 pounds of trout annually to replace lost resident sport fisheries in Washington and Idaho.

Hatcheries involved in the program include:

Clearwater State Fish Hatchery - Idaho will be located across the North Fork of the Clearwater River from Dworshak NFH. It will be designed to produce 1.4 million spring chinook smolts weighing 91,000 pounds and 2.5 million steelhead trout smolts weighing 350,000 pounds. The production is expected to return 12,200 spring chinook and 14,000 steelhead adults back to the project area.

The facility is currently under design, and is scheduled for completion in 1987 at an estimated cost of $35,000,000. It will be operated by the Idaho Department of Fish and Game.

McCall State Fish Hatchery - The McCall State Fish Hatchery Expansion was completed in July, 1980, at a cost of $5,053,000. The hatchery is located on an Idaho Department of Fish and Game (IDF&G) owned hatchery site in McCall, Idaho. Hatchery water is delivered to the site through a pipeline from Payette Lake. A minimum flow of 15 cfs at seasonal water temperature ranging from 35° F to 50° F is available.

The hatchery includes an intake structure and submarine intake pipe into Payette Lake; hatchery building with incubators and short term rearing tanks, food freezer, mechanical and electrical rooms, shop area, and covered vehicle storage; two outside rearing raceways; settling ponds for fish waste discharge; three residences; office/dormatory, and visitors center with public restrooms.

The hatchery has the capacity to rear 1,250,000 summer chinook salmon smolts to a size of approximately 17 fish per pound, and a weight of 74,000 pounds for distribution to the South Fork of the Salmon River. The production is expected to return 8,000 summer chinook adults to the project area. A state funded trout program is also maintained at the hatchery concurrent with the LSRCP program.

The hatchery is operated by the IDF&G. A satellite station is located on the South Fork of the Salmon River. The station provides for adult trapping, holding, and spawning. The eggs are transported to the McCall hatchery facilities for incubation. Approximately two million summer chinook eggs are required for the hatchery program.

Magic Valley Fish Hatchery - Construction of the Magic Valley Hatchery is scheduled for completion in April, 1986. The site is located on a former commercial hatchery site near Buhl, Idaho. The hatchery has a water right for 125.5 cfs of 59° F water from Crystal Springs.

The facility will include water intake structures and pipelines; sixty-four 10' X 100' concrete raceways; mechanical feeding system utilizing a traveling bridge; settling basin for hatchery wastes; hatching building with forty tube type incubators, twenty 4' X 40' short-term rearing tanks, food freezer, mechanical and electrical rooms, chiller for cooling smolt transportation water, and visitors area with public restrooms; shop area and covered vehicle storage; four single-family residences; office/laboratory structure (with temporary help housing), visitors orientation center; and consideration for power generation. None of the existing commercial hatchery facilities are suitable for use at the new site.

The hatchery is designed to rear approximately 1,457,500 steelhead smolts to a size of five fish per pound, and a weight of 291,500 pounds. The production is expected to return 11,660 steelhead adults to the Snake River Basin.

Satellite facilities for adult trapping and holding are located at the Sawtooth Hatchery, and East Fork Salmon River Satellite Facility. Sawtooth hatchery will also provide for egg incubation into the late stages of egg development. Approximately three million eyed eggs will be required for the hatchery program.

Sawtooth Hatchery - Sawtooth Hatchery is to be constructed along the upper reaches of the Salmon River in Idaho.

The hatchery, scheduled for completion in September, 1984, is expected to cost approximately $8 million.

The facility will be operated by Idaho Department of Fish and Game and is scheduled to produce 2,235,000 spring chinook smolts weighing 149,000 pounds, with a responsibility to return 19,232 adults to the system. A detailed report of this facility will be presented in a later talk by Tom Rodgers.

Irrigon/Wallowa Hatcheries - Irrigon/Wallowa is a complex of two hatcheries that together will produce the full complement of steelhead allocated to the State of Oregon under the Lower Snake River Compensation Plan.

Irrigon Hatchery will be constructed on the south bank of the Columbia River. Wallowa Hatchery, currently operated by the Oregon Department of Fish and Wildlife for trout production, is located in Wallowa County, Oregon. Wallowa Hatchery will be expanded to provide 300,000 steelhead smolts weighing a total of 50,000 pounds. This expansion cost is estimated at $3,439,000. At the Irrigon site a small test production has been carried out in temporary raceways since 1980 and will continue while a hatchery to produce 1,377,600 smolts weighing 229,600 pounds is constructed at an estimated cost of $11,292,000. This steelhead production should return 11,000 adults to the river system. The construction is slated to be complete in 1985. A design memorandum is currently being prepared.

Lookingglass Fish Hatchery - Construction of the Lookingglass Hatchery was completed in July, 1982 at a construction cost of $5,000,000. The hatchery is located on Lookingglass Creek, Oregon about two miles up stream of it's confluence with the Grande Ronde River. Hatchery water is delivered to the site from an intake on Lookingglass Creek; up to 50 cfs of water can be diverted for fish culture at seasonal water temperatures ranging from 31° F to 63° F.

The new hatchery facility will be operated by the Oregon Department of Fish and Wildlife and includes a fishway, two 20' X 80' adult holding ponds with transportation channel, thirty-two 21' X 32' juvenile starter troughs, eighteen 10' X 100' rearing ponds, a settling basin, hatchery building, storage building, water intake and supply system, drainage system, three residences, mechanical building, parking area and roadways, and outside storage and utilities.

The hatchery has the capacity to rear 1,390,000 spring chinook smolts, to a size of approximately twenty fish per pound, and a weight of 69,500 pounds, for distribution between the Grande Ronde and Imnaha River systems. The production is expected to return approximately 9,000 spring chinook adults to the project area.

Lyons Ferry State Fish Hatchery - Washington is located at the confluence of the Palouse and Snake Rivers, this facility when complete, will be two hatcheries in one. Phase I is complete and being operated by Washington Department of Game (WDG). It is designed to produce 1.2 million steelhead trout smolts weighing 116,000 pounds and 45,000 pounds of rainbow trout.

A renovation of Tucannon State Fish Hatchery will be accomplished by the Corps in order that an additional 41,000 pounds of rainbow trout can be produced by WDG. Its operation will be as a satellite of Lyons Ferry Phase I. The remaining 7,000 pounds of rainbow trout production stipulated in the compensation plan will come from stream enhancement accomplished by the Corps at the request of WDG.

Facilities at the Tucannon site include: one existing residence with a second to be constructed, a hatchery building with offices and restrooms, a dormatory providing living space for four seasonal employees, a small (approximately two acre) lake used to rear trout, and six circular ponds 40 feet in diameter.

Phase II at Lyons Ferry is currently under construction. Phase II will provide facilities for operation by Washington Department of Fisheries (WDF) in which 9.1 million fall chinook smolts weighing 102,000 pounds and 132,000 spring chinook smolts weighing 8,800 pounds will be produced. Lyons Ferry will be completed in late 1984 at an estimated total cost of $22 million. When both phases of Lyons Ferry construction are complete, hatchery facilities will include a fishway, adult sorting and handling facilities, well water supply and waste water treatment systems, 47 concrete raceways (10 feet wide by 100 feet long), three earthen type steelhead rearing ponds (about 80 feet by 1,000 feet), spawning facilities for chinook and steelhead, incubation facilities, smolt collection facilities, administrative office spaces for both Washington Department of Game and Washington Department of Fisheries, visitors center, fish feed storage, maintenance facilities, garages, equipment storage and eight residences.

Hagerman National Fish Hatchery - Expansion is nearly complete at the U.S. Fish and Wildlife Service (FWS) owned hatchery which is located on the Snake River approximately two miles east of Hagerman, Idaho.

The new construction includes an Administration Building with visitor facilities, concrete sedimentation ponds for waste water treatment, nursery tank facilities, feed storage and garage, sixty-six 10' X 100' concrete raceways, twelve 8' X 70' raceways, domestic water supply, water collection and pipeline for installation of future hydroelectric unit, and two trailer pads. Existing facilities that are to be integrated into the new hatchery program include the hatchery building, equipment storage building, garage and storage building, bulk feed storage facilities, four employee residences, twenty-four 8' X 70' raceways, and spring water supply systems.

When reconstructed, the hatchery will have the capacity to rear 440,000 pounds of salmonids annually. Of this capacity, the Compensation Plan will require facilities to rear 1,105,000 steelhead smolts to a size of approximately 3 fish per pound, and a weight of 340,000 pounds for distribution to the Salmon River Drainage. The production is expected to return 13,100 steelhead to the Snake Basin. Facilities for the remaining 100,000 pounds rearing capacity will be retained for FWS programs.

The hatchery expansion is scheduled for completion in early 1984, at an estimated construction cost of $6,200,000. The facilities will be operated by the FWS.

Dworshak National Fish Hatchery Expansion - The Dworshak National Fish Hatchery Expansion was completed in June 1982. The federally owned hatchery is located at the confluence of the North Fork and the Middle Fork of the Clearwater Rivers near Orofino, Idaho. The hatchery constructed by the COE in 1968 as compensation for steelhead losses resulting from the construction and operation of Dworshak Dam. The hatchery was expanded to rear an additional 1,050,000 spring chinook salmon smolts, to a size of approximately 15 fish per pound, and a weight of 70,000 pounds.

The hatchery expansion includes 30 additional 8' X 80' raceways, waste water treatment facilities, 40 ton water chiller, and bird netting over raceways. The water supply for the expansion is pumped to the raceways through an existing pipeline from the North Fork Clearwater River. Adequate water at seasonal temperatures ranging from 38° F to 56° F is available. The expanded hatchery will continue to be operated by the FWS.

Consistent with the desires of the administration and Congress, the Corps proposes to transfer title to the above state operated hatcheries and satellite fish facilities to the Fish and Wildlife Service. The Corps is currently conveying operational responsibility for constructed fish facilities to the FWS by Memorandum of Understanding.

Many fish runs affected by the Lower Snake River Project have rapidly declined since operation of the dams; consequently, to maintain these existing races of fish in the system egg bank activities for both upriver fall chinook and spring chinook salmon have been funded by the LSRCP in an effort to build up the fish runs and egg takes in anticipation of the new hatchery construction. These egg bank programs will be phased out as permanent facilities for the fish are brought on line.

For several years, Snake River Fall Chinook have been trapped at Ice Harbor Dam. The adults trapped have been spawned and the progeny reared by the State of Washington, and the U.S. Fish and Wildlife Service. The State of Washington has moved the chinook to the Tucannon Hatchery for spawning, and subsequently moved the eyed eggs to Klickitat and Kalama Falls Hatcheries for rearing and release. The FWS has received adults from Tucannon and have spawned them at Dworshak NFH. The eyed eggs are moved to Hagerman NFH for rearing and release in the Snake River near Asotin, Washington.

The Idaho Spring Chinook egg bank involves trapping adults in the upper Salmon River using temporary facilities provided by the Corps. After the fish are spawned, the green eggs are moved to McCall Hatchery for incubation and rearing. The smolts are trucked from McCall to the upper Salmon for release.

Fishery Evaluations - In addition to hatchery production, a major component of the program is fishery evaluations. In order to conduct an effective propagation program, fishery managers and hatchery operators must be able to measure the effectiveness of each particular mode of operation. Each fish species, fish stock, hatchery facility and water supply, and fish stocking area has unique combinations of factors or problems that must be identified and considered in establishing the most effective program. Consequently, the operation of each hatchery facility must be evaluated individually as it relates to the particular stock or spawning run it is meant to compensate. Hatchery loading, release goals, smolt size and time of release, stocking sites, fish health and disease, adult return goals, and harvest estimates are all examples of the types of factors that must be understood to conduct a successful, cost-effective hatchery propagation program.

Evaluation of the effectiveness of LSRCP activities will be a cooperative effort by all the cooperating agencies. An interagency committee will review all proposed evaluation projects for technical and scientific merit, project design, budgetary consistency, and adherence to LSRCP restoration goals. However, the actual studies will be conducted by the participating agencies that proposed them.

REARING SUMMER STEELHEAD IN

COLUMBIA RIVER WATER 1981 - 1983

RICHARD C. STILWATER
WASHINGTON DEPARTMENT OF GAME
TURTLE ROCK ISLAND FACILITY

The Turtle Rock facility is located on the Columbia River approximately 7 miles upstream from Wenatchee WA. The rearing pond used by the WDG is a trapezoid shaped concrete pond 175' in length, 40' wide, and has an average depth of 4-1/2'. The average water flow of 8 cfs. is supplied by one of 5 - 75 HP. pumps, and is aerated. The facility as a whole consists of a spawning channel converted into 4 rearing sections, with the operation of the majority of this rearing space by the Washington Department of Fisheries.

The summer steelhead reared at Turtle Rock are Ringold stock which originated from the Skamania Hatchery (WDG) located on the N. Fork of the Washougal R.

Disease

The interaction between virulent columnaris bacterium and "Ich" have caused devastating results when river water temperatures ascend above 58^{o} F. At this temperature prophylactic treatments of terramycin must be started and continued throughout the warm water period. Feeding the recommended levels of TM-50 every other day has proven to be the most effective controll for columnaris. In the fall of 1981 the steelhead experienced an outbreak of columnaris despite the TM-50 treatment, and mortalities during this time period averaged 100 fish per day. The fish at this time were placed on a 10 day treatment and were responding very well when the effects of an outbreak of "Ich" started to surface. The water temperature at this time was 65^{o} F. and the water flow was 6.5 cfs.

This was the begining of the end for many noble steelhead. Due to the infestation of "Ich" the fish went off all feed and within 4 days the columnaris was begining to reappear. At this time, we administered a 1:6000 formalin 0.1 ppm. malachite combination bath. The steelhead did not take this treatment very well, consequently we changed tactics and used a parastoltic pump to meter formalin into the pond at a concentration of 1:40,000 for a 24 hr. period every other day for 1 week. The results of this treatment were still very "harsh". The highest mortality for a 24 hr. period was 2% of the population, and the total combined loss from the major "Ich" - columnaris outbreak was 20% of the population.

Back to the books we went and came up with a promising alternative to the caustic measures previously tried, which was malachite green. Not much literature was found expounding the possible benefits of malachite for the treatment of virulent columnaris and the free swimming form of "Ich", however a treatment of malachite green at 1 ppm dripped for 1 hr. for 1 week, then every other day for 2 weeks was tried. This treating process proved to be safer for the fish and produced the desired results in the eradication of columnaris and "Ich".

Disease Summary

The solutions for disease control are quite simple, they are;

1. Hold the steelhead at another installation until river temperatures drop below 58^{o} F.

or - 2. Stock large quantities of medicated feed and malachite green, to be used throughout the warm water rearing period.

Behavior

During the winter and spring month's, when the water temperatures drop below 45^{o} F. the summer steelhead behavior is influenced by sunlight intensity. It does not matter if there is high or low barometric pressure at the time, the fish will reject feed if there is enough sunlight to cast a shadow.

The instant the shadows dissapear the fish will feed vigorously. I have yet to explain this, nor has any person that I have talked to been able to come up with a reason or solution. Eventhough this phenomenon is not a major problem, it is however quite inconvenient to wait for cloud cover to feed the steelhead.

Sawtooth Hatchery Update

Thomas L. Rogers
Fish Hatchery Supt. III

The Sawtooth Hatchery is part of the Lower Snake River Fish and Wildlife Compensation Plan and is being constructed along the upper reaches of the Salmon River, five miles south of Stanley in Custer County, Idaho. This project also includes a satellite facility located sixteen miles up the East Fork of the Salmon River, also in Custer County. Both facilities are being constructed by the U.S. Army Corps of Engineers and will be operated by the Idaho Department of Fish and Game under contract funding by the U.S. Fish and Wildlife Service.

The Sawtooth Hatchery is designed to produce 2,980,000 Spring Chinook Smolts to be released at the site. In addition, provisions have been made to trap, hold, take eggs and incubate Steelhead to the eyed stage. These eyed eggs will be shipped to another hatchery for hatching and rearing, and returned to Sawtooth for release.

The East Fork Satellite function is to trap, hold and spawn Chinook Salmon and Steelhead for the production programs at Sawtooth, Magic Valley Steelhead and Hagerman National Hatcheries.

Construction began on the Sawtooth Hatchery in the spring of 1983, with an expected substantial completion date of November 1, 1984, at a cost of approximately 8.6 million dollars.

To perform its function, the hatchery will include the following major elements: a water supply consisting of an

intake control structure, four wells and transmission lines; a hatchery building which involves a headbox and screens, incubators, early rearing tanks, food freezer, mechanical and electrical rooms, shop area, covered vehicle storage, office, and a visitors center; four single family residences; a seasonal employees dormatory; twelve fry raceways; twenty eight final rearing raceways; settling ponds; and an adult holding facility, with fish ladder and weir for trapping returning adult Salmon and Steelhead.

The Sawtooth Hatchery is approximately 45% complete at this time. 4,000 yards of concrete have been placed out of the total 6,700 yards needed. Most of the main water transmission lines are in place along with the septic tank, sewer and domestic water lines. Settling ponds are to grade and 60% complete. Framing of the dormatory has begun and will have a temporary roof on it this winter. Raceway construction has progressed to a point of 90% complete with piping tied in. The weir bridge has wing walls placed, steel piers installed and pier slabs poured. Exceptionally good weather this fall has brought the construction schedule back in line after a slow start.

When in operation, the hatchery will encounter severe weather conditions due to its geographical location and elevation. It is in one of the heaviest snow belts in Idaho and has an elevation of 6,400 feet. Mean air temperatures range from 14 degrees F. in January to 58 degrees F. in July. Long term recorded extremes are 96 degrees F. and -49 degrees F. Average annual precipitation is 17 inches, with the majority

in the form of snow from November through March.

One of the many challenges of this project will be maintaining rearing water temperatures at an acceptable level. This will be attempted by the use of three deep wells, the water of which will be introduced at various points in the system. Past well pumping tests on these wells have indicated a temperature of 45 degrees F. to 46 degrees F. during the summer months, and a January or February test is planned in 1984 to determine the volumn and temperature present at that time.

Other design features incorporated into this facility due to weather conditions include: a back-up electrical generator; a minimum of seven feet of earth cover over water and sewer piping; heat tracing and thawing cables at vulnerable locations; snow removal equipment; increased insulation; and a vigorous winterizing program.

The East Fork Satellite project began construction in June of 1982 and is basically complete. Operation of this facility will begin in March of 1984. The facility will be capable of holding 500 adult Chinook Salmon and up to 2,500 adult Steelhead per season. In order to accomplish this work, the project includes the following major elements: two holding ponds; fish ladder, trap and sorting area; storage building with spawning area; water intake structure; velocity barrier with radial gates to bypass river flow; trailer pad with utilities; domestic water well; septic tank with drain-field; area lighting and an intrusion alarm system.

The site will not be operated during the winter months and therefore the facility has been designed to allow complete drainage of all water holding components.

Sawtooth Hatchery personnel trapped and spawned Spring Chinook at the Sawtooth Hatchery site this year as in the past several years, using a tempory weir and trap. We took 650,000 eggs which were transported to the McCall Hatchery for incubation and rearing. These fish will then be returned to Sawtooth for planting to ensure viability of this severely depressed stock.

Sawtooth Hatchery is a critical component in the recovery of Spring Chinook Salmon numbers into Idaho. A continued cooperative effort by all agencies involved is necessary to bring these fish back to a level of prosperity which will not only benefit the fish, but man as well.

Deschutes River Spring Chinook Hatchery Program

Success at Last

Ray Hill, Oregon Department of Fish and Wildlife

Zeke Madden, Portland General Electric Company

At Round Butte hatchery Deschutes River spring chinook (1972-76 brood) have been incubated and reared at a constant 50°F and released as "0" age smolts after six months. Returns of this type release has resulted in a very poor return to the hatchery (0.02%). In 1977 it was decided to use the chiller at the hatchery to slow down the incubation time by chilling the water on eggs and fry from 50°F to 43°F on part of our production. Most of the production at the hatchery since 1977 has been slow incubated along with a fast incubated group as a control.

Initial results indicate that additional survival is achieved by transferring slow incubated spring chinook into the lower 100m section of the unused Pelton fish ladder in November about fourteen months after egg take. These fish are reared through the winter at very low density, fed once each day five days per week (½ rations), and then allowed to emigrate volitionally starting March 1. Movement peaks in late March, fish have the appearance of wild smolts. When all coded-wire-tags are read, returns to the Deschutes River on the first production group from the Pelton ladder will likely approach 2%. See table 1.

For more information on this incubation and rearing strategy please contact;

Round Butte Hatchery

P.O. Box 513

Madras, Oregon 97741

Phone 503-475-6393

TABLE 1. Returns of spring Chinook to Pelton Trap. 1972-80 brood years.

Brood year	Incubation type	Age	Release site	Month released	Size fish/lb.	Return (%)
1972-76 (mean)	Fast	"0" Age	Reg-Dam	May/June	20-30	0.02
1977	Fast	"0" Age	Reg-Dam	May	28.0	0.01
1977	Slow	Subyearling	Reg-Dam	Oct.	13.0	0.48
1977	Slow	Yearling	Reg-Dam	April	9.1	0.21
1978	Fast	"0" Age	Pelton Lad.	March 1/	91.0	0.05
1978	Fast	"0" Age	Reg-Dam	May	22.0	0.00
1978	Slow	Yearling	Reg-Dam	April	8.0	0.43
1979	Fast	"0" Age	Pelton Lad.	March 1/	95.0	0.03
1979	Fast	Subyearling	Reg-Dam	Oct.	5.9	0.00
1979	Slow	Yearling	Reg-Dam	March	7.0	0.25
1979	Slow	Yearling	Reg-Dam	April	5.0	0.74
1979	Slow	Yearling	Pelton Lad.	March	8.8	1.42
1980 2/	Fast	Subyearling	Reg-Dam	Oct.	5.8	0.01
1980	Slow	Subyearling	Reg-Dam	Oct.	10.9	0.01
1980	Slow	Yearling	Reg-Dam	March	5.0	0.04
1980	Slow	yearling	Pelton Lad.	March	6.0	0.12

1/. Fish had access to entire ladder. No supplemental feeding. Migrated from ladder in May.

2/. 1980 returns are incomplete, only indicates jack returns.

HISTORY OF INFECTIOUS HEMATOPOIETIC NECROSIS AT DWORSHAK NATIONAL FISH HATCHERY

Jerry R. McClain
U. S. Fish & Wildlife Service
Dworshak National Fish Hatchery
Ahsahka, Idaho

Infectious hematopoietic necrosis (IHN) was first isolated in spring chinook salmon adults which had returned to Kooskia National Fish Hatchery (NFH) in 1980 and were transferred to Dworshak NFH for holding and spawning. In September 1980, IHN was confirmed in sub-yearling rainbow trout. IHN was again confirmed in rainbow trout and spring chinook salmon fingerling in the spring of 1981. Some losses were experienced but were minimal (≤10%).

In the spring of 1982, IHN was confirmed for the first time in adult steelhead returning to Dworshak NFH. A total of 3.8 million fry were started in the nursery reuse system at Dworshak NFH and 1.2 million were reared at Kooskia NFH. From June to August, an epizootic resulted in a 48 percent loss at Dworshak NFH. No indication of the disease was observed at Kooskia NFH. To supplement the losses at Dworshak NFH, we began returning fish from Kooskia NFH in July. Within days, the virus began showing in these fish, and significant mortality resulted. In 1982, it appeared that as the fish approached 200 per

pound, they had more resistance to the disease.

First indications of problems in 1983 were observed in rainbow trout. In January and February, IHN was confirmed in 7- to 8-inch catchables and in 2- to 3-inch fingerling rainbow trout. Losses were approximately 10 percent and 30 percent respectively. In February, a late group of rainbow trout were received from Ennis NFH. IHN struck these fish shortly after initial feeding in early March. By mid-April, 100 percent loss had been suffered. It became apparent that, in all probability, we would see it again in our fingerling steelhead.

Following the problems in 1982, we met with Dan Mulcahy (National Fisheries Research Center, Seattle) and Warren Groberg (Oregon Department of Fisheries) to discuss the problem and possible solutions. It was thought that as a first step we had to determine the overall infection rate in the adults and to attempt to determine the mode of transmission.

During the 1983 spawning operation, ovarian samples were taken from all spawned females and sent to Lower Columbia River Fish Health Center for determination of viral infection. After receiving the diagnosis, the eggs were separated as either positive or negative for IHN. As a backup to Dworshak's program, 2.4 million eyed eggs were transferred to Kooskia NFH for rearing. With the exception of small groups of early and late eggs, only eggs from IHN negative females were sent to Kooskia NFH. In addition, only eggs from IHN negative

females were put in Dworshak's nursery reuse system. All IHN positive eggs were destroyed or reared separately on single-pass, raw water.

The first indication of problems was in two tanks on reuse. When IHN was suspected, these tanks were removed from reuse to single-pass, raw water. Mortality continued in these fish; and within ten days an 80-90 percent loss had been experienced. Meanwhile, the virus and related mortality spread through all tanks on reuse and later through most of the single-pass tanks. An inventory of tanks was completed in mid-July with the following results:

Egg Take	Number Eyed Eggs Started	Number of Fingerling Surviving to 07/12/83	Percent Survival
10	512,500	31,484	6.14
11	1,225,500	115,614	9.43
12	460,000	9,786	2.13
13	423,000	4,167	0.98
14	460,000	7,100	1.54
15	298,750	8,962	3.00
16	90,000	2,700	3.00
TOTALS	3,469,750	179,813	5.18

Fortunately, from the 2.4 million shipped to Kooskia, 2.2 million fingerling were returned to constitute 95 percent of Dworshak's current inventory.

With the experience of the 1982 and 1983 epizootics behind us, and after further collaboration with Warren Groberg and Dan Mulcahy, procedural changes are planned for 1984. With the mode of transmission still questionable, we will attempt to manage around the problem with both vertical and horizontal transmission in mind. First of all, sterile spawning techniques and individual incubation will be employed (similar to Cowlitz State Fish Hatchery and Leavenworth NFH in Washington). The National Fisheries Research Laboratory in Seattle will conduct tissue culturing of ovarian fluid from the females. In addition, male viscera will be tested at the Dworshak Fish Health Center in an attempt to ascertain the degree to which males are involved in transmission of the virus. To test the involvement of water-borne transmission, we will be testing ozone sterilization. It is hoped that, if indeed the virus is present this year, insight may be gained towards preventing the massive losses experienced in 1983.

As a precautionary measure, 3.5 million eggs (from IHN negative females) will be transferred to Kooskia NFH. Hopefully, enough survival will be realized between the two stations to maintain a full program at Dworshak NFH in 1984-85.

TITLE: Proliferative Kidney Disease in the Pacific Northwest

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There have been three annual episodes of proliferative kidney disease (PKD) at the Hagerman State Trout Hatchery, Idaho Department of Fish and Game. Our epidemiological studies have clearly indicated the following:

1. The organism causing PKD is not transmissable fish-to-fish.
2. The disease does not occur in waters less than 15 °C (59 °F).
3. The clinical course lasts about 3-4 months with a natural disappearance of the organism in late October.
4. The mortality rate in uncomplicated PKD is on the order of 10-15 percent during the season from late June to late October.
5. Although it remains to be conclusively proven, the PKD-causing organism is thought to be a natural resident of the intestinal tract of migratory, fish-eating water fowl. We have observed a morphologically similar organism in the lower GI tract of sea gulls. Also, farms in Europe having bird-tight enclosures have not experienced PKD.
6. Transporting the fish at 4 °C for more than 6 hours has an abating effect. The organism apparently does not tolerate low water temperatures.

EVALUATION OF PROS AND CONS OF USING ULTRAVIOLET OR OZONE IN THE TREATMENT OF HATCHERY WATER FOR IHN DISEASE CONTROL.

During the past two years, much attention has been focused on the possible transmission of the IHN virus in the hatchery intake water supply. Disinfection of this water supply with chlorine, ultraviolet light or ozone has been considered, piloted or used in full scale operations in a few plants in the Northwest.

The results have indicated that they can be effective, and additional pilot studies are under way at at least three locations to determine specific dosage rates required under varying water quality conditions.

The purpose of this paper is to review some of the specific capabilities of ultraviolet sterilizers and ozonators and the design considerations that need to be evaluated to choose a cost effective system.

Since the varying quality of water directly affects the amount of ultraviolet intensity exposure and the ozone dosage rate, we will also discuss various methods of pretreatment for the raw water and its costs.

Our company has, for the past ten years, specialized in equipment for water treatment, including disinfection systems such as Ultraviolet and Ozone.

About five years ago, we created a hatchery and aquaculture group and developed a line of process equipment for application to hatchery design and upgrading.

We began to attend the fish culture workshops and to display some of our equipment there.

Last year, in attending the 1982 Fish Culture workshop at Gleneden Beach, Oregon, I listened with interest to the many papers presented from Oregon, Washington, Idaho and Alaska discussing the experiences with the IHN virus outbreaks.

Theories and data supporting horizontal and/or vertical transmission were presented as well as some discussion about disinfection of the hatchery and/or incubation water.

During the past 18 months, we have worked with both Ultraviolet and Ozone Pilot Study evaluations in all four states. At the present time, a study on ultraviolet and ozone disinfection from IHN has been completed by the Alaska Fisheries Department (Dr. Grischkowsky) and a Ultraviolet Piolot Test is continuing at the Round Butte Hatchery in Oregon (Drs. Groberg and Mulcahy) and an Ozone Pilot Test at Dvorshak is just begining (Drs. Mulcahy and Dave Owsley).

Finally, at the recent fish disease conference at the University of California at Davis, the general feeling on IHN was that evidence of both horizontal and vertical transmission was sufficient to warrant pursuing both areas in trying to deal with the IHN problem.

The Purpose of this paper is not to state that ultraviolet light or ozone contracting is a better disinfectant for dealing with IHN. The work of Dr. Wiedemeyer, Dr. Groberg and Dr. Grischkowsky has shown atat both can be effective and the pilot testing presently underway will determine optimum dosages for given water conditions. From this data, hatchery designers can then evaluate the most cost effective choice for a given application.

With this background, I would like to discuss some of the things you need to consider when selecting and designing and ultraviolet or ozone system.

Let's cover the subject in the following sequence:

1. Ultraviolet systems
2. Ozonators
3. Ozone - Ultraviolet
4. Pretreatment of Hatchery Water

Ultraviolet Systems

In its simplest form, an ultraviolet disinfection system exposes the water to be treated to the ultraviolet frequency at 253.7 manometers for a specific length of time, usually 3 to 8 seconds. The dosage then is a direct function of intensity x contact time and expressed at Micro Watt Seconds/CM2.

In talking with designers and hatchery operators who have used ultraviolet, you cna find those who think they are good and those who have had nothing by troubles. In most of these cases, the problem was not that ultraviolet couldn't achieve an effective kill, but much more often that the equipment or water conditions were at fault.

Here are four common reasons for a poor ultraviolet preformance.

1. Unit is undersized either by the original sizing or the unit does not deliver its rated capacity.

2. Mechanical Failure - difficulties encountered in keeping the lamps and ballasts functioning due to seal failures.

3. Intensity is not uniformaly applied and is diminished by clouding or coating of the quartz surface.

4. Water Quality - excessively high turbidity and suspended solids interfere with ability of intensity to penetrate the water.

In selecting and evaluating the cost effectiveness of an ultraviolet system, each of these need to be taken into consideration. Let's look at some of these.

1. Dosage - The pilot studies on IHM will set optimum levels of dosage, but some factor of safety should be used to allow for varing water quality. For larger systems (above 500 GPM), an intensity monitor is a good investment.

2. Operating Pressure - How much water pressure do you have available and how much pressure drop can you afford? In smaller systerms, pumping costs may not be a factor but in larger ones, gravity flow may be essential.

3. Contact Method - In the design of the unit, it is important that each gallon of water gets the same exposure time and that no short circuiting be permitted. This can usually be best achieved by assuring a plug flow through tubing not greater than 2½ to 3" in diameter.

Operating Costs

It is important to take a close look at power costs, lamp replacement and day to day maintenance costs. The power costs are easily calculated by the number and wattage of the lamps and the amount of time used. The lamps are normally guaranteed by the lamp manufacturer for one year and cost in the $30.00 to $40.00/lamp range. Access to the lamps can be a maintenance time factor depending on the type of unit chosen.

Cleaning of the contacting chamber to assure that optimum transmission is obtained is also a maintenance factor that needs to be considered.

Summary

Not as an exact rule, but my experience has been that you should consider an ultraviolet system if the following design factors are involved.

1. Water quality is good - say under 30 ppm S.S.

2. If water flow is already pressurized.

3. If hatchery water flow is under 2000 GMP, an ultraviolet system's first cost should be favorable, but higher flows can sometimes still be cost effective.

4. If multiple points or application are desirable.

Ozone

An ozonator consists of an air preparation system and an ozone generator. This is important to understand because the major cause of problems in ozone systems can be traced to either a poor air preparation system or an inadequately designed contacting system.

Ozonators

Let's first look at the ozone generator part of an ozonator. The majority of the manufacturers use the electric arc principle to generate 03 from air or 02. Generally, the heavy duty units are water cooled and constructed of materials to withstand a very corrosive and destructive atmosphere within the generator. It is important to note that any mosture or impurity in the incoming air feed to the generator will have s serious destructive effect on the generator. For this reason, incoming air should be dried to a -60^0 F frost point and filtered with a 15 micron filter prior to and after drying.

Other things to consider are:

1. Turn down capability of the unit.
2. Dual transformers to assure continuous power if one transformer unit is out of service.
3. Multiple generator units to permit continuous operation if one unit is down for repairs.

Contacting System

Efficient use of the ozone generator calls for attention to the contact chamber design. In general, the following parameters apply.

1. Contact time $\pm$ 5 minutes.
2. Depth - recommend 9-10'.
3. Diffusers - pourous stone.

Deozonization

One of the purposes of the pilot plant studies is to determine the minimum amount of ozone residual that would be toxic to the fish being reared. Most recent contact systems provide for a post aeration system to sparge out any remaining ozone with aeration devices using normal blower air.

Ozonators

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Ozone Monitoring

Larger ozone installations should include an ozone output meter to verify ozone generator output. An ozone residual monitor is also desirable but care must be taken in selecting one especially for low residual levels.

Summary

Again, not as an exact rule but as a guideline, ozone should be considered in the following cases.

1. Water quality varies and some turbidity may be present at different times of the year.

2. Hatchery water flows in excess of 2000 GPM.

3. Gravity flow required.

4. Wide range of turndown needed.

Combined Use of Ozone and Ultraviolet

Recent studies by the EPA lab in Cincinnati, under the direction of Albert Venosa on secondary effluents, have shown that the combined use of ozone and ultraviolet can be cost effective on very large installations (over 14,000 GPM) and should be part of an evaluation for a hatchery application.

Pretreatment of Raw Water Supplies

Most of the use of ozone and ultraviolet as a disinfectant is predicated on the assumption that reasonably low levels of turbidity and suspended solids are maintained in the water to be treated. While it may be cost effective to oversize disinfection units to deal with increased solids, there is a limit of perhaps 40 to 50 ppm of suspended solids before pretreatment is a necessity.

Because of this, evaluation of the source of raw water would justify a serious search for spring fed or infiltration gallery type sources. It should be noted, however, that although this might solve the excess turbidity problem, it does not guarantee a disease or virus free water source.

In general, the pretreatment of the water can be classified as follows:

1. Desilting and desanding - This has been accomplished with pre settling ponds as well as the mechanical rotating screens using size openings as low as 25 microns. Some work has been also done with low head cyclone separators.

2. Rapid Sand Filtration - The use of pressure type or open gravity type sand filters is the most common method of turbidity and fine suspended solids removal, and these units can be sized for filtration rates from 6 to 15 GMP/ft2 and cost vary from $100.00 to $250.00 GMP.

Summary

This paper has presented the following information:

1. Both ultraviolet and ozone can be effective disinfectants to deal with IHN.

2. Pilot tests have been already completed in Alaska and are underway in Washington, Idaho and Oregon to determine optimum dosages and design criteria for their use.

3. Previous failures have in most cases been caused by poor design or equipment failure.

4. Recommend evaluation of both ozone and ultraviolet on a cost effective basis, but ultraviolet should be attractive at hatchery flows under 2000 GMP and ozone at flows over 5000 GMP depending on water quality.

5. Water quality is important. Try for the best source, but if turbidity is a problem, evaluate higher dosages versus pretreatment screening and/or filtration.

If you have any questions, I can be reached at EMA Marketing Inc. 5065 SW Nash Ave. Corvallis, Oregon 97333.
Phone: Ted Gregg, 503-758-1555.

PROGRESS TOWARD THE DEVELOPMENT OF A COMPREHENSIVE FISH HEALTH PROTECTION PROGRAM FOR THE PACIFIC NORTHWEST

James W. Warren
U.S. Fish and Wildlife Service
Vancouver, Washington

Abstract

The Northwest Power Planning Act and the Salmon and Steelhead Conservation and Enhancement Act (SSCEA) include requirements for biologically sound measures which minimize man's adverse impact on fragile fishery resources. These legislative mandates provide impetus for the development of comprehensive, coordinated programs for the prevention and control of serious fish diseases. To organize these efforts a fish health protection committee is being formed that is composed of representatives from Federal and State conservation agencies, tribal groups and commercial hatchery operations. Close liaison will be maintained with the Columbia Basin Fish and Wildlife Council, SSCEA enhancement planners, the Northwest Power Planning Council's Fish Propagation Panel, and other organizations. The committee will not serve as a standing committee of any of these bodies, however.

This report describes progress made by a steering committee toward the creation of the new fish health protection committee. Insight is also provided on perceived committee objectives, its composition and its methods of doing business to prevent the introduction of new diseases into areas now free of them, preventing the amplification and spread of existing disease problems, and seeking mutually agreeable methods of eliminating disease as a factor in the success of public and private programs.

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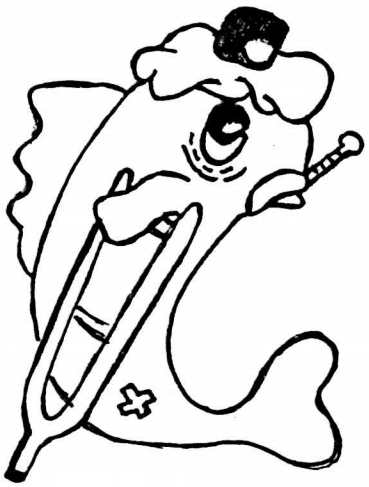

PROGRESS TOWARD THE DEVELOPMENT OF A COMPREHENSIVE FISH HEALTH PROTECTION PROGRAM FOR THE PACIFIC NORTHWEST

James W. Warren
U.S. Fish and Wildlife Service
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This segment of the Northwest Fish Culture Conference is devoted to fish health topics. Fish health is not just a technical matter for discussion at meetings, but the heart and soul of fish culture. Successful fish culture is obvious evidence that at least the minimum health requirements of fish have been met. There may be room for improvement, however.

Consider, if you will, a rather simple question: "If I were to deliver to you, all the clean, healthy, guaranteed disease-free eggs you needed, what would be the health status of the fish you produced from these eggs at the time of their release?" If you had A-1 eggs at the start and don't have A-1 stock at release time, we need to examine what we're doing and make some adjustments.

In March 1975 I was deeply involved in a whirling disease problem at Michigan's Sturgeon River Hatchery. We held a big inter-agency meeting to determine the fate of the 90 tons of infected coho salmon and rainbow trout on hand at the hatchery. To bury that many fish would put a sizeable dent in Michigan's fishery program. To stock them would have flown into the face of a newly approved fish disease control plan and could have possibly led to a disease problem of far-reaching magnitude. Dr. S.F. Snieszko was asked to participate in this 1975 meeting as a respected outside expert. When he was finally called upon to speak he put the whole agonizing situation into perspective by simply stating that "Fish hatcheries must not be the site of the amplification of fish diseases." Shortly thereafter the fish were buried. The hatchery was later closed and four families were relocated to other stations. As drastic as this action was, however, Michigan knew they had strong support from neighboring states and the Canadians through their joint participation in the Fish Disease Control Committee established by the Great Lakes Fishery Commission in 1973.

The Great Lakes Fish Disease Control Committee is composed of both top level hatchery administrators and fish pathologists from each of the eleven conservation agencies involved in Great Lakes programs. The value of this unique mix of "white coats" and administrators cannot be overemphasized! The reason for this is communications. Effective fish health protection comes not so much from the use of malachite green and erythromycin, but from sound management choices that continually strive to prevent diseases and to contain and minimize the impact of those outbreaks that do occur. Much of this can be achieved through the development of clean safe water supplies, careful disease monitoring, good facility designs, sound nutrition and the integrated application of an array of disease control techniques. But how can administrators, remote from the technical disease arena and charged with planning and implementing broad fishery management programs, know the right things to

do? By actively participating in Fish Disease Control Committee deliberations alongside fish pathologists the important "nuggets" of technical information, essential for decision-making, can be obtained together with an invaluable interpretation for solving local problems. Neighboring administrators and fish pathologists, together, develop a better understanding of the context in which recommendations must be made. While the administrators are getting a crash course in the disease problems of the day, the fish pathologists also get a crash course in the fiscal, personnel, and political aspects of program management. As a result, both sides get a clearer understanding of the real world and can apply this realism to the development of policies and programs that make good sense and serve the long-term interests of the resource.

The Great Lakes Fish Disease Control Committee moved quickly after its 1973 inauguration to draft a one-page disease control policy and a detailed disease control program. The program identified diseases of mutual concern, spelled out strict control measures, designated disease inspection methods, and defined hatchery disease classification procedures for all agencies to follow. When the draft was readied in 1974 we were proud of our product and everyone agreed that if we were to effectively control serious fish diseases, this was the program we needed. The only problem was that when it came time for Committee members to vote its adoption as an official Great Lakes program, no one could do it. It would have put most operations out of business if it were immediately and strictly applied as written. We drastically rewrote whole sections trying to make changes that would smooth the rough spots and make it acceptable. We found that the eleven different jurisdictions involved had such impossibly different concerns and needs that only something akin to the original unacceptable program could adequately do the job. After more than a year of struggling, we finally adopted our original program by adding just one word to its title. Instead of the title reading "Great Lakes Fish Disease Control Program" we made it read "Model Great Lakes Fish Disease Control Program." The word "model" set up the program as a goal rather than a mandate. Even as a model program it has provided a common set of policies and procedures that have helped to guide fishery programs and the creation of effective agency disease control efforts for the past eight years.

But what does all this have to do with resource management and fish culture in the Pacific Northwest. The remarkable track record of the Great Lakes Fish Disease Control Program has not been lost on Northwest fisheries organizations. The opportunity for developing a unified approach to fish health protection crystalized following the 1980 passage of the Northwest Electric Power Planning Act and the Salmon and Steelhead Conservation and Enhancement Act. These legislative measures require the implementation of biologically sound, coordinated, comprehensive programs of which fish disease control has been identified as an important element. The Northwest conservation agencies, through the Columbia Basin Fish and Wildlife Council, designated the Fish and Wildlife Service as the lead agency for fish disease control program development. In response to a June 13, 1983 work assignment from the Council, the Fish and Wildlife Service transferred me to Vancouver, Washington. Since that time I have been working with the conservation agencies, Indian fish commissions, and the private sector to help to organize a comprehensive fish health protection program for the Pacific

Northwest.

Fish health protection is a sensitive issue that can have complex management, political, and public relations impacts, not to mention the resource impacts caused by serious mortalities and stock transfer complications. Obviously, unilateral disease control efforts by any one agency or group cannot be as successful, over the long term, as a coordinated program built upon common goals and close cooperation between pathologists and management and between the public, tribal and private sectors of fish culture. There has been general agreement on this point and a strong effort is now underway to create a Pacific Northwest Fish Health Protection Committee (PNFHPC).

The creation of a broad-based, representative committee required the convening of a Steering Committee to lay the groundwork. The Steering Committee met first on October 12th and concluded their assignment on November 21st. Out of these meetings came a brief review of progress on disease problems made by previous committees and workshops, a draft set of goals for a comprehensive program, and a proposed charter for the new committee.

Highlights of the charter include:

1. Area of Concern: "For deliberations of this committee, the area of concern encompasses the States of Washington, Oregon, Idaho, the Columbia River Basin of British Columbia and that portion of the State of Montana that lies west of the North American Continental Divide. This area includes, but is not restricted to, the geographical areas and waters defined in P.L. 96-561 (The Salmon and Steelhead Conservation and Enhancement Act of 1980) and P.L. 96-501 (The Pacific Northwest Electric Power Planning and Conservation Act of 1980)."

2. The committee shall meet at least twice annually.

3. Cooperating Parties:

   British Columbia Ministry of the Environment-Fish & Wildlife Branch
   Columbia River Inter-Tribal Fish Commission
   Canadian Department of Fisheries and Oceans
   Idaho Fish and Game Department
   Montana Department of Fish, Wildlife and Parks
   National Marine Fisheries Service
   Northwest Indian Fisheries Commission
   Oregon Department of Fish and Wildlife
   Private Sector - British Columbia
   Private Sector - Idaho
   Private Sector - Montana
   Private Sector - Oregon
   Private Sector - Washington
   U.S. Fish and Wildlife Service
   Washington Department of Fisheries
   Washington Department of Game
   Other parties as determined by the committee

4. Cooperator Representation: "A maximum of two representatives shall be appointed to the committee by each cooperating party. Representation is encouraged to include an experienced administrator or business leader authorized to make program, policy, fiscal and personnel decisions affecting the acquisition of eggs or fish, the operation and maintenance of hatcheries, and the destiny of cultured fish or eggs and a lead fish pathologist or fish health research specialist."

5. Officers:

   Chairperson - the previous year's Vice-Chairperson.

   Vice-Chairperson - elected by simple majority.

   Executive Secretary - elected by committee to serve an indefinite term, at the pleasure of the committee, to lend administrative support and program continuity.

6. Decision-making process: "Consensus will be employed in the making of committee decisions. Consensus is defined as the unanimity of opinion of all authorized representatives present at a duly scheduled formal meeting of the committee. Each cooperating party shall have a single voice in the decision-making and election process."

The inaugural meeting of the PNFHPC is scheduled for January 24 and 25, 1984 at a hotel near the Portland Airport. The committee will elect officers, conduct discussions on refining its goals and charter, and establish important subcommittees to work on developing a Pacific Northwest fish health protection policy and a program to implement such a policy which can be endorsed by all of the cooperating parties involved. In addition, subcommittees could also be organized to establish research priorities, assess facility and water supply rehabilitation needs, and to work on the development of integrated fish health protection activities that orchestrate optimum nutrition, genetics, sanitation, fish cultural practices, immunization, chemoprophylaxis, and chemotherapy into fish cultural programs to enable the release of healthy fish fully capable of meeting the challenges of the environment.

This is no small task. Ten years of hard work on the Great Lakes demonstrates that these efforts can yield positive results. Great Lakes workers quickly discovered that infectious diseases in fish were much like tags. When disease-free fish were released, the background level of disease in the population quickly dropped. Just like "dilution is the solution to pollution", so too is dilution the solution to disease problems. The catch is, however, that everyone has to contribute to the dilution or you have no solution. This is the challenge before the new Pacific Fish Health Protection Committee as it begins it work in early 1984.

IHN Transmission Study at Round Butte Hatchery

Don Ratliff, Portland General Electric Company
Bill Nyara, Oregon Department of Fish and Wildlife
Warren Groberg, Oregon Department of Fish and Wildlife

History of IHN at Round Butte Hatchery

IHN was first detected at Round Butte Hatchery in 1973, but in adult spring chinook salmon. Little concern was voiced about steelhead, as IHN had never caused losses in steelhead at that time. This changed drastically in 1975, however, when 550,000 steelhead fry died. Only two small experimental groups of fish were left. Luckily, 300,000 extra Deschutes steelhead eggs had been taken that year and sent to a state hatchery, eventually to have been planted in the Willamette River System. These eggs were brought back to Round Butte and made up of the bulk of the release that year. Because of the huge losses in 1975, the first management technique to compensate for potential apizootics was institute - rearing three times the number of fry needed to meet production goals.

Large losses occurred in 1976 (182,000) and 1978 (425,000). If any more fish would have been lost in 1978, agreed-upon production would not have been met. These losses led to the second mangement technique in an attempt to circumvent losses - increasing the number of rearing containers to decrease the number of fry destroyed with each epizootic. Incubator stacks were divided, and the four 10-ft by 30-ft oval starting ponds were replaced with twenty-four 6-ft-diameter circular tanks. These tanks were installed just in time, as in 1980 five separate epizootics occurred; however, because of the smaller rearing units, only 144,000 fish died.

In 1981, no epizootics occurred, although a 50 percent carrier incidence was detected in adults. In 1982, we thought we would have no losses as no IHN was detected in the parent brood; however, we suffered severe losses. More than 400,000 fry died or had to be destroyed. In addition, some of the groups kept developed IHN later at a larger size than previously seen. Although this loss was heavy for a period, it was not catastrophic. The Oregon Department of Fish and Wildlife changed its policy of destroying all infected fish to allow the release of these steelhead into the Deschutes River. However, for the first time, IHN seriously affected steelhead production at Round Butte Hatchery. Not enough fish survived to allow normal grading. Consequently, many fish were released at a size too small for migration to the ocean. The health of these fish is also in question.

With the 1983 brood, carrier rate was the highest ever seen, 70 to 100 percent in the different parent groups. Three epizootics occurred, with loss of approximately 70,000 fish. Because of the huge losses in 1982 and the high carrier rate in the 1983 brood, an IHN transmission study has been planned starting in 1984 to help assure that steelhead mitigation requirements will be met at Round Butte Hatchery.

IHN Transmission Study

Purpose of this two-part study is to determine if the IHN virus causing epizootics in steelhead is coming through the water supply (horizontal transmission) or is transmitted from the adult brood (vertical transmission), or if both routes of transmission occur. IHN virus is found in kokanee in the reservoir above the hatchery and in the steelhead brood stock.

Cooperators in this study are: Portland General Electric Company

which owns Round Butte Hatchery and is purchasing the UV sterilization equipment; Ultra Violet Technology, Inc. which will supply the sterilization equipment at reduced cost and be certain it is installed and operated effectively; Bonneville Power Administration who is financing the IHN sampling program; Oregon State University Microbiology Department and the USF&WS Seattle Fisheries Research Center whose labs will jointly do the sampling; the Oregon Department of Fish and Wildlife which operates Round Butte Hatchery and will do the spawning, pairing, and rearing of the various groups.

In the first part (horizontal transmission), embryos from sixteen steelhead pairs will be divided into two groups, and half incubated and reared using UV-sanitized water and half using normal hatchery water. Eight replicates will be conducted annually for 3 years. All brood fish will be sampled for IHN virus.

In the second part (vertical transmission), all adults will be sampled for IHN at spawning and the gamates stored at 34°F until virus tests are complete. Ideally, high-titer adults and no-virus adults will then be mated, incubated, and reared separately using UV-sanitized water. Four trials will be conducted annually for 3 years. Results should determine if vertical transmission occurs, and if brood stock culling significantly reduces the chances of an epizootic.

Gamate Storage Trials

Initial gamate-storage trials were conducted with 1983 brood spring chinook. It was found that by placing eggs and sperm in separate plastic bags, inflating the bags with oxygen, and placing them in the cool room at 34°F for up to 6 days prior to fertilization, survival to hatching (86.1%) was similar to production eggs (88.1%) fertilized at spawning.

Gamate storage trials will be conducted with steelhead as soon as fish are ripe.

For further information on these studies contact:

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Selenium Accumulation Associated with Reproductive Failure in Domestic Westslope Cutthroat Broodstock

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Introduction

Because of declining egg production of a natural westslope cutthroat (Salmo clarki) broodstock at King's Lake, a domestic broodstock of the King's Lake stock was established. Ford hatchery, in northeastern Washington was selected in 1978. Egg and sac fry mortality in progeny of the Ford cutthroat broodstock has been in excess of 50%, as compared to a 15% mortality in progeny of King's Lake fish.

The purpose of this study was to identify the cause of the reduced embryo survival and to present some practical solutions.

Methods

Of the factors which could be affecting egg quality, nutrition was identified as the most probable cause. Moore-Clark trout brood diet was used from 1978 through 1982 with poor survival in the resulting year classes.

In 1982-83, two brood diets, Rangen's and Biodiet were tested. Diets were feed for one year prior to spawning to yearling cutthroat. At spawning, eggs from each test group were spawned and incubated seperately to compare egg quality.

To provide some information on the nutritional status of eggs produce by King's Lake and Ford cutthroat, samples of mature, unfertilized eggs were collected in April, 1983. Proximate, vitamin C and E, and selenium analysis were conducted by Biomed Research Laboratories, Inc., Seattle, WA.

Results

Poor embryo survival was noted in eggs produced by broodstocks fed either Biodiet or Rangen's diet. The total mortality through hatching was 53 and 56% from fish fed Biodiet and Rangen's, respectively. Results of the broodstock diet test are presented in Table 1.

Analysis of the nutritional status of egg from King's Lake and Ford cutthroat showed no differences in proximate and vitamin C and E. However, selenium concentration was 25 times greater in eggs from Ford cutthroat as compared to eggs from King's Late cutthroat. Table 2 contains results of the egg analysis.

Discussion

It is apparent from the brood diet tests that either the tested closed formula diets are inadequate or that nutrition is not the factor affecting egg quality. Smith et al. (1982) presented evidence that egg quality of westslope cutthroat was greatly affected by the water temperature which the broodstock were held. Their data showed that fish held in creek water which vared throughout the year from 36 to 50 F had higher egg survival then fish held at constant 50F spring water. Ford's spring water supply ranges from 43 to 53F throughout the year which suggest that water temperature alone may not be responsible for the reduced embryo survival.

The egg analysis may have yielded an important key to the reduced egg and sac fry survival. The difference in selenium concentration between wild and domestic eggs suggest that the domestic cutthroat broodstock are accumulating selenium and the accumulated selenium is responsible for the embryo mortality. Reproductive failure

in other non-salmonid fishes has been caused by accumulated selenium (Cumbie and Van Horn, 1978; Sorensen et al., 1982). Thus, selnium accumulation may be responsible for the reduced egg and sac fry survival in progeny of domestic cutthroat broodstock.

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Table 1. Broodstock Diet Test - Embryo Mortality

Diet	Total Eggs	Percent Mortality		
		Green-Eyed	Eyed-Hatch	Total
Biodiet	409,000	40	15	53
Rangen's	360,000	34	23	56

Table 2. King's Lake and Ford Cutthroat Egg Analysis

Analysis	Egg Source	
	King's Lake	Ford Hatchery
Proximate (%)		
Protein	25.6	24.9
Fat	2.1	2.0
Moisture	61.3	61.4
Ash	2.5	2.2
Carbohydrate	8.5	9.5
Vitamin (ug/gm)		
C	100	90
E	<6	<6
Selenium (mg/L)	<0.2	5.1

A Study of the Carrier State of Infectious Hematopoetic Necrosis Virus (IHNV) in Adult Female Sockeye Salmon (O. nerka)

Kevin H. Amos, Kathleen Hopper, and Lori LeVander
Washington State Department of Fisheries

Infectious hematopoetic necrosis virus (IHNV) is found throughout North America, but has shown a dramatic increase in the Northwest in the past five to ten years. This viral agent affects most salmonid species with sockeye and chinook salmon, and rainbow trout being particularly susceptible to infection. The disease caused by the virus can result in devastating losses in hatcheries. Many of us have witnessed an epizootic and need not be told of the significance of the disease.

The fish health expert and hatchery staff are challenged when trying to control and prevent this salmonid nightmare. One reason for difficulty in managing IHNV is the elusiveness of the viral agent. The only time we can isolate the virus is at the time of clinical illness or at spawning, otherwise, the detection of the carrier state in a healthy fish is impossible. Also unknown is the relative significance of horizontal and vertical viral transmission in causing epizootics or establishing the carrier state in survivors. The existence of the lifelong carrier

state was demonstrated in rainbow trout when juveniles, which survived an epizootic and were reared to maturity in pathogen-free water, exhibited IHNV at spawning (Amend, 1975). Researchers, however, have failed when trying to demonstrate vertical transmission of IHNV. Green eggs from known infected female adults have been incubated, hatched, and reared in pathogen-free water and at no time, even after stress, was IHNV isolated from these fish. Eyed eggs, however, exposed to contaminated water have subsequently experienced IHNV epizootics as fry (Amend, 1975, Groberg, Mulcahy, personal communication).

One may presume the lifelong carrier state of IHNV occurs in anadromous salmonids, though it has not been unequivocally demonstrated. Also, we do not understand the role of horizontal infection between adults on the spawning grounds. Our experiment was designed to answer these questions, and if successful we would have a better understanding of the disease and could develop better health management techniques at our hatcheries.

Methods

On August 1, 1983, 20 adult sockeye salmon (19 females, 1 male) were trapped at the Chittenden U.S. Government Locks at the interface of Puget Sound and Lake Union. The fish were anesthetized with MS-222, injected with Ery 200 (Erythromycin) at the rate of 20 mg/kg for the control of bacterial diseases and transported to their individual holding containers at the U.S. Fish and Wildlife Laboratory at Sandpoint.

The holding containers were customized fish totes. The water volume was about 600ℓ and the flow was five to six ℓ per minute. The water was chilled, aerated, and chlorinated - dechlorinated city water (source - Cedar River). The temperatures ranged from 9°C to 17°C and the dissolved oxygen levels were from nine to ten ppm. From August 1 to October 15, the tanks were treated biweekly with 0.5% NaCl solution to control fungus.

All mortalities and spawners were examined for the presence of bacterial and viral pathogens. Ovarian fluid, eggs, kidney and spleen were assayed individually as prescribed in the Amercian Fisheries Society "Bluebook". Adults were not sacrificed at first spawning, but were held an additional two days before respawning and necropsy. Previous work has indicated that delayed sampling after the first spawning will increase the likelihood of virus isolation.

Two control groups were sampled to compare to our test group. During trapping on August at the locks, 20 additional adult sockeye (10 male, 10 female) were sacrificed and assayed for virus to determine the detectable carrier state of the fish as they left saltwater. Our other control group consisted of viral assays conducted by Dr. Dan Mulcahy on sockeye salmon as they spawned in the Cedar River (the presumed destination of our trapped fish).

Results

The results section of our paper is a short story. To date, only five females and one male have survived to sexual maturity, and none of them have

been found to be carrying IHNV. Six females are still holding and will hopefully, mature. Eight other females did not survive to spawning (their cause of death is listed in Table 1). Due to the warm and stressful holding conditions, Furunculosis became a problem. We decided to give all the fish an injection of Terramycin (10 mg/kg) on September 8, resulting in no further bacterial problems. We should also mention that in late October, the water temperatures dropped to less stressful levels.

None of the control fish, which were trapped at the locks, exhibited IHNV. This is not surprising because of their physiological state, and the results concur with work previously done by Dr. Mulcahy. The control fish sampled on the Cedar River showed quite a difference in results. Fish from the lower weir site and the upper side - channel site were examined. At the time of sampling in mid-October, the number of spawning fish was much greater and the progression of spawning more advanced in the upriver site compared to the lower river site. At the side channel, 50 spent and 18 ripe females had an incidence of IHNV of 97% and 100%, respectively. At the lower site, there were two spent and 11 ripe females, all exhibiting no IHNV.

Discussion

Due to our limited data base, it is impossible to make statistically valid conclusions. Failure to isolate IHNV from our test sockeye does not eliminate the possibility of the lifelong carrier state and perhaps, at the completion of our experiment we will find a positive fish. Our tests have illustrated that adult sockeye taken directly from seawater and held in solitary confinement will develop to sexual maturity. Because of this normal physiological development of our test fish, IHNV should be expressed if it is present.

The isolation of IHNV from a large and advanced-in-spawning sockeye population in the Cedar River is not surprising and is in agreement with previous years' findings. Infection rates approaching 100% are not at all unusual. We find it unlikely, however, that a majority of the Cedar River fish would be lifelong carriers yet, not one of the test fish is a carrier. These results suggest that a mechanism besides a lifelong carrier state, is responsible for the high infection rates among the feral population. Quite likely, horizontal transmission between adults is partially responsible for the high incidence of IHNV. Data from infected hatchery spawners indicate that as the spawning season passes, the number of detectable carriers increases (graphs, Skamania Hatchery, Washington Department of Game, 1983). The mechanism of horizontal transmission would support these observations.

We still have a lot to learn about IHNV and every bit of information helps to solve the puzzle. Management techniques already utilized

include culling of eggs from positive females, disinfection of water supplies and disinfection of eggs (green and eyed) before introduction into incubation containers. Another important control method is the prevention of adult carriers contaminating hatchery water supplies. Also, when holding multiple lots of brood stock (species, year, class) simultaneously, we can prevent horizontal transmission of IHNV between groups by not re-using hatchery water.

We would like to express our thanks to the following people for their assistance:

Dan Mulcahy and Clarence Johnson - U.S.F.W.S.

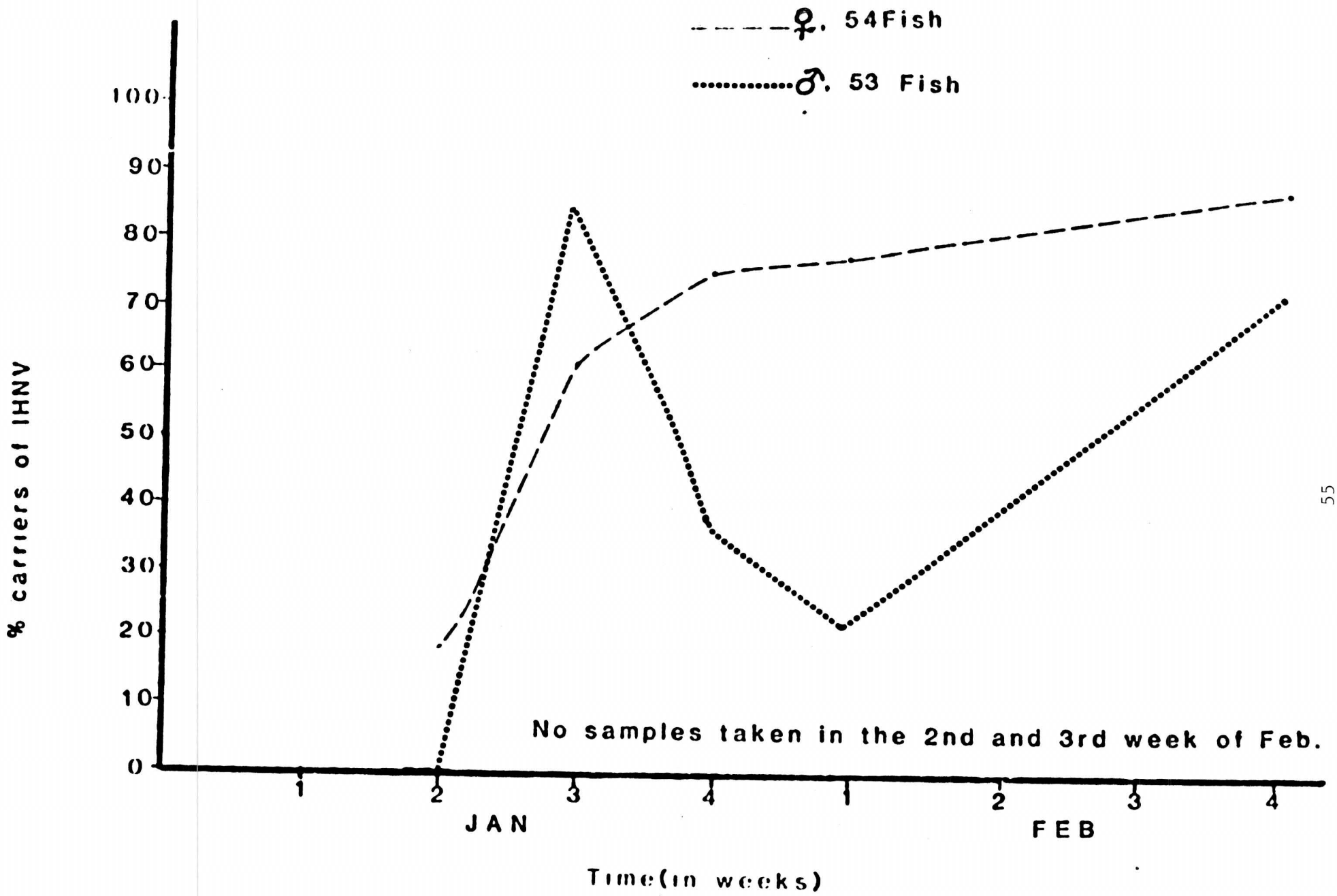
Green River Hatchery Crew

Corps of Engineers

Table 1. SUMMARY OF NECROPSIES OF ADULT FEMALE SOCKEYE SALMON (O. nerka)

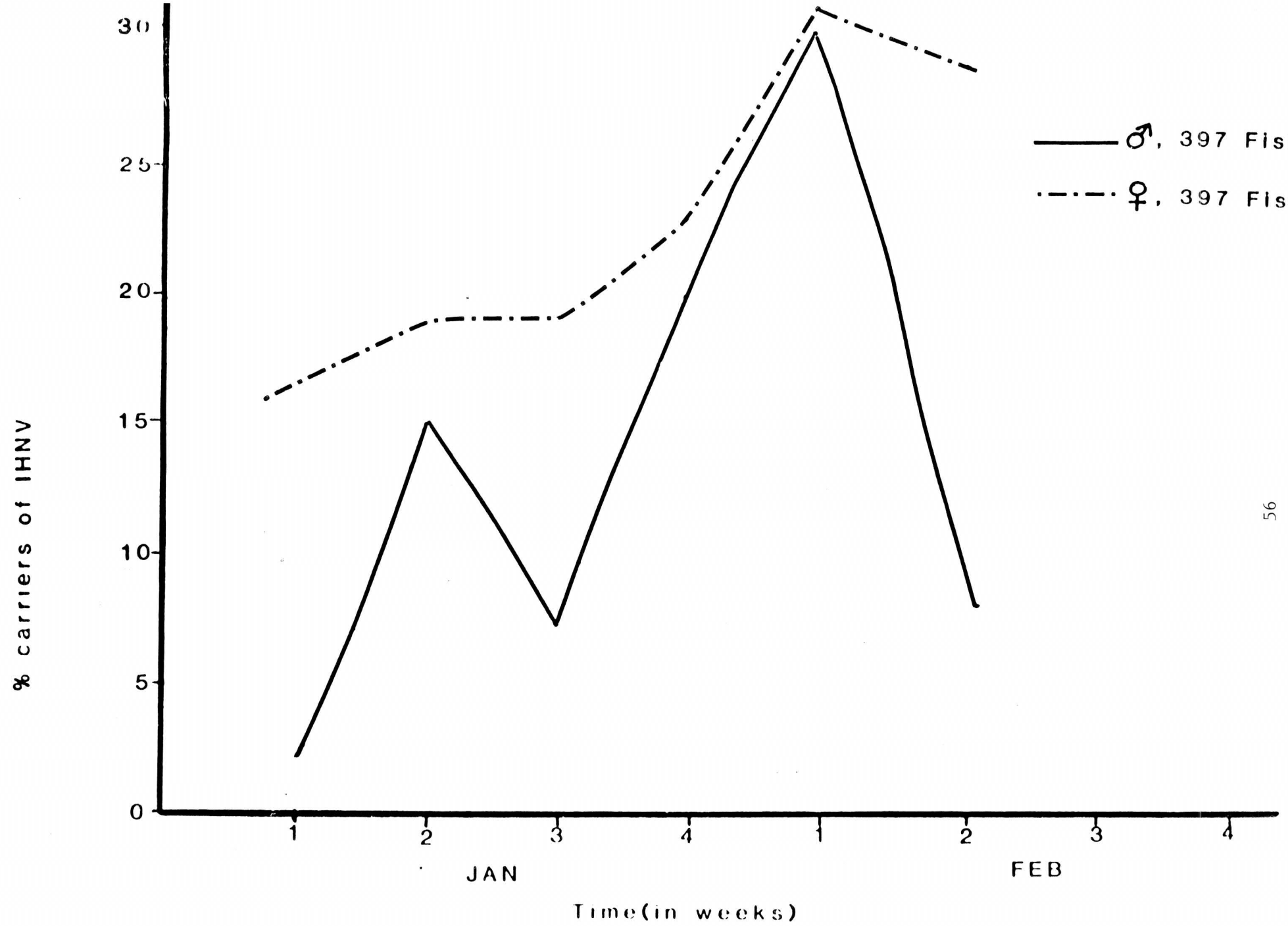
Date	H_2O temp. (max)	Tank #	Cause of Death	Status of IHNV
8/5	63	19,11	2-suicide	neg.
8/17	64	18,8	2-Furunculosis	neg.
8/28	61	9	1-Furunculosis	neg.
9/6	62	6	1-Furunculosis*	neg.
9/29	55	5	1-N.P.I. (stress)	neg.
10/7	54	10	1-N.P.I. (stress)	neg.
10/26	54	2	1-senility (partially ripe)	neg.
11/13	52	17	1-senility (ripe)	neg.
11/17	53	14	1-senility (ripe)	neg.
11/29	49	12,20	2-spawned	neg.
12/1	47	12,20	2-respawned	neg.

* Injected fish with Terramycin



Incidence of IHNV vs. Spawning Time in Random Winter Steelhead Adults

Skamania Hatchery, 1983



Incidence of IHNV vs. Spawning Time in Random Summer Steelhead Adults

Skamania Hatchery, 1983

AN EVALUATION OF THREE SYSTEMS USED TO DEGAS SUPERSATURATED REARING WATER

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ABSTRACT

Three separate degassing systems were put into use at the Nashua National Fish Hatchery to reduce levels of gas supersaturation in the hatchery's rearing water. Swedish, vacuum, and packed column degassers were installed and used in various combinations in order to obtain desired total gas levels. This paper discusses the effectiveness of the degassers and the relative merits of each system.

INTRODUCTION

Supersaturated water and degasser are terms familiar to most fish culturists. Unfortunately many of us learn the first after an encounter with gas bubble disease, and the second when a quick-fix solution is sought to save the fish that have survived it.

This paper deals with three methods implemented at the Nashua National Fish Hatchery to help mitigate the effects of supersaturation, with a field oriented evaluation of the effectiveness of each. I would like to first briefly review some of the causes of gas supersaturation and how they singly or in combination wreak havoc on fish cultural operations.

The problem, at least in New England, is nitrogen supersaturation in a hatchery's water supply. Nitrogen gas is basically biologically inert and in water its content fluctuates with changes in temperature and/or pressure. To the culturist, this means that whenever water is handled an excellent possibility exists for encountering supersaturated conditions. Causes of the problem are found in items common to most hatcheries, i.e., wells, plumbing and heating.

Supersaturation most often occurs when air is dissolved into water. When water passes down through the ground, pressure on it increases in relation to depth, thereby supersaturating the water enroute to a well's aquifer. This problem is often compounded during periods of snow melt when cold water is warmed passing through soil, thus increasing saturation levels with temperature and pressure changes. Once in the aquifer, biological activity

can consume oxygen in water, liberating nitrogen gas that is pumped, pressurized and used for rearing purposes.

Air leaks in pumps and plumbing can cause air bubble entrainment leading to supersaturated conditions. Even gravity flow hatcheries can encounter problems when air is picked up in submerged orifices or unvented piping.

Heating water for increased fish growth was one of the first recognized means of producing gas bubble disease. When water is heated the solubility of gases decreases with increasing temperature, creating a supersaturated condition. Even a one degree rise in temperature can, under the proper circumstances, raise levels of gas 2 to 3 percent.

What does supersaturation mean to fish and to the culturist? Basically, fish health problems. Because nitrogen gas is inert, it cannot be metabolized by nor absorbed into the blood of fish. As a result a myriad of equilibrium related problems develop within the body of a fish. Low levels promote stress which, particularly in fry, leads to chronic mortality caused by a failure to properly digest food, and secondary invasions of bacteria and parasites. Higher levels produce acute mortality with overt symptoms such as pop-eye, loss of equilibrium, white spot and bubbles in the fins, skin tissue and gut.

Atlantic salmon fry, the fish reared at Nashua, cannot tolerate levels above 102% without sustaining chronic mortality, while parr over 4" can handle up to 104%. The hatchery's well water averaged 118% nitrogen supersaturation throughout the year with levels of 120-125% not uncommon following periods of snow melt.

METHOD

Swedish Degasser. A Swedish or diffuser degasser similar in design to the one described by Dennison and Marchyshyn (1973) was the first system to be tried to combat the problem. The device uses air driven through water under ten ounces of pressure to agitate and mechanically strip entrapped excess gases. Unfortunately air contains 78% nitrogen by volume and using nitrogen laden air to strip nitrogen from water does not result in efficient degassing. Water treated in this manner contained levels of 102.5% to 105% nitrogen saturation.

In order to improve the quality of water, packed column "pre-degassers" were installed upstream of the Swedish unit to lessen its workload with the hope of improving its output. Packed columns (Owsley, 1978) (Fig. 1) are constructed of pipe filled with media (1½" Kock or Norton Rings) which baffle water flowing through the pipe causing turbulence that in turn liberates excess gas.

When first tested, the columns did not duplicate Owsley's predicted results of saturation levels of 100-101% and did little to help the Swedish unit. To help determine the cause of the discrepancy, a "test" column of clear pipe was used in order to allow for visual observation of what took place within the unit. The test began (results listed in Table 1) by using a small flow, 15 GPM, in the column which was designed to handle 40-60 GPM. It was observed that the water literally trickled over the media and no turbulence was created. The result, not surprisingly, was a level of 112% supersaturation. The flow was gradually increased from 40 to 67 GPM and the best degassing effect was

obtained using 55 GPM yielding 101.5%. At low flows turbulence was noticeable only in the lower sections of the column and very little was noted at the top. At higher flows, although there was turbulence at the top, the bottom of the column filled up with water, preventing any action from taking place. The optimum flow produced a great deal of turbulence throughout the column, especially within the upper six inches of media.

Using the best flow regimes available, both degassers were tested in tandem and marginally acceptable levels of 101% to 103% were obtained. The packed columns reduced incoming readings from 119 to 102 to 105% depending on the somewhat variable output of the well pump.

It became apparent simple mechanical stripping using air would, at best, produce saturation levels of 101% nitrogen while leaving open the possibility of water being even further supersaturated downstream of the degassers by leaks or air entrainment in plumbing fixtures. The task then became to obtain a level of 95% saturation in order to provide some leeway for plumbing problems. This was accomplished by the installation of a vacuum degasser.

Vacuum Degassers

The system consists of a three part vessel upon which a constant vacuum is applied. Water is sprayed into the top section, then cascades through Koch rings contained in the second compartment, with the intent of atomizing the water to increase surface area. The decreased pressure within the vessel permits the

liberation of gases which are carried off by the vacuum pump. The lowest section is filled with the column of water drawn up by the vacuum. The amount of vacuum applied determines the quantity of gases drawn off and hence the degree of degassing obtained. Desired levels of saturation can literally be dialed by using a vacuum gauge as a guide.

This system does have a major drawback in that it indiscriminately lowers the level of all gases present, including oxygen. Only four ppm of dissolved oxygen remained when nitrogen was brought down to an acceptable level. To raise dissolved oxygen, packed columns, which are also efficient aerators, had to be added to plumbing upstream of rearing units. The amount of media within the columns had to be adjusted to produce an adequate D.O. without substantially elevating the level of nitrogen.

DISCUSSION

None of the degassers tested and installed produced results that were totally acceptable; each had its own idiosyncratic drawbacks. Packed columns probably performed the best of the three, having the advantages of being inexpensive to construct, requiring no maintenance, consuming no power, aerating efficiently, and, not being mechanical, of not breaking down. In our experience columns must be precisely sized for a specific flow rate in order to obtain maximum efficiency from the units. If flow rates through the columns are not kept constant, lethal levels of gas can remain in treated water. Species of fish not particularly affected by low levels of supersaturation would probably live

comfortably with these devices provided the columns were located at the end of a water distribution system.

Although vacuum degassers do work well, they should only be considered for installation after it has been determined packed columns would not be adequate for an individual application. This recommendation is made because vacuum degassers are mechanical devices that are doomed to constant maintenance and eventual failure in addition to depleting oxygen. Swedish degassers aren't significantly more efficient than packed columns and are subject to mechanical disorders. Their use is probably best suited to low head gravity flow situations where packed columns, generally five feet tall, can't be installed.

ACKNOWLEDGEMENTS

I thank David Owsley of the Dworshak National Fish Hatchery and Terry McLaughlin and Lester Bush of the U.S. Fish and Wildlife Service Denver Engineering Center for their invaluable aid in testing and trouble shooting the degassers discussed in this paper.

TABLE I -- VARIABLE FLOW THROUGH A 6" PACKED COLUMN

GPM	% Nitrogen Supersaturation		Temp. °F
	Incoming	Treated	
15	118	112	50
40	118	109	50
45	118	105	50
50	118	104	50
55	118	101.5	50
60	118	103	50
67	118	111	50

REFERENCES

Dennison, B.A., and M.J. Marchyshyn 1973. A device for alleviating supersaturation of gases in hatchery water supplies. Prog. Fish-Cult. 35(1):55-58.

Owsley, D.E. Nitrogen gas removal at Dworshak National Fish Hatchery. (Unpublished.) 15 pp. (1977)

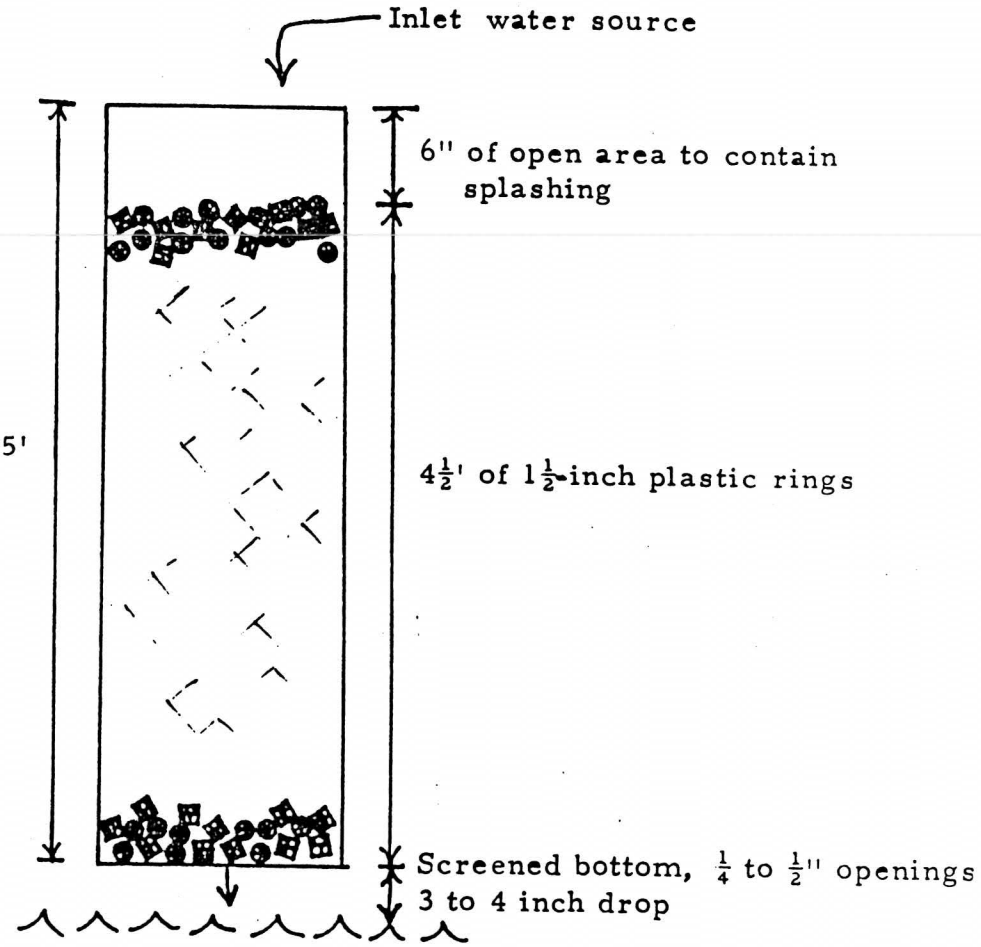


Figure 1.a Packed Column Degasser

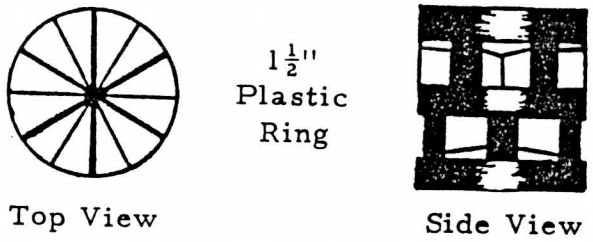
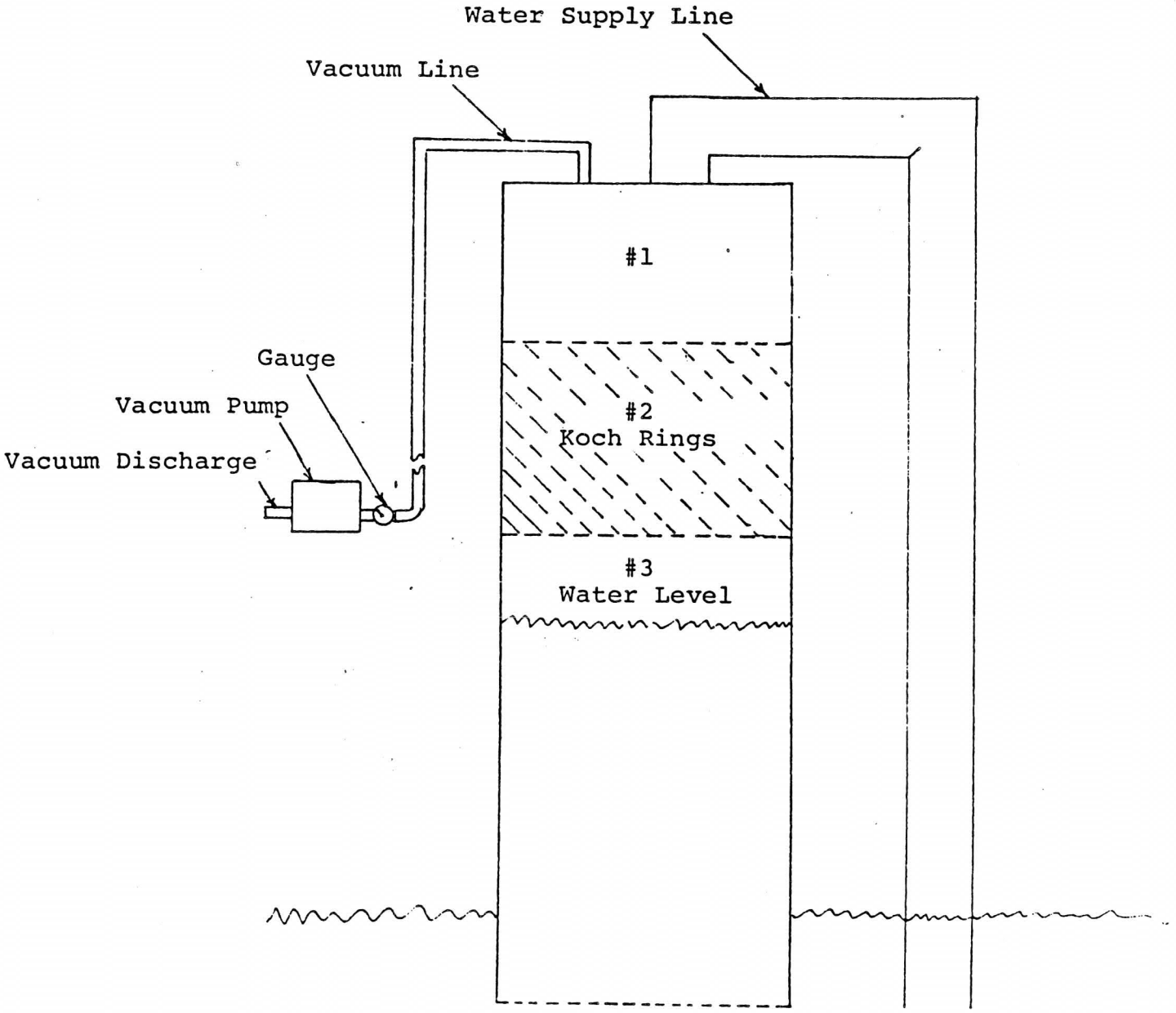


Figure 1.b Plastic ring
Diagram courtesy of David Owsley, Dworshak National Fish Hatchery.

Figure #2

VACUUM DEGASSER



"One Fish, Two Fish"

Andy Appleby
and
Rich Schneider
Washington Department of Fisheries

The critical nature of hatchery inventory information to both hatchery and fishery management makes it imperative that contemporary approaches to quantifying fish hatchery populations be explored. The Washington Department of Fisheries (WDF) recently investigated the use of electronic counting hardware for quantification of large numbers of salmonids in hatchery environments.

Inventorying hatchery pond populations can be a difficult task for hatchery managers. Undetected mortality and uncontrollable predation can change accurate ponding figures into inaccurate "guesstimates". The degree of error may not be large in smaller, standard size ponds but can be quite difficult to estimate in today's large asphalt and gravel ponds.

Electronic fish counters have been used successfully in other states to measure downstream migration of wild fish and to quantify volitional out-migration of fish from hatcheries. The intent of our investigation was to develop a portable fish counting apparatus that would accurately and rapidly count production-size populations of hatchery salmonids.

The electronic counter chosen for our design is a commercially

available model that operates on the balanced bridge principle. It consists of a counting head 3.5 x 5.5 x 11 inches with 16 one-inch diameter counting tunnels. The electronics package is also compact (4½ x 6 x 12 inches) and is operated by a standard 12 volt battery. The fish tally is shown on a lighted 8 digit display. The one-inch counting head can be used to count fish up to 35 to the pound. A counting head with two-inch diameter tunnels also is available for counting larger fish (up to 3½ fish/pond). The compact design of the counter makes it adaptable to a variety of hatchery outlet structures for counting fish during release.

To make the counter portable for use statewide, WDF's Auburn Shop designed a 4 x 8 x 2 ft. aluminum box into which two counters could be mounted. The box was placed on a trailer with the counters at the rear so that it can be backed to a pond into which the fish can spill as they are counted. The box also contains a removable center wall so that separate groups of fish can be passed through each counting head.

Initial counting trials were conducted at Minter Creek Salmon Hatchery. Yearling coho salmon were hand-counted into a concrete pond. Water was supplied to the counting trailer via a small pump and the fish were transferred from the pond to the trailer using dip nets.

Three trials were done. The results showed an average 5% over estimate by the counter. While a 5% average was not as good as hoped, if the error proved constant, future population estimates could

be corrected with good results.

Following the initial trials, the trailer was plumbed to allow the hook up of a four-inch Morton fish pump. This facilitated movement of fish and water to the trailer, but the pulsing water from the pump created a large standing wave inside the box which could have adversely affected the counters. Subsequent counting trials produced numbers ranging from -4.5% to +5.3% of the handcounted number.

The standing wave was eliminated by pumping the water and fish across a dryer grate before spilling into the trailer. The resultant smooth flow of water to the trailer eliminated the wide variation in counts, but did not correct the aforementioned 5% overestimation.

Close inspection of the counter in operation led to the realization that occasionally, as fish passed out of a tunnel, an air bubble would propogate itself back up the tunnel, causing an extra count to be registered. A splash-guard was attached to keep the rear of the tunnels flooded but the turbulence created by the splash-guard allowed some fish to re-enter the tunnels from the rear, again tallying extra counts. The counting tunnels were then extended using 1 x 12" ABS pipe.

Accuracy improved immediately (Table 1). We then began to use the counter on larger size groups. The opportunity presented itself at Cowlitz Salmon Hatchery, where 50,000 fish groups were being tagged for a pond loading experiment.

Fish which were to be tagged were first counted via the electronic counter, then taken to the tagging trailer, where a handcount was made

in conjunction with tagging. Results are listed in Table 2.

Head differential played an important role in determining the accuracy of our counters. Velocities through the tubes were calculated and compared to the burst swimming speed of coho of appropriate size.

Accuracy increased as head increased, but so did mortality. Too high of a head caused spinal injuries as fish would be sucked rapidly into or across the face of the counter.

With too low of a head the fish were able to enter the tunnels and swim back out of the counter and enter again, thus tallying extra counts.

Head differentials of 10-12" prove to be the best middle ground with accuracies of 1-2%, and mortality of 1% or less.

Continued testing will be done as the opportunities present themselves. If we continue to see the degree of accuracies we have become used to, and assuming sufficient financial backing, the next several years should see the WDF using counters as a regular hatchery tool for improving the accuracy of on-station pond splits and final release number.

TABLE 1. COUNTING TRIALS AT MINTER CREEK HATCHERY

Trial	Hand Count	Counter Tally	% Diff.
1	500	503	0.6
2	494	497	0.6
3	502	506	0.7

TABLE 2. COUNTING TRIALS AT COWLITZ HATCHERY

1" counting head

Trial	Hand Count	Counter Tally	% Diff.
1	53100	53066	-.06
2	55180	53951	-2.2
3	54619	55366	+1.3

BIRD PREDATION ON HATCHERY-RELEASED CHINOOK SALMON

During the spring downstream migration season for salmon, the Big Qualicum River estuary was a popular area for bird watchers during the late 1970's and early 1980's. In 1979, Pamela Mace, a graduate student at the University of British Columbia began studying sculpin predation on chum fry in the Big Qualicum estuary. She simultaneously censused the bird population and subsequently convinced Department of Fisheries and Oceans staff that bird predation was serious enough to warrant an in-depth study. She continued and expanded her observations in 1981 and 1982 under contract to DFO and documented the response of predatory birds to increased numbers of fish, and their feeding success (Mace, 1983). This paper summarizes the impact of fish-eating birds or juvenile chinook salmon and ways to reduce this impact.

Big Qualicum River is located on the east coast of Vancouver Island. The hatchery is 1.6km upstream from the mouth and produces chinook, coho and steelhead. Production rates from Big Qualicum have been very high, but the increasing number of birds was a concern.

The Big Qualicum estuary is very small, approximately 0.14km^2 and most bird predation occurs in an area about 100m long. Despite this small area, instantaneous counts up to 2348 birds were recorded. The birds made up to 650 strikes and 200 successful strikes in one five minute interval. There was usually an increase in the bird population within hours after a chinook smolt release from the hatchery. For example on June 1, 1981 1,100,000 chinook smolts were forced out of the rearing ponds. Release started at 15:00 hours and significant migration to the estuary was evident by 16:00 hours. At 16:05 hours there were 72 Bonaparte gulls at the river mouth. By 17:20 hours there were 619 and by 21:00 hours there were 1222 Bonaparte gulls. When the release started there were no concentrations of gulls three km north or south of the hatchery yet within three hours dramatic aggregation occurred, and they were all actively feeding.

Fall chinook smolt losses were much greater than hatchery coho or steelhead losses. Predation was estimated from the number of birds present at regular intervals and observed feeding rates for gulls, and from reported average body weight, feed rates and diet composition for other species. Chinook losses averaged a minimum of 266,000 (9.8% of release) in 1979 and 1980, and 851,000 (19.6% of release) in 1981 when an outbreak of cataract disease rendered smolts extremely susceptable to predators. In 1982, losses were less than 48,000 (1.2% of release) (Table 1).

The dramatic reduction in 1982 was due to changes in chinook release strategy by Big Qualicum Hatchery staff. These changes reflected migratory and feeding behaviour of the birds and included:

1. Delayed release to mid-June to reduce the impact of mergansers, loons and harlequin ducks. These species diminish in number from April to June, mergansers because they lose their flight feathers and move to protected areas and loons and harlequins as they leave for their breeding areas.

2. Release late on a day when tides will be high the morning following and when no extreme low tides will occur over the next 3 or 4 days. This will reduce the feeding success of Bonaparte gulls, the major predator on chinook since this species is most successful when water depth is less than one meter. Water depth in the feeding area reaches 1m at tidal height of 3m.

3. Forced release to reduce the length of time chinook are present in high densities in the estuary. Large numbers of chinook will saturate the initial predator population. Short residence time will minimize the impact of birds recruiting to the area in response to fish availability.

This strategy worked in 1982. In 1983, although predation was not monitored, the number of birds present was significantly lower than in the four previous years.

Reference:

Mace, P.M. 1983. Bird predation on juvenile salmonids in the Big Qualicum estuary, Vancouver Island. Can. Tech. Rep. Fish. Aquat. Sci. No. 1176, 77 pp.

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TABLE 1. Estimated number of juvenile chinook taken by piscivorous birds in the Big Qualicum estuary (estimates considered conservative).

Year	No. Chinook Released	Estimated Predation
1979	2,554,000	>221,000
1980	2,896,000	301,000
1981	4,335,000	857,000
1982	3,467,000	46,000

OPERATIONAL PREFERENCES IN SIZING NEW HATCHERY REARING VESSELS

Preface:

This paper is presented from the point of view of a consulting engineer who has worked on the conceptual design of new salmonoid hatcheries for difference fisheries agencies throughout the Northwest. There appears to be no common preferred configuration of rearing vessels among the agencies. This is due primarily to different operational preferences although the availability of construction funds is also limiting.

Different species of salmonids demand different operational criteria due to differing behavior, physical size, etc. For simplicity's sake, this paper will be limited to rainbow and steelhead trout rearing. It is not the intent of this paper to establish whether one rearing system is superior to another, but to discuss the operating rational for selection of a particular system. It is hoped that this paper will serve to stimulate dicussion among those hatchery operators and designers in attendance so that all may benefit from others' innovation and operating strategies.

Aside from incubation, rearing facilities for rainbow/steelhead trout consist of starter tanks (or early rearing tanks) and final rearing facilities (raceways or ponds). Before a discussion of these facilities may proceed, a number of gross assumptions must be made in order to compare the systems:

(1) A reliable source of high quality water is available, meeting the demand based on "Cannady's Flow Index."

(2) Disease-free swim-up fry are introduced into the starter tanks.

(3) Manual transferring of fry from starter tanks to final rearing facilities.

(4) Fingerling trout will be "fish-pump" loaded into transport tanks at 5 per pound (approximately 8 inches long). Steelhead shall be assumed to still be parrs at transport time.

(5) Concrete final rearing raceways shall be either in pairs with roadways between pairs with vehicle-mounted blower feeders or common wall for all raceways with demand or air-operated feeders.

(6) Rearing densities will be low enough for all systems to produce "quality" fish.

In order to fully evaluate a rearing system, one must look at the total rearing system from "starting fry" to out-planting.

Therefore, combinations of starting tanks and final rearing facilities are chosen for evaluation. The following are some of the rearing systems the author has designed or observed for rearing steelhead or rainbow: (Some of the systems were not designed according to the previously mentioned assumptions but are listed here for comparison anyway.)

(1) 24" x 20' x 24" high starter tanks with 10' x 100' x 48" high concrete raceways.

(2) 36" x 20' x 30" high starter tanks with 8'x 100' x 48" high concrete raceways.

(3) 36" x 16' x 42" high starter tanks with 8' x 75' x 48" high concrete "Burrows" raceways.

(4) 48" x 38' x 42" high starter tanks with 10' x 100' x 48" high concrete raceways.

(5) 6' diameter x 42" high circular starter tank 10' x 100' x 48" high concrete raceways.

(6) 12" x 14' x 8" high incubation/starter trough with 10' x 100' concrete raceways, 80' wide x 1,100' long x 7.5' average depth earthen rearing pond.

(7) 16" wide x 12' long x 7" high incubation/starter trough mounted over 24" wide x 17' long x 24" high trough with 15' wide x 50' long x 48" high concrete raceways (1st pass has the upper 25 ft. divided into thirds).

These rearing facilities are different due to emphasis on one or more of the following operational criteria:

(1) Ability to start the fish on feed.
(2) Ability to observe fish behavior.
(3) Ability to prevent disease outbreaks.
(4) Ability to treat disease outbreaks.
(5) Ease of feeding.
(6) Ease of cleaning.
(7) Ease of grading fish.
(8) Ease of transferring fish.
(9) Flexibility.
(10) Relative cost.

The author's bases for rating the systems are as follows:

(1) Ability to start the fish on feed. Primarily, the smaller and shallower the starter tank, the easier for the fry to come to the surface for feed.

(2) Ability to observe fish behavior. Again, the smaller the rearing vessel, the easier to observe the fish.

(3) Ability to prevent disease outbreaks. With all other stress-related disease considerations equal, the more containers the fish are in, the fewer the affected fish or the smaller the rearing units, the fewer affected fish.

(4) Ability to treat disease. The more uniform flow through the vessel, the more effective the treatment. This favors raceways or troughs with weirs in and out of the system. Rearing ponds usually have large "dead areas" that are hard to treat and "Burrows" recirculating raceways are hard to treat and flush immediately.

(5) Ease of feeding. Generally, the smaller and narrower the vessel, the easier to feed effectively.

(6) Ease of cleaning. The narrower the vessel, the easier to either brush-down or vacuum clean. Also, the shorter the vessel, the easier to brush-down clean. "Burrows" raceways are the easiest to keep clean.

(7) Ease of grading fish. Also, the narrower the vessel, the easier to crowd the fish and grade. Recirculating raceways are more difficult to grade fish in.

(8) Ease of transferring fish. Same as (7) the larger the starter tank, the larger the fish may be at transfer time and less resulting stress. Circular and recirculating tanks/raceways make transferring more difficult. Large rearing ponds are released into the receiving stream.

(9) Flexibility. Generally, the larger the rearing vessel, the more flexible, especially starter tanks, where fingerlings may be reared if they are 48" wide x 40'. Partitioned raceways also provide flexibility in rearing different fish sizes.

(10) Relative cost. The larger the rearing size, the less concrete and cost. Larger starter tanks require less hatchery building space.

The author has taken a stab at rating the seven aforementioned rearing systems according to these operational criteria. The rating system will be based on 1 to 5 with 5 being the highest. However, each factor does not deserve the same rating. I would like each hatchery operator to rate the rearing systems himself and add the weight to each operational factor that he deems appropriate.

Tables 1 and 2 show the result of the author's attempt at rating starter tanks and final rearing facilities. Every operator will probably have different weights to apply to the criteria and, consequently, will rate each rearing system differently.

I would appreciate it if each operator would complete the rating and mail to: Phil Jeppson, Idaho Fish and Game, P.O. Box 25, Boise, ID 83207. I will then collate the data and present at next year's conference.

TABLE 1. STARTER TANKS

OPERATIONAL CRITERIA	REARING SYSTEM ① 24"x20'x24" TANKS w/ 10'x100'x4' RACEWAYS	② 36"x20'x30" TANKS w/ 8'x100'x4' RACEWAYS	③ 36"x16'x42" TANKS w/ 8'x75'x4' BURROWS RACEWAYS	④ 48"x38'x42" TANKS w/ 10'x100'x4' RACEWAYS	⑤ 6'Ø x 42" CIRCULAR TANKS w/ 10'x100'x4' RACEWAYS	⑥ 12"x14'x8" TANKS, 10'x100' RACEWAYS w/ 80'x1,100'x7.5' PONDS	⑦ 16"x12'x7" w/ 24"x17'x24" TANKS w/ 15'x50'x4' w/ PARTITIONS	⑧ ?	WEIGHTED TOTAL
ⓐ Start fish on feed	4 x =	3 x =	3 x =	1 x =	3 x =	5 x =	5 x =		
ⓑ Observe fish behavior	3 x =	3 x =	3 x =	2 x =	4 x =	5 x =	5 x =		
ⓒ Prevent disease outbreak	3 x =	2 x =	2 x =	1 x =	3 x =	4 x =	5 x =		
ⓓ Treat Disease	4 x =	4 x =	4 x =	3 x =	1 x =	5 x =	5 x =		
ⓔ Feeding Ease	3 x =	2 x =	2 x =	1 x =	4 x =	5 x =	5 x =		
ⓕ Cleaning Ease	4 x =	3 x =	3 x =	2 x =	1 x =	5 x =	5 x =		
ⓖ Grading Fish	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
ⓗ Transferring Fish	3 x =	4 x =	4 x =	5 x =	1 x =	1 x =	3 x =		
ⓘ Flexibility	3 x =	4 x =	4 x =	5 x =	2 x =	3 x =	4 x =		
ⓙ Relative Cost	3 x =	4 x =	4 x =	5 x =	4 x =	2 x =	2 x =		
ⓚ ?									
WEIGHTED Total									

TABLE 2

FINAL REARING

OPERATIONAL CRITERIA	REARING SYSTEM								
	① 24"x20'x24" TANKS w/ 10'x100'x4' RACEWAYS	② 36"x20'x30" TANKS w/ 8'x100'x4' RACEWAYS	③ 36"x16'x42" TANKS w/ 8'x75'x4' BURROWS RACEWAYS	④ 48"x38'x42" TANKS w/ 10'x100'x4' RACEWAYS	⑤ 6'Ø x 42" CIRCULAR TANKS w/ 10'x100'x4' RACEWAYS	⑥ 12"x14'x8" TANKS, 10'x100' RACEWAYS w/ 80'x1,100'x7.5' PONDS	⑦ 16"x12'x7" TANKS w/ 24'x17'x24" w/ 15'x50'x4' w/ PARTITIONS	⑧ ?	WEIGHT
ⓐ Start fish on feed	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ⓑ Observe fish behavior	4 x ___ =	5 x ___ =	5 x ___ =	4 x ___ =	4 x ___ =	1 x ___ =	3 x ___ =		
ⓒ Prevent disease outbreak	3 x ___ =	4 x ___ =	5 x ___ =	3 x ___ =	3 x ___ =	1 x ___ =	4 x ___ =		
ⓓ Treat Disease	4 x ___ =	5 x ___ =	1 x ___ =	4 x ___ =	4 x ___ =	2 x ___ =	3 x ___ =		
ⓔ Feeding Ease	4 x ___ =	4 x ___ =	5 x ___ =	4 x ___ =	4 x ___ =	1 x ___ =	3 x ___ =		
ⓕ Cleaning Ease	3 x ___ =	4 x ___ =	5 x ___ =	3 x ___ =	3 x ___ =	5 x ___ =	2 x ___ =		
ⓖ Grading Fish	4 x ___ =	5 x ___ =	2 x ___ =	4 x ___ =	4 x ___ =	1 x ___ =	3 x ___ =		
ⓗ Transferring Fish	3 x ___ =	4 x ___ =	2 x ___ =	5 x ___ =	2 x ___ =	1 x ___ =	3 x ___ =		
ⓘ Flexibility	4 x ___ =	3 x ___ =	3 x ___ =	4 x ___ =	4 x ___ =	1 x ___ =	5 x ___ =		
ⓙ Relative Cost	3 x ___ =	3 x ___ =	2 x ___ =	3 x ___ =	3 x ___ =	5 x ___ =	2 x ___ =		
ⓚ ? ___									
WEIGHTED									

The Effects of Artificial Substrate on Growth and Survival of Hatchery Coho Salmon (Oncorhynchus kisutch)

Howard Fuss and Charles Johnson
Washington Department of Fisheries

The use of artificial or natural substrates in hatchery incubation systems has been shown to produce larger size salmon fry at yolk absorption (Bailey and Taylor 1974; Leon 1975; Snyder 1977; Leon and Bormey 1979; Fuss 1982). Additionally, the use of gravel substrates have produced fry with greater swimming stamina and mere ability to escape predators than fry incubated without gravel (Brannon 1965; Bams 1967).

There has been little data to indicate how incubating fish on substrates in a hatchery effects both pre- and post-release survival. Bams (1972) showed that survival to the adult stage for hatchery-reared fry of pink salmon (O. gorbuscha) incubated in gravel was similar to that of pink salmon fry incubated in a natural stream.

The objectives of this study were as follows:

1) Does substrate have an effect on coho alevin size at yolk absorption;
2) Whether a potential size advantage would be maintained during a 12-month rearing period;
3) Does incubation on substrate affect disease susceptibility;
4) Does incubation on substrate affect subsequent survival in the ocean.

Methods and Materials

The study was conducted at the Dungeness Salmon Salmon Hatchery near Sequim, Washington. A pooled sample of eggs was eyed and randomly distributed in shallow trough baskets. A total of 20 troughs were used in the experiment of which 10 were designated as control troughs and the remaining 10 as experimental troughs. Each trough was divided into three sections. The upper section was used to settle particulate matter. The middle section was twice as large as the upper section and contained two baskets of eggs (25,000 eggs per basket). The lower section was of similar size to the upper section and contained one basket of eggs (also 25,000 eggs per basket). Five layers of 1.9 cm Vexar plastic netting, conforming to the length and width of each trough section were on the bottom of each trough and held in place by lengths 1.3 cm diameter rebar. Fry were allowed to hatch in the baskets and drop through to the substrate below.

Two treatments were tested: covered and uncovered substrate with corresponding covered and uncovered controls. Five of the 20 troughs were used for each treatment and control.

At yolk absorption, 50 fish from each treatment and control were measured to the nearest millimeter and weighed to the nearest 0.01 g on a Mettler PN1210 balance. After ponding, 50 fish from each treatment and control were similarly weighed and measured each month until release.

The fish were stocked on May 1, 1982, in four concrete ponds, 6 x 24 m at equal densities. The fish were maintained at normal rearing densities for the remainder of the experiment. All fish were fed Oregon Moist

Pellet II at ration levels of 3.4% (May-October), 0 5% (November-March) and 2.5% (April-June). Approximately six percent (10,000 fish) of the fish in the control and substrate groups were tagged with a uniquely coded micro-tag and adipose fin excision. Fish were tagged in October 1981. All fish were released on May 18, 1982.

The hypothesis of equal mean length or weight between and within treatments was tested using two-way analysis of variance. Differences in death rates between substrate and control groups were tested by using the relative difference test given by Shep (1959). Marked fish were sampled from the Washington and Canadian fisheries, as well as at the hatchery. Estimated contribution rates are not available at this time, therefore, number of recoveries and survival rates are calculated from observed recoveries.

Results

Fry in the substrate groups were significantly larger (P 0.05) than the control groups in both mean weight and length at yolk absorption (Table 1). There were no significnat differences in mean weight and length due to covering. There was a sigificant (P 0.05) interaction effect of substrate and covering on mean weight. This was due to a larger number of fry in the uncovered control group having not reached 100% complete yolk absorption in comparison with the other groups. As a result, these fish were slightly heavier per unit of length than the covered control fish. This delay in yolk absorption relative to fish

incubated on substrate has been noted previously in studies conducted on chum salmon (Fuss 1982), coho salmon (W.D.F. unpublished data), and Atlantic salmon (Leon 1975).

Fry from both treatment and control groups were ponded on May 5, 1981. One month later, in June 1981, fry in the substrate groups were significantly larger (P 0.05) in both mean weight and length than fry in the control groups. There were no significant differences within treatments. Condition factors were similar between the two groups. There were no significant differences in either mean weight or length between or within the treatments during the remaining 11 months of rearing. However, the fish in the substrate groups tended to be somewhat larger than the fish in the control groups (Table 1).

Freshwater Mortality

The mortality rates of the substrate and control groups differed significantly (P 0.05) for the first two months of rearing (Table 2). The mortality dropped in June due to the addition of terramycin to the diets. Mortality was caused by cold temperature disease (Cytophaga psychrophillia) which has historically caused mortality problems during the early summer at Dungeness Hatchery. The mortality rates of the control groups were similar to the mortality rates of production groups for the remainder of the hatchery. The production groups were incubated similarly as the control groups. Mortality was insignificant for the remaining 10 months of rearing.

Marine Survival

Although no estimated survivals are available at this time, observed recoveries from the Washington and Canadian fisheries, as well as hatchery escapement are available. A total of 76 substrate fish (0.8 percent survival) and 60 control fish (0.6 percent survival) have been recovered thus far. Mean fork length of the substrate group and control group fish was 62 and 63 cm, respectively. There are no apparent differences in ocean survival.

Discussion

The use of Vexar as a substrate during the incubation of coho salmon alevins produced significantly larger fry compared with fry incubated without substrate. This size difference became insignificant after the third month of rearing. Both Leon (1975) and Shroder (1976) found that Atlantic salmon (*Salmo salar*) and Chum salmon (*O. keta*) respectively, incubated on artificial substrate maintained a size advantage over fish incubated without substrate for the initial rearing period.

Perhaps of greater importance to the fish and the fish culturist is the reduction of disease incidence during the rearing period due to incubation on substrate. Stressing of fish has been recognized as an important mediator of many diseases. It is conceivable that fish incubated on a substrate lacking rugosity suffer enough stress to make them susceptible to certain pathogens. Also, once exposed to these pathogens, the fish may suffer chronic stress that is not detectable by

by poorer food conversion rates or higher mortality.

In addition, this long-term stress may ultimately effect ocean survival in several ways. One, the fish may be carrying the pathogen in a latent or non-epidemic form, and because of the stress during salt water transition succomb to the pathogen, or 2) the long-term stress associated with disease occurrence or exposure might effect the osmoregulatory ability of these fish.

Coded wire tag returns do not indicate any differences in marine survival (Table 3), but do indicate that survival is not adversely affected by using substrate.

Incubating coho salmon in shallow troughs utilizing Vexar netting as a substrate is feasible in a production scale hatchery. The substrate itself is both easy to install and remove for cleaning. However, moderately clean water should be available due to the potential of smothering of alevins during heavy silt loads.

Table 1. Mean Weight (g) of Fry at Ponding (April 26, 1981) and Subsequent Rearing Periods.

Treatment	April[1/]	June[1/]	July	August	Sept.	Oct.	Rel.
Covered substrate	0.34	0.97	2.12	4.33	9.15	14.40	18.35
Uncovered substrate	0.32	0.93	1.89	4.41	8.64	14.14	19.42
MEAN	0.33**	0.95*	2.01	4.37	8.90	14.27	18.88
Covered control	0.30	0.91	1.92	4.13	8.34	14.73	17.03
Uncovered control	0.31	0.86	1.95	4.17	8.44	12.66	17.65
MEAN	0.30	0.89	1.94	4.15	8.39	13.69	17.37

[1/] The difference in means between substrate and control groups was significant at = 0.05.

Table 2. Mean Monthly Mortality Rates for Substrate, Control, and Hatchery Production Groups. Covered and Uncovered Groups Within Treatments have been Combined.

Group	Percent Mortality	
	May	June
Substrate	0.34	0.035
Control	1.31	0.31
Production	0.97	0.50

Table 3. Observed Recoveries, Estimated Survival and Mean Fork Lengths for the Substrate and Control Group Fish.

Treatment	Number Released	Total Recoveries	Survived	Catch Distribution			Mean Fork L (SD)
				Wash.	Can.	Escape.	
Substrate	9,835	76	0.8	29	24	23	62.0 (6.0)
Control	10,008	60	0.6	19	23	18	63.0 (5.0)

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AIR-SPAWNING OF RAINBOW TROUT AT ROARING RIVER FISH HATCHERY

Air-spawning was first reported at the Northwest Fish Culture Conference in 1963. Since that time recent studies have shown air-spawning to be an effective tool in the spawning of rainbow trout.

Spawning of rainbow brood trout has been done at Roaring River Fish Hatchery, Oregon Department of Fish and Wildlife, since the early 1940's. Egg retention broken eggs, pseudo-kidney disease have been problems in the past.

In 1982 an air-spawning system was introduced at Roaring River. This system was set up to test adult survival, increase egg quantity, egg survival and generally improve the overall spawning operation.

The system consists of an air compressor, black iron pipe, two control valves two pressure cooker gauges hypodermic needles and surgical tubing.

Three tests were conducted. Each test consisted of 35 females hand spawned and 35 females air spawned. Females air-spawned produced 1,125 more eggs per female than the hand spawned females. Air spawned females averaged 20% egg loss compared to 28% from the hand spawned females. Hand spawned females had 6% more loss than the air-spawned adults.

Air-spawning is faster and easier on both fish and personnel. This procedure will be continued to be tested at Roaring River Fish Hatchery.

A slide presentation accompanies this article.

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BROODSTOCK RESTORATION PROGRAMS AT MANCHESTER MARINE EXPERIMENTAL LABORATORY PUGET SOUND, WASHINGTON

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The possible extinction of individual races of salmonids is an increasing concern of management biologist. Habitat degradation, coupled with overfishing and pollution, led to the near total loss of Atlantic salmon (Salmo salar) stocks in the United States Southern New England streams by the mid 1800s. Some west coast Pacific salmon stocks (Oncorhynchus spp.) are presently facing the same fate. These stocks represent unique spawning populations which were historically and economically important to the region. Although these runs are threatened, habitat restoration and improved management practices could allow these runs to eventually rebuild.

While long-term possibilities for re-establishing threatened runs appear to be improving, a substantial, reliable source of eggs must be assured before the objective of the restoration efforts can be realized. Adult returns from eggs of threatened runs can be as low as a few tenths of a percent (in the case of Atlantic salmon). Thus, it could take many years under the most favorable conditions to naturally build up depressed stocks to a point where there are eggs available on a large scale for stream restocking or for expanded hatchery rearing.

Another approach is a captive broodstock program where progeny from threatened stocks are reared to maturity and these eggs used to enhance the natural runs. Captive broodstock should produce a minimum of 5% egg to adult spawner (e.g. 500 adult spawners/10,000 eyed eggs started), thus a large number of eggs can be available for enhancement purposes at the end of the first spawning cycle. This ability to quickly produce a substantial egg supply makes captive broodstock programs a necessary adjunct to serious restoration efforts.

During the past decade, the National Marine Fisheries Service (NMFS) has implemented captive broodstock programs aimed at producing stable supplies of eggs for the restoration of threatened runs of both Atlantic and Pacific salmon. Because of the moderate climate and seawater temperature range in Puget Sound (6-15°C), NMFS's Marine Experimental Laboratory near Manchester, Washington was chosen as the seawater culture site for these programs. Presently, four stocks of Atlantic salmon (bound for southern New England restoration programs) and six stocks of chinook salmon, Oncorhynchus tshawytscha, (four brood years of Columbia River upriver bright stock and two brood years of Puget Sound White River spring chinook stock) are being maintained at the laboratory.

Small numbers of eggs from a selected stock, usually between 10,000 and 20,000 eggs subsampled from as many mating pairs as possible (to preserve genetic diversity), are shipped to the Marine Experimental Laboratory's satellite station near Seabeck, Washington for freshwater rearing. These fish are transferred to floating marine net-pens at the Manchester site as 0-age, 1, or 2-year old smolts (depending on species and stock) and grown to maturity. Mature fish are moved back to the freshwater station for spawning, and ultimately eyed eggs are shipped to the targeted restoration programs.

A necessary adjunct to these production programs is a parallel research study that includes experiments on fish health, nutrition, rearing strategies, and acclimation of smolts to the marine environment.

Fish Health

Most freshwater mortality in Atlantic salmon occurs early, during the delicate alevin and swim-up stages, and again as fish begin to smolt. Disease problems encountered during the freshwater rearing of chinook and Atlantic salmon are bacterial, primarily Myxobacteria sp. and Aeromonas sp., and documented in the literature, thus requiring little or no further investigation.

After transfer to the marine net-pens, the salmon are subject to new, previously undescribed diseases as well as those already described in the literature. Several new marine diseases are currently under investigation; these include two protozoon parasites; an undescribed systemic fungal pathogen, and an infectious anemia of chinook salmon.

Nutrition

Semi-moist, high lipid (>15%) diets provide optimum acceptability for first feeding fry and are preferred for early fry rearing. Various dry and moist rations have proven effective for freshwater grow-out. However, a moist pelleted (OMP-type) diet is commonly used throughout smolt rearing.

Most broodfish in marine net-pens are fed a staple diet of moist and/or semi-moist pellets. Some chinook salmon stocks are periodically fed supplements of fresh frozen herring and krill. During the fall of 1982, our research demonstrated that maturing Atlantic salmon which were fed a ration with 30% whole krill had a substantially higher post-stress survival than a control group which was fed a standard commercial pelleted diet without krill. Further research is planned to test the effects of dietary changes on the pre-spawning survival and egg viability of chinook salmon.

Rearing Strategies

Husbandry methods common to most salmon hatcheries are routinely used at our facilities. However, ongoing research indicates that modification of some common procedures may be beneficial. For instance, traditional methods favor leaving fish totally exposed during outside rearing. Our results suggest that the addition of shade providing covers will increase growth, survival, and food conversion.

Cover types, of which most approximate the shading fish would naturally seek at a particular size, appear the most beneficial. Surplus

U.S. Army camouflage netting is routinely used at our freshwater rearing station. This netting produces a mottled shading effect which imitates the natural shading of stream side cover and appears to be the preferred cover type in freshwater rearing. Behavioral observations indicate most fish voluntarily stay under camouflaged portions of tanks, indicating a strong preference for covered versus open rearing situations.

During broodstock rearing, seawater net-pens are shaded with black vinyl covers. These both reduce net fouling and, more importantly, provide a naturally darkened environment (without shade the fish would be unnaturally confined to the zone of maximum illumination). The black vinyl covers provide the low light environment that seawater salmonids naturally seek. This duplication of the natural system provides a more acceptable environment for fish rearing.

Smolt Acclimation

Recently, a pipeline was constructed at Manchester that extends to the marine rearing facilities at the end of a 350-foot pier. Beaver Creek water is pumped into the sea cages that are sided with sheet vinyl, and an artificial freshwater lens is created. This system allows us to gradually acclimate smolts to full strength seawater and has substantially reduced losses due to osmoregulatory shock and handling stress. We are also investigating the use of this system as an alternative to moving nature fish back to freshwater facilities.

During early November of 1983, we began spawning our first brood stock. Approximately 300 mature 1979 brood Atlantic salmon were transferred from seawater net-pens to freshwater holding facilities in September. This first take will be shipped as eyed eggs to southern New England for restoration of the Merrimack and Connecticut Rivers.

The Effect of Hatchery Water Velocity on the Feed Consumption, Growth, Food Conversion and Stamina of Brook Trout

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Abstract

This study was designed to compare the practical effects of rearing brook trout (*Salvelinus fontinalis*) in units either with or without water currents sufficient to force them to swim actively and continuously. T-A fish were reared in directed water currents of 1.5-2.0 body lengths per second and were fed to satiation. T-B fish were reared without directed water currents and fed to satiation. T-C fish were reared in currents equal to those for T-A fish but were fed only the same percentage body weight per day as T-B fish. T-A fish were heavier than T-B or T-C fish after 10 weeks of experimental treatments. T-B and T-C fish showed no difference in final weight. T-A and T-C fish both had greater swimming stamina than T-B fish at the end of the study. Food conversions for T-A, T-B, and T-C fish respectively were 1.54, 1.58, 1.49.

Introduction

The characteristics that constitute high quality hatchery-produced juvenile salmonids, destined for release into the wild, are as yet not unanimously agreed upon by managers and researchers. Burrows (1969), Vincent (1960), and Wendt and Saunders (1972) reported improved survival or ability to combat stress in groups of salmonids that had been intentionally exercised for varying periods of time prior to release. In contrast, Horak (1972) disputed the value of stamina testing for trout that were to be placed in lakes and streams for sportfishing.

Belonging to the school of thought that higher animals are generally physiologically healthier when exercised regularly, I conducted a study to measure the effects of forced exercise and level of feeding on the growth, food conversion, and swimming stamina of brook trout (*Salvelinus fontinalis*) juveniles.

Methods

On 24 May 1972, 400 brook trout at a mean individual weight of 3.7g were placed into each of 12 fiberglass circular rearing units having an inside

diameter of 84cm and a mean water depth of 30cm. The water volume (minus the standpipe volume) of each unit was approximately 160 liters. The 8°-9°C freshwater entered each tank at a rate of 11.3 liters/minute via three holes drilled perpendicularly into a 2.5-cm horizontally oriented PVC pipe. Incoming water was introduced at the surface and exited from the bottom of the unit through two concetric standpipes--the outer one passing water through perforations around its lower 10cm. The standpipe design helped to continuously remove fecal and other waste products from the units. The incoming water was filtered to ensure that the fish received no food unintentionally.

After a 2-week acclimation period under uniform conditions with no directed water currents in the units, the experimental treatments were begun. The design incorporated three treatments, each replicated four times. In treatments A (T-A) and B (T-B), incoming flow was directed at an angle to the water surface so that a current velocity of 11cm/sec, as measured 1/3 of the radius in from the perimeter of the tanks, was generated. The current was increased to approximately 15cm/sec after 5 weeks in the eight tanks of treatments A and C. In treatment B (T-B), the incoming water was baffled by an aluminum container suspended beneath the three holes delivering water so that there was no measurable current produced in those tanks, i.e., the fish did not have to actively swim to hold their position in the rearing unit.

All fish were fed Rangen's trout diet (Zeigler Bros., Inc., Gardiners, PA), but those in T-A and T-B were fed to satiation five times per day, i.e., when a food pellet or two remained on the bottom of the tank for more than a minute, no more food was given during that feeding period. Fish in T-C were fed, as nearly as possible, the same percentage of their body weight per day as those in T-B, i.e., they were not fed to satiation.

Determining the amount to feed T-C fish required a complicated procedure of calculating what T-B fish ate in percentage of body weight per day. During the first 2 days of the treatments, T-C fish were fed the same percentage of their body weight as was eaten by T-B fish during the two previous days. Throughout the study, the 2-day rations for T-C fish were determined after calculating the previous 2-day ration in percentage of body weight for T-B fish. Because fish were weighed every 2 weeks, I didn't know exactly what the mean weights were on any particular day between the days of weighing. Without making any corrections for weight gains during these 14-day intervals, I would have had significant errors in calculating the percent of body weight per day eaten by T-B fish. Therefore, during the first 4 weeks after the treatments began, I assumed a 10% increase in mean body weight at the midpoint of each 2-week interval. From previous experience, this assumption could be expected to approximate the actual increase in weight. However, to further reduce this source of error, I calculated the growth of T-B and T-C fish using linear regression of the form $\log y = a + bx$ once I had enough data points. A new regression was calculated at the end of each 2-week period. Using the regressions, I was able to very closely estimate the mean weight of fish in T-B and T-C for any day during the interval so that I could determine the percentage of body weight eaten by T-B fish and, therefore, the amount to be fed to T-C fish.

The following summarizes the experimental treatments:

T-A	Current Velocity = 11-15cm/sec	Fed to satiation
T-B	Current Velocity = 0cm/sec	Fed to satiation
T-C	Current Velocity = 11-15cm/sec	Fed same % of body weight as T-B

After 10 weeks of treatments, I tested the swimming stamina of two replicates from each treatment group using a modified method (Leon, unpublished MS) developed by Thomas et al (1964). ANOVA was used to test for significant treatment effects on growth and stamina. Mean food conversions were also calculated.

Results

Throughout the study, it was obvious that T-A and T-C fish actively swam to hold their positions in the tanks. In contrast, T-B fish milled about haphazardly, apparently exerting little muscular energy. T-A fish grew at a constantly faster rate for the 10 weeks whereas T-B and T-C fish showed parallel growth rates during the last 4 weeks (Figure 1). T-A fish had greater ($P<.01$) final mean weights than T-B and T-C fish (Table 1). There was no difference ($P>0.5$) between T-B and T-C fish weights. T-A fish displayed greater ($P<.01$) swimming stamina than T-B but not than T-C fish (Table 2). T-C fish had greater ($P<.05$) stamina than T-B fish. Mean food conversion values (amount fed divided by gain in weight) for the 10-week period were best for T-C fish and worst for T-B fish. No statistical analysis was performed on this parameter because only the mean conversions for each group were available--the individual replicate conversion data were inadvertently lost.

Discussion

As the data obviously show, under the experimental conditions, brook trout grew best when reared in a current velocity of 1.5-2.0 body lengths per second if fed to satiation. Furthermore, exercised fish will eat more than unexercised fish if given the opportunity. Although one might expect that the increased activity and greater food intake would have resulted in poorer food conversion efficiency, such was not the case. I propose that T-A fish were physiologically healthier, thus requiring less energy per unit of activity and for maintenance than T-B fish. Burrows (1969) noticed beneficial changes in exercised fish that could partially account for the increased efficiency of T-A fish observed in this study. Their greater swimming stamina supports this proposition. Another possible contributor to the higher efficiency of the exercised fish was in the increased irrigation of the gills caused by the water current. This might reduce the fish's energy required to absorb oxygen and excrete metabolites. However, considering the light loading of each unit, exchange rate of 4.3/hr, and near saturation in respect to oxygen, I believe that the irrigation effect was less than the exercise effect.

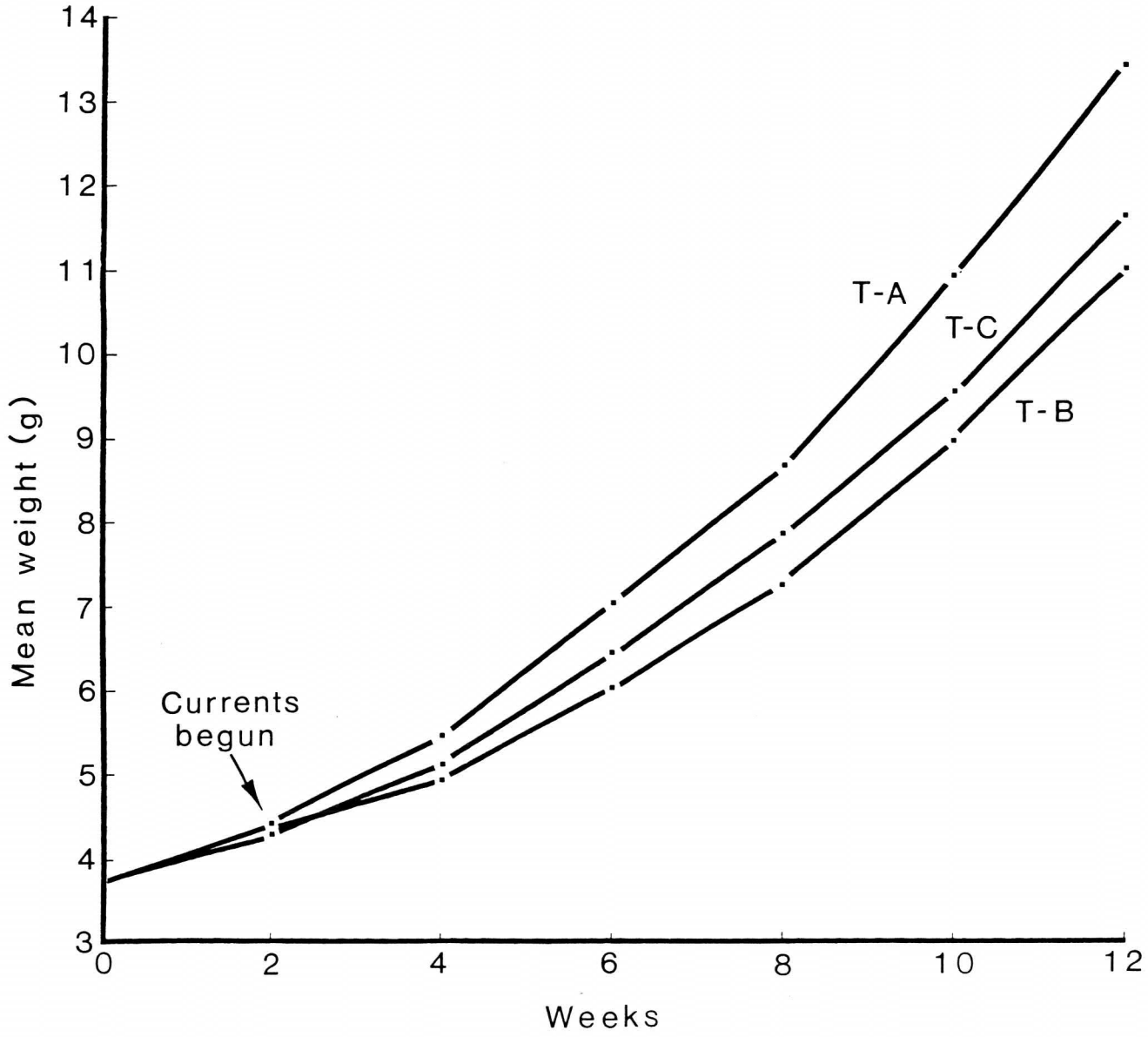

Figure 1. Comparison of growth in weight over time for brook trout reared in directed current and fed to satiation (T-A), reared with no current and fed to satiation (T-B), and reared in directed current and fed the same percentage body weight per day as T-B fish (T-C).

Table 1. Means of four replicates for each of three treatments in respect to food fed, weight gain, and food conversion for 14-day intervals with brook trout at 8-9°C.

	T-A					T-B					T-C				
Week	Fed/ fish (g)	% body wt fed/day	Wt. (g)	Gain (g)	Fed / Gain	Fed/ fish (g)	% body wt fed/day	Wt. (g)	Gain (g)	Fed / Gain	Fed/ fish (g)	% body wt fed/day	Wt. (g)	Gain (g)	Fed / Gain
0			4.42					4.41					4.35		
2	1.73	2.50	5.48	1.06	1.63	1.06	1.61	4.99	0.58	1.83	0.96	1.44	5.15	0.80	1.20
4	2.31	2.63	7.06	1.58	1.46	1.75	2.26	6.05	1.06	1.65	1.76	2.17	6.44	1.29	1.36
6	2.74	2.48	8.71	1.65	1.66	2.01	2.15	7.33	1.28	1.57	2.17	2.16	7.88	1.44	1.51
8	3.36	2.43	10.97	2.26	1.49	2.59	2.27	9.00	1.67	1.55	2.75	2.25	9.57	1.69	1.62
10	3.89	2.27	13.51	2.54	1.53	3.08	2.19	11.05	2.05	1.50	3.29	2.21	11.69	2.12	1.55
Total	14.03			9.09		10.49			6.64		10.93			7.34	
$\bar{X}$ a/					1.54					1.58					1.49

a/ Mean food conversion for 10 weeks is obtained by dividing total food fed by total gain, not by averaging each 2-week conversion.

Table 2. Mean distance swam by brook trout in stamina tunnel using two replicates for each of three treatments.

Treatment	Distance swam (m)		
	Test 1	Test 2	Mean
T-A	1029	985	1007
T-B	842	876	859
T-C	929	951	940

As was the case, one could have guessed that T-A fish would have better stamina then T-B fish. On the other hand, I did not expect the T-C fish to be better swimmers than T-B fish because they were to receive less than their "optimal" caloric needs. Not only did they have more stamina than T-B fish, but they had the best food conversion of all treatments. Similar findings in respect to food conversion for fish fed to less than satiation have been commonly observed by others.

I was also surprised that there was no difference in mean weight between T-B and T-C fish. Perhaps the physiological superiority of T-C fish caused by exercise counteracted their "less-than-desired" intake of food.

From the results of this study, I strongly recommend that fish culturists should exercise their juvenile salmonid fish regularly. Even if the fish are being reared for market rather than release, it would appear that faster growth and better food conversion can result from such a regimen. If enough water is not available to create the necessary water velocity in typical raceways, then circulating rearing tanks should be used, e.g., Swedish or circular ponds.

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EFFECTS OF SALINITY ON ADULT CHUM SALMON (*Oncorhynchus keta*) HELD IN PENS AT DESERTED CREEK, HISNIT INLET, BRITISH COLUMBIA

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Introduction

Since 1979, gametes have been collected from adult chum salmon held in holding pens anchored in Deserted Creek estuary, Hisnit Inlet, Vancouver Island, British Columbia. Viability of these eggs was low and highly variable. Similar experiences have been encountered in Alaska, Washington, and Oregon. Results of a preliminary investigation (Lam, et. al. 1982) suggested that a failure in the osmoregulatinory ability of the held adults eventually results in prespawning mortality and lowered gamete viability. Consequently in 1982, a field experiment was conducted to test the following hypotheses:

(1) for the males:-

high external salinity → increase in blood plasma osmolality → increase in milt plasma osmolality → decrease in milt fertilizability

(2) for the females:-

high external salinity → increase in blood plasma osmolality → increase in ovarian fluid osmolality → increase in egg ion content → decrease in egg viability

Results of the 1982 experiment confirmed certain aspects of these hypotheses. It also suggested that handling stress plays an important role in egg viability.

Materials and Methods

Figure 1 shows the locations of seawater pens and river pen used in the experiment. All the fish held in the seapens were seined from Hisnit Inlet between October 16 and 18. Fish held in the river pen was seined from a deep pool in the river. The seapens were 3x3x3m, while the river pen was 1.2x1.2x2.4m. Salinity was monitored either on the same

day or on the day before fish samples were taken. YSI meter model 33 was used. On October 22 (t_3) after completing two sampling series t_o and t_2, each series consists of (fish samples and salinity monitoring), heavy rain began to fall. Salinity in the estuary turned brackish.

On each sampling day, 3 males and 3 females were taken from each pen and killed by a blow to the head. Blood samples were taken by heart puncture and were centrifuged to obtain the plasma. Duplicated plasma samples were stored in plastic vials. Eggs from each female were stored in separate plastic containers. Milt was kept in Whirlpaks®. All gametes were kept cold in cooler with reusable ice (Fridgepak®). On arrival to the hatchery, milt plasma was obtained by centrifugation. Samples of 5 eggs each, were taken from each female. Ovarian fluid samples were also taken. All samples were frozen at -25 °C till analysis. Fertilizability of all gametes was evaluated.

Osmolalities of blood plasma, ovarian fluid, and milt plasma were determined with a Wescor Vapour pressure osmometer (model 5100 C). Ion content in eggs were determined by method described by Rombough (1980).

Results and Discussion

Salinity measurements ranged between 0 °/oo and 28.3 °/oo, (Table 1). The values of male blood plasma osmolality, milt plasma osmolality and milt fertilizability are presented in Table 1. The values of female blood plasma osmolality, ovarian fluid osmolality, ion content in eggs, and egg fertilizability are presented in Table 2.

Males:-

Significant correlations ($P < 0.01$) were observed between external salinity and male blood plasma osmolality ($r = 0.677$), between male blood plasma osmolality and milt plasma osmolality ($r = 0.816$), milt plasma osmolality and milt fertilizability ($r = 0.637$). It therefore appears that the hypothetical sequence of events listed earlier has gained more supportive evidence. High external salinity raises blood plasma osmolality which raises milt plasma osmolality which consequently lowers the fertilizability of the milt.

Females:-

Significant correlations ($P < 0.01$) were observed between external salinity and female blood plasma osmolality ($r = 0.463$), and between blood plasma osmolality and ovarian fluid osmolality ($r = 0.864$). However, no correlation was observed between ovarian fluid osmolality, egg ion content and egg fertilizability ($r = -0.196, -0.65, 0.072, 0.182, -0.082$ for ovarian fluid osmolality, Na^{+}, K^{+}, Ca^{++}, and Mg^{++} respectively).

J. Stoss has shown a negative correlation between ovarian fluid osmolality and egg fertilizability (pers. comm. 1982). It appears that Stoss's data lie in the higher end of the ovarian fluid osmolality range (range 330 to 480 m Osm/Kg with a mean of 396 m Osm/Kg + 43.6) while those from this study lie in the lower end (between 290 and 410 m Osm/Kg with a mean 325.8 m Osm/Kg +22.9), (Figure 2). A significant correlation ($r = 0.455$, $P < 0.01$) was obtained when all data points were considered.

The following interpretation may accommodate these observations. In this present study, the held fish was never handled after the initial sorting and transfer. When the fish was sampled, the first 3 males and 3 females captured by the dip-net were used. No sorting was employed. In Stoss's study, the fish was sorted every two days for ripeness and then spawned. Besides, the fish in this present study was held in pens anchored in the estuary while Stoss's fish were held in laboratory tanks. Consequently there was a major difference in the amount of handling these fish were exposed to; more in Stoss's study and less in the present study. Although in both studies, the highest salinity experienced by the held fish was about 28 °/oo (28 °/oo in Stoss's study, 28.5 °/oo in this study) the ovarian fluid osmolality was much higher in Stoss's fish than that in the present study. Mazeaud and Mazeaud (1981) have shown that stressed fish has a higher level of catecholamines in their circulation which leads to hemoconcentration. Since blood plasma osmolality is highly correlated with ovarian fluid osmolality ($r = 0.864$, this study), we can say that the drastically increased ovarian fluid osmolality in Stoss's fish was due to the high stress level his fish were

exposed to. Furthermore, the significant correlations observed in the present study between external salinity and blood plasma osmolality, and between blood plasma osmolality and ovarian fluid osmolality suggest that even in the relatively calmer seapen environment, salinity still raises the osmolality in blood plasma and ovarian fluid. To summarize, we can say that blood plasma and ovarian fluid osmolality is raised by holding the maturing fish in seawater; this increase in osmolality is made more drastic when the held fish is stressed.

The step in the hypothesis relating ovarian fluid osmolality to egg viability is egg ion content. Unfortunately, data collected in the present study failed to establish the relations between ovarian fluid osmolality and egg ion content and between egg ion content and egg viability. However, Sower (1980) reported a higher sodium content and osmolality in eggs from females held in seawater than those held in fresh water (unfortunately, she did not present her actual data in her manuscript). Futhermore, the significant correlation between ovarian fluid osmolality and egg viability observed in the combined data from Stoss's study and the present study suggests that egg viability is related to the egg ion content.

Conclusions

1) We found strong supportive evidence for the hypothetical sequence of events leading from external salinity to reduced milt fertilizability in mature male chum salmon held in seawater.

2) We found strong evidence of the effect of external salinity on ovarian fluid osmolality in matured female chum salmon held in seawater. This effect appears to be magnified when the fish is stressed by handling.

3) The step in the hypothesis relating ovarian fluid osmolality to egg viability was not established in this study although results from other studies lend weight to its validity.

Recommendations

Since handling of the held fish is unavoidable, seawater holding of mature chum salmon per se is not a viable practice in production facilities. However for sites where space is limiting, sea pens can still be used provided

that a fresh water source is available. A plastic liner opened on top and bottom (with water-tight walls) can be installed on the inside of the pen. With the difference in density between seawater and fresh water, a freshwater layer (pumped in from a nearby creek with a fire pump and fire hose) can be maintained inside the pen. This offers a preferred environment for the maturing fish, and prespawning mortality and low gamete fertilizability can be avoided.

If the relation between egg ion content and egg fertilizability proves to be correct, hatchery operators are opened to a further option, though less desirable than the above one. Hatchery operators can salvage the ovulated eggs by rinsing them before fertilization with a slightly hypotonic saline to rid them of this excess ion. This option, however, can not by-pass the problem of prespawning mortality.

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Table 1. Osmolalities of blood plasma, milt plasma, and fertilizability of milt collected from males held in sea pens and river pen from t 0 to t 10, (October 19 to October 29).

Pen	Sampling Day	Salinity (°/oo)	Blood Plasma Osmolality (m Osm/Kg)	Milt Plasma Osmolality (m Osm/Kg)	Milt Fertilizability (%)
Sea Pen	t 0	27.5*	350.5	361.0	20.8
			327.5	330.0	0.0
			335.0	326.0	51.7
			334.0	331.5	84.5
			350.5	343.5	82.3
			334.0	329.3	71.7
			338.5	342.5	51.7
			329.5	327.5	65.2
			339.0	317.0	78.6
			339.5	346.5	81.0
			319.5	331.5	89.2
			373.5	322.0	90.8
	t 2	28.3*	360.5	354.0	76.5
			331.5	317.0	97.3
			339.5	332.0	73.3
			343.5	329.0	87.5
			326.5	319.0	93.1
			327.0	319.5	88.8
			372.0	363.0	0.0
			328.5	320.5	89.6
			338.0	324.7	89.2
	t 4	8.5	319.5	320.5	84.1
			322.0	309.5	80.5
			321.5	310.0	88.4
	t 6	5.4	314.5	308.3	97.9
			311.0	294.7	98.1
			315.5	310.0	74.2
	t 8	6.7	314.0	306.5	93.8
			310.5	307.0	94.8
			325.0	305.7	88.2
	t 10	7.5	332.0	312.0	86.4
River Pen	t 0	◄ ——NO	FISH ———		►
	t 2	9.6*	312.0	298.7	85.8
			332.5	316.5	97.8
			332.5	307.3	97.3
	t 4	◄ ——NO	DATA ———		►
	t 6	3.3	303.0	297.0	97.4
			313.5	300.5	94.8
			333.0	304.3	90.4
	t 8	0.0	303.0	302.0	82.4
			306.0	298.5	85.5
			305.5	300.5	90.4
	t 10	0.0	316.0	305.5	96.9
			324.0	308.0	94.2
			330.0	318.0	90.7

*Salinity readings taken on the day before fish were sampled. Heavy rain began to fall on t 3.

ble 2. Osmolalities of blood plasma, ovarian fluid, ion content and fertilizability of eggs collected from ovulated females held in sea pens and river pen from t 0 to t 10, (October 19 to October 29).

Pen	Sampling Day	Salinity (°/oo)	Blood Plasma Osmolality (m Osm/Kg)	Ovarian Fluid Osmolality (m Osm/Kg)	ION CONTENT IN EGGS Na^+	K^+	Ca^{++}	Mg^{++}	Egg Fertilizability (%)
Sea Pen	t 0	27.5*	329.5	332.5					51.7
			321.5	327.0					84.5
			334.5	314.5					0.0
			328.7	326.5	N.A.	N.A.	N.A.	N.A.	78.6
			321.0	317.0					16.0
			347.0	346.5					87.8
			333.5	331.5					90.8
			312.5	322.0					6.9
	t 2	28.3*	356.3	350.0	76.7	176.9	37.9	67.3	89.1
			435.3	415.7	78.6	185.5	29.5	56.5	9.3
			418.5	376.	76.6	177.0	28.9	67.0	97.3
			332.0	314.5	62.6	179.4	26.3	71.7	78.4
			350.0	331.0	67.1	182.9	22.5	67.8	93.1
			323.3	322.0	70.1	180.9	33.0	64.1	6.7
			401.0	372.5	69.7	191.2	24.2	59.6	0.0
			327.7	320.5	62.0	177.2	31.4	61.6	89.6
	t 4	8.5	321.0	315.0	88.1	213.1	39.4	77.3	81.1
			316.0	318.5	80.9	193.6	33.6	74.0	4.0
			309.5	311.5	80.7	190.9	35.4	72.0	88.4
			319.3	314.0					75.2
			318.3	311.7	N.A.	N.A.	N.A.	N.A.	74.0
			324.0	306.5					98.1
	t 8	6.7	299.0	317.0	70.6	185.1	29.2	58.2	60.4
			315.5	308.0	67.0	178.9	33.0	67.3	84.8
			311.5	322.0	67.8	165.7	44.1	52.9	94.8
	t 10	7.5	320.5	322.0	76.6	184.2	17.6	64.8	70.9
			332.0	303.5	75.5	188.2	29.4	62.6	21.7
			330.0	309.0	78.8	169.2	27.0	65.9	86.4
River Pen	t 0	◄	NO	FISH					►
	t 2	9.6*	344.0	319.0	65.1	175.1	30.5	49.7	82.6
			331.0	315.5	65.8	168.5	33.0	61.4	97.8
			333.5	312.5	67.6	195.1	31.4	53.3	96.0
	t 4	◄	NO	DATA					►
	t 6	3.3	323.0	305.5	N.A.	N.A.	N.A.	N.A.	84.8
			330.0	310.5					97.4
	t 8	0.0	308.7	293.5	69.0	174.6	34.0	63.9	90.4
	t 10	0.0	328.5	308.5	57.3	175.6	97.9	54.8	73.2
			315.5	328.0	156.1	152.7	48.4	43.8	96.9

*Salinity readings taken on the day before fish were sampled. Heavy rain began to fall on t 3.

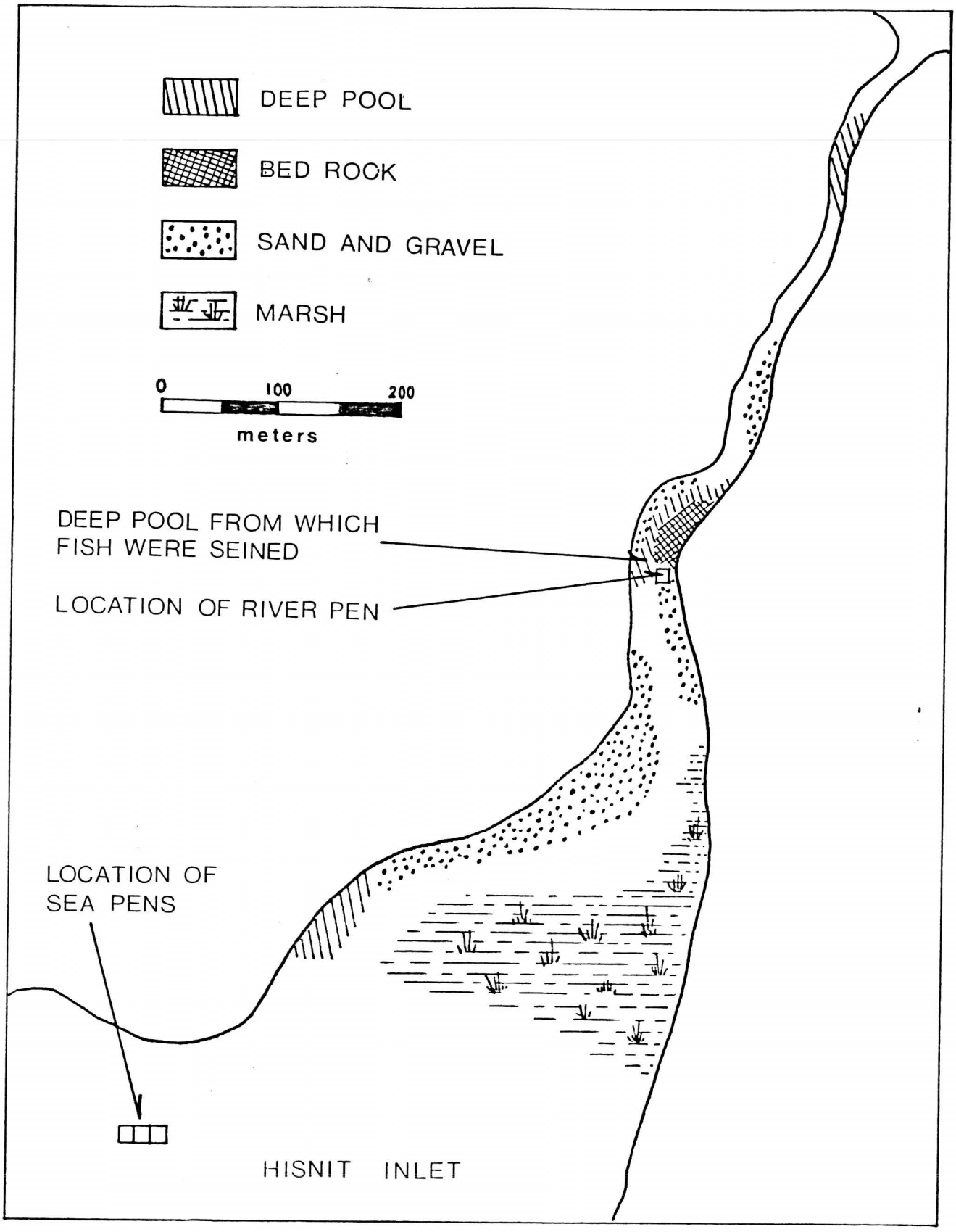
DEEP POOL
BED ROCK
SAND AND GRAVEL
MARSH
0
100
200
meters
DEEP POOL FROM WHICH FISH WERE SEINED
LOCATION OF RIVER PEN
LOCATION OF SEA PENS
HISNIT INLET

FIGURE 1

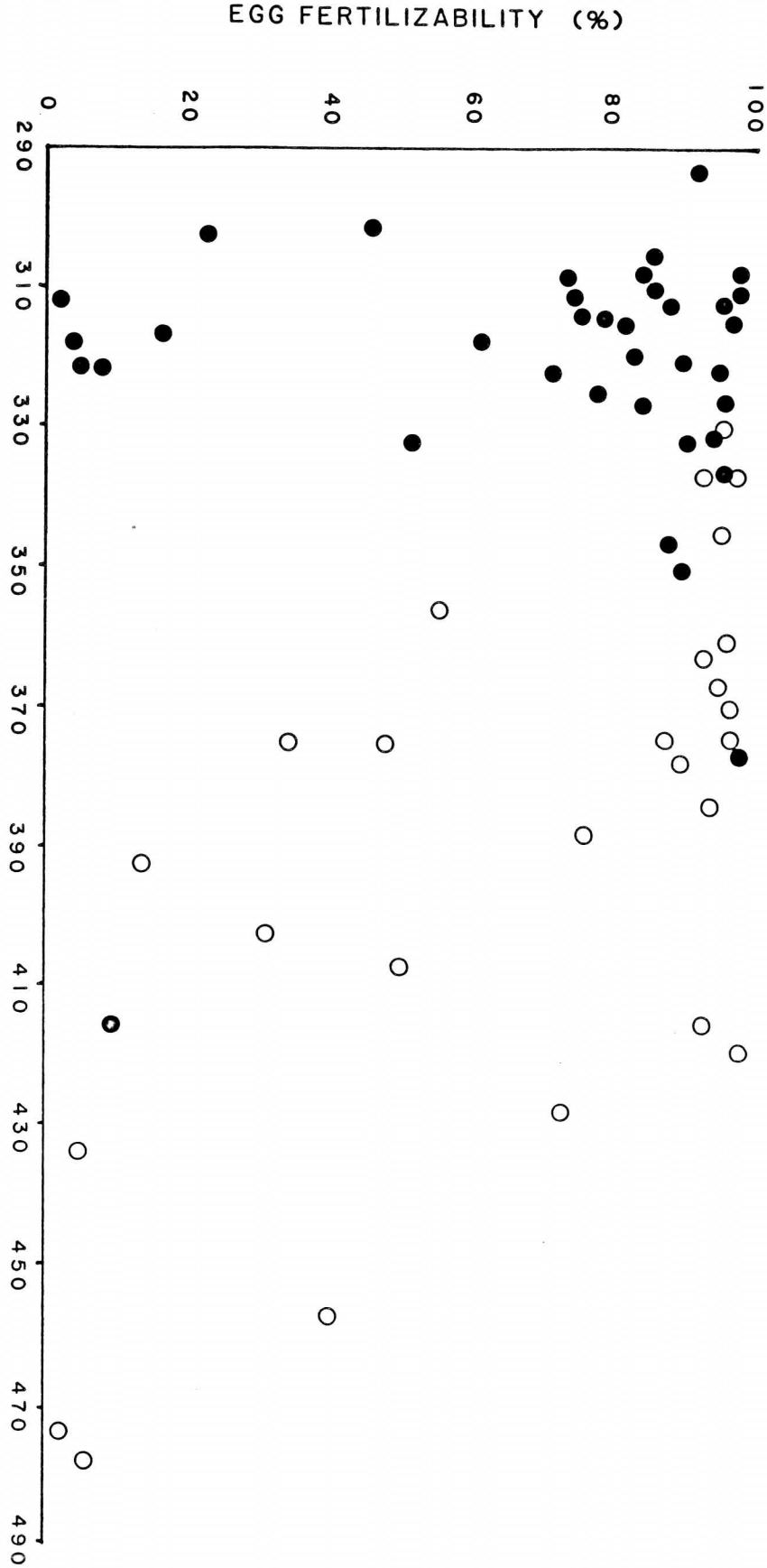
EGG FERTILIZABILITY (%)
0
20
40
60
80
100
290
310
330
350
370
390
410
430
450
470
490
OVARIAN FLUID OSMOLALITY (mosm/Kg)

FIGURE 2

Effects of Raceway Cover on Incidence of Bacterial Kidney Disease, *Renibacterium salmoninarium*, in Yearling Spring Chinook Salmon

Abstract

The performance and health of Little White spring chinook salmon reared in covered and uncovered raceways were compared during a six-month period to determine if cover had a beneficial effect in reducing the incidence of bacterial kidney disease (BKD) outbreaks.

Presence of available cover had no discernible effect upon the incidence of BKD as determined by Fluorscent Antibody Technique (FAT) analysis. Fish with cover exhibited better growth and were larger at release than those in uncovered raceways. Although the percentage of mortality in covered raceways remained consistently higher than the controls throughout the trial, mortality of covered fish declined from November 1982 through January 1983. Control fish showed an increase in mortality during this time. It appeared cover may have been beneficial in reducing stress, thereby limiting mortality, during the pre-release holding period when spring chinook salmon are highly susceptible to stress.

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EFFECTS OF RACEWAY COVER ON INCIDENCE OF BACTERIAL KIDNEY DISEASE, *Renibacterium salmoninarium* IN YEARLING SPRING CHINOOK SALMON.

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INTRODUCTION

Bacterial kidney disease (BKD) has been shown to be stress induced in spring chinook salmon. Young salmon startle easily in open raceways exposed to bright sunlight. Any activity surrounding the raceway, including routine fish cultural operations such as feeding or pond cleaning, may cause additional stress and increased swimming.

To determine if cover has a beneficial effect in reducing the incidence of BKD outbreaks, the performance and health of spring chinook salmon reared in covered and uncovered raceways was compared during a six-month period.

METHODS

Eight raceways were loaded with approximately 30,000 Little White spring chinook salmon at 52 fish per kilogram (23 fish per lb.) by September 1, 1982. Four raceways were covered with 1.2M x 2.4M x 5cm (4ft. x 8ft. x 2in.) sheets of styrofoam to create holding cover (Figure 1). Fifty percent (59.5m^2) of the raceway surface area was covered. Covers were easily removed for fish cultural activities and immediately replaced. The four remaining raceways were left uncovered.

All fish were fed Abernathy dry diet (8/64" pellet) via Babington self-feeders on a demand basis. However, fish were hand fed for several weeks until acclimated to the feeders (approximately September 23, 1982). Feed consumption was recorded daily for each raceway.

Fish numbers were reduced during January 1983 in two ponds of each group to alleviate overcrowding. Sample size of a representative raceway in each group was monitored monthly. Length-frequency distribution was taken on November 18, 1982 and at release (April 1, 1983). Fluorscent Antibody Technique (F.A.T.) analysis for BKD and routine fish health exams were conducted by the Division Fish Disease Biologist at Dworshak Fish Health Center on several dates throughout the trial.

Raceways were cleaned at weekly intervals whenever possible. Mortalities were removed and recorded daily. Flows averaged 1892 liters per minute (500gpm) while water temperatures ranged from 4.7°C to 12.9°C. Fish were released on March 31 and April 1, 1983.

Cost of covers was approximately $100 per raceway for a total of $400. Production personnel were responsible for installation of covers and routine monitoring of fish performance.

RESULTS AND DISCUSSION

Performance of spring chinook salmon, as measured by the parameters summarized in Table 1, in covered and uncovered raceways was quite similar. Fish numbers were somewhat less in the covered group as compared to the uncovered controls throughout the trial. Covered raceways produced somewhat larger fish, 13.3/kg (5.9/lb.), and a higher total weight, 6,379kg (14,034 lb.), by release than controls which were 6,063kg (13,339 lb.) at 15.3/kg (6.9/lb.). Both groups showed similar condition factors at release.

Length-frequency relationships measured November 18, 1982 (Figure 2) and at release (Figures 3 and 4) indicated a slightly higher percentage of larger fish in the covered raceways than in the controls. However, spring chinook salmon in covered raceways were slightly

larger, 124mm (4.9 in.), as compared to controls, 122mm (4.8 in.), at initiation of study. This relationship apparently held through release where covered raceways averaged 180mm (7.1 in.) and controls 170mm (6.7 in.) total length. A bimodal length distribution was evident in both groups in November 1982 and at release.

Covered fish exhibited better growth than controls throughout the study period (Figure 5). However, the large size variation evident in both test groups may have influenced the monthly sampling size, with resulting sample not truly representative of the population. Regardless of possible sampling error, covered fish were consistently larger than controls.

Fish density was comparable in covered and uncovered fish at initiation and termination of trial (Table 1). Percent monthly mortality (Figure 6) was slightly higher in covered fish as opposed to the controls. Covered raceways had approximately 11,000 more total mortality than controls. No data was available on length distribution of daily mortality from either groups but general observation indicated all sizes were represented.

Although percent mortality in the covered raceways remained consistently higher than controls throughout the trial, mortality of covered fish declined from November 1982 through Janaury 1983.

It appeared cover may have been beneficial in reducing stress, thereby limiting mortality during the pre-release holding period when spring chinook salmon are highly susceptible to stress.

Spring chinook salmon in covered raceways consumed more food and showed a higher conversion (1.92) as compared to those in uncovered raceways (1.61). Feed consumption was greater during the fall months for both groups when raw water temperatures were higher and conducive to faster growth (Table 2).

Fish health examinations conducted periodically throughout the trial showed no significant differences in incidence of BKD for both study groups as determined by F.A.T. analysis. Table 3 summarizes percent incidence of BKD in covered and uncovered raceways at four time periods. BKD was evident in 28 percent of fish in both groups at initiation of trial and increased to 60 percent of fish by release date. F.A.T. analysis of mortality from one raceway of each group showed almost all fish positive for BKD. At time of release, fish had noticeably declined in health with BKD contributing to higher mortality. Although fish quality and health were considered good for most fish of both groups at release, mid-size range fish were of somewhat better quality.

Spring chinook salmon in covered raceways primarily utilized shade provided by covers. Fish formed comma shaped schools beneath the covers. Spring chinook salmon in uncovered raceways also utilized shade adjacent to sides of raceway walls. Although covers needed to be removed before raceways could be cleaned, these raceways showed less algae buildup on bottom, due to reduced light, and consequently required less effort during cleaning.

A major disadvantage of covers was increased mortality from fish jumping onto covers. Mortality was more difficult to pick with covers in place. Wind tended to remove covers and snow and ice buildup during the winter months caused breakage of several covers.

CONCLUSIONS AND RECOMMENDATIONS

The presence of available cover had no discernible effect upon the incidence of BKD in yearling spring chinook salmon. However, fish with cover exhibited better growth and were larger at release than those in uncovered raceways. Since mid-size fish appeared healthier at release, little benefit could be attributed to producing slightly larger fish in covered raceways as opposed to those released from uncovered raceways.

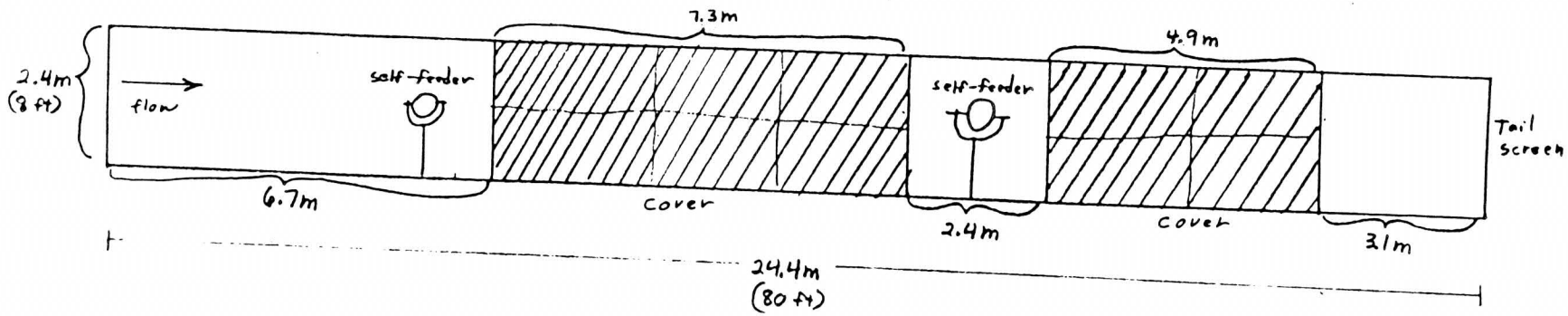


Figure 1. Schematic depicting placement of self-feeders and styrafoam covers on spring chinook salmon raceways.

Figure 2. Length-frequency distribution of spring chinook salmon in covered and uncovered raceways on November 18, 1982.

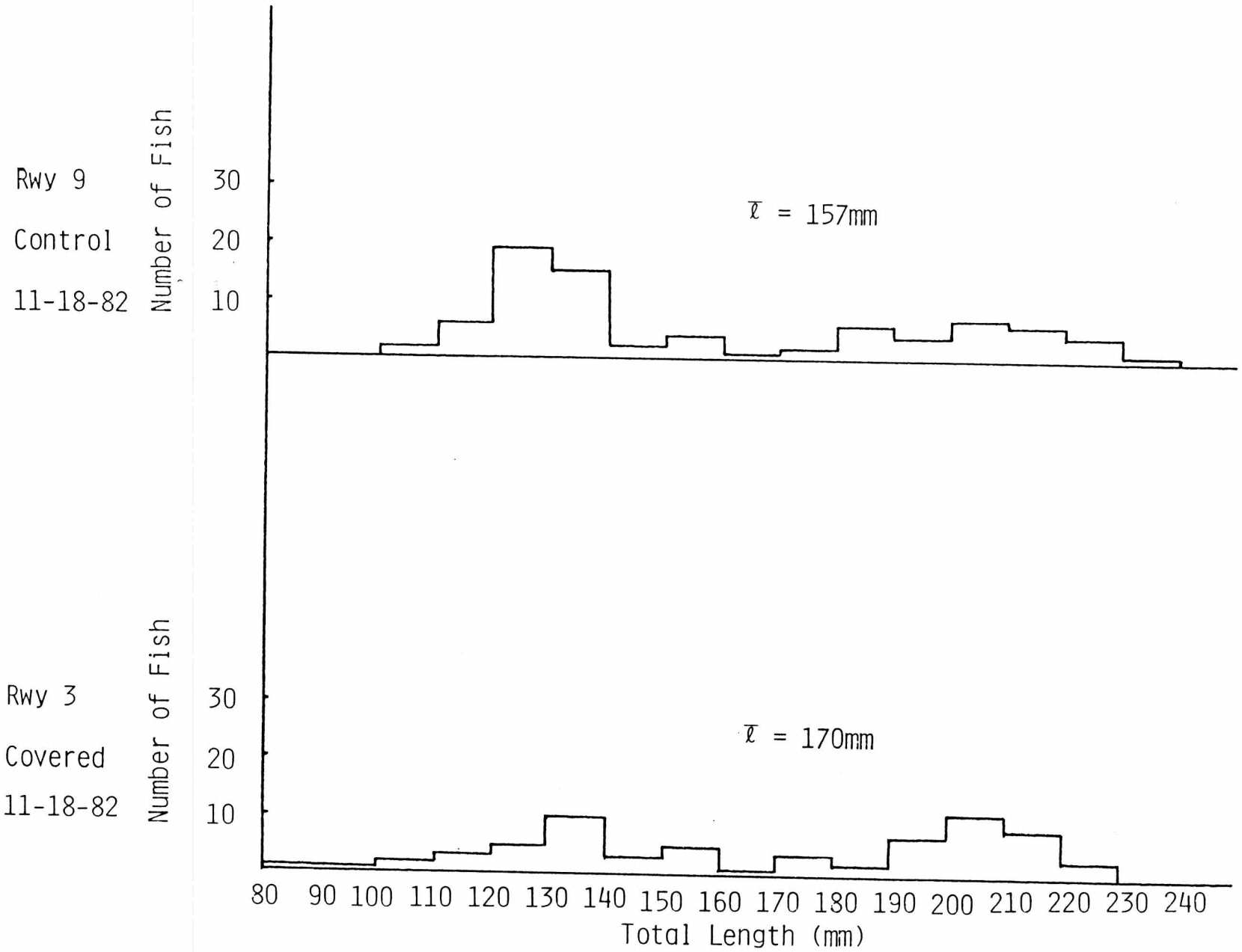


Figure 3. Length-frequency distribution of spring chinook salmon in covered raceways on March 28, 1983

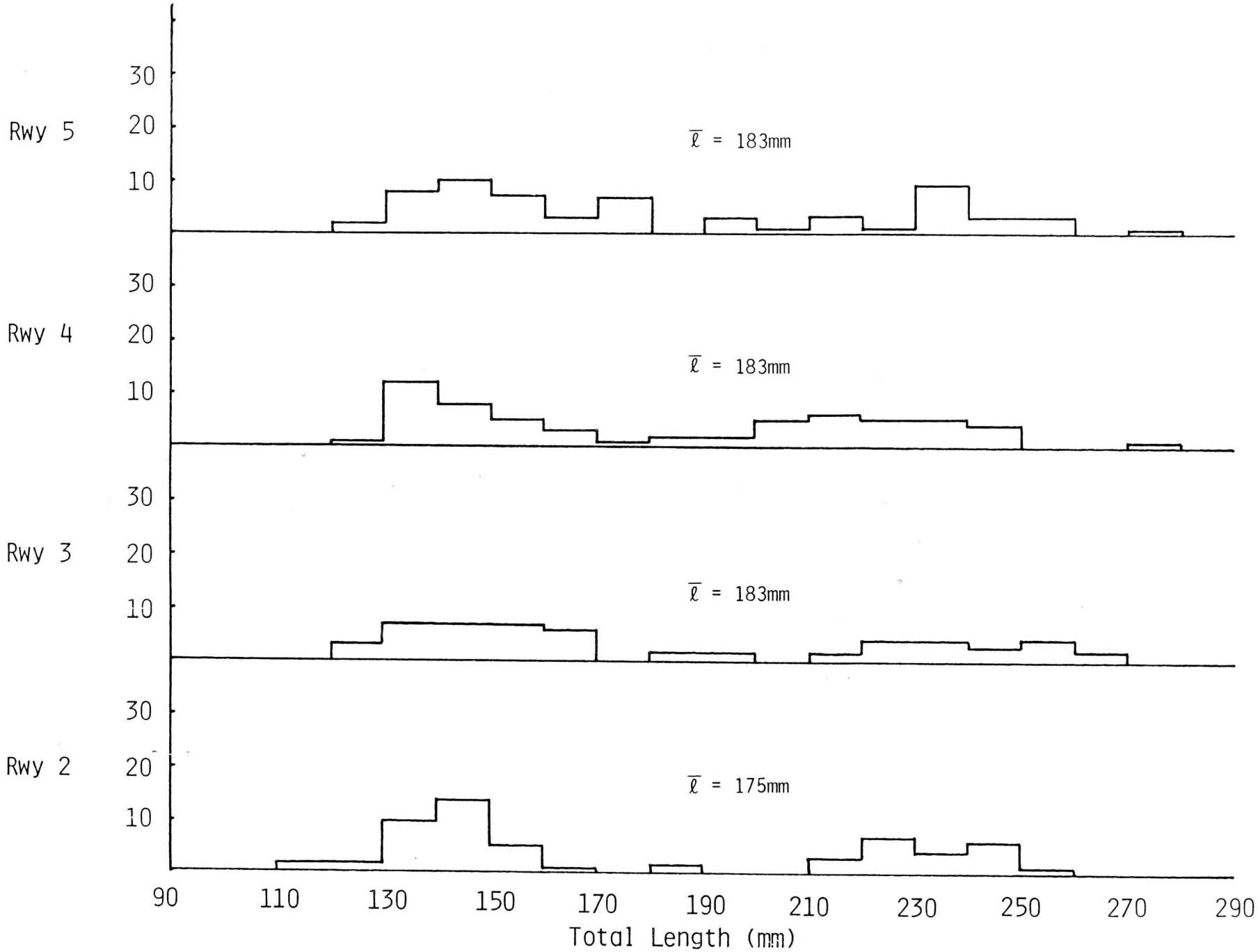


Figure 4. Length-frequency distribution of spring chinook salmon in uncovered raceways (control) on March 28, 1983.

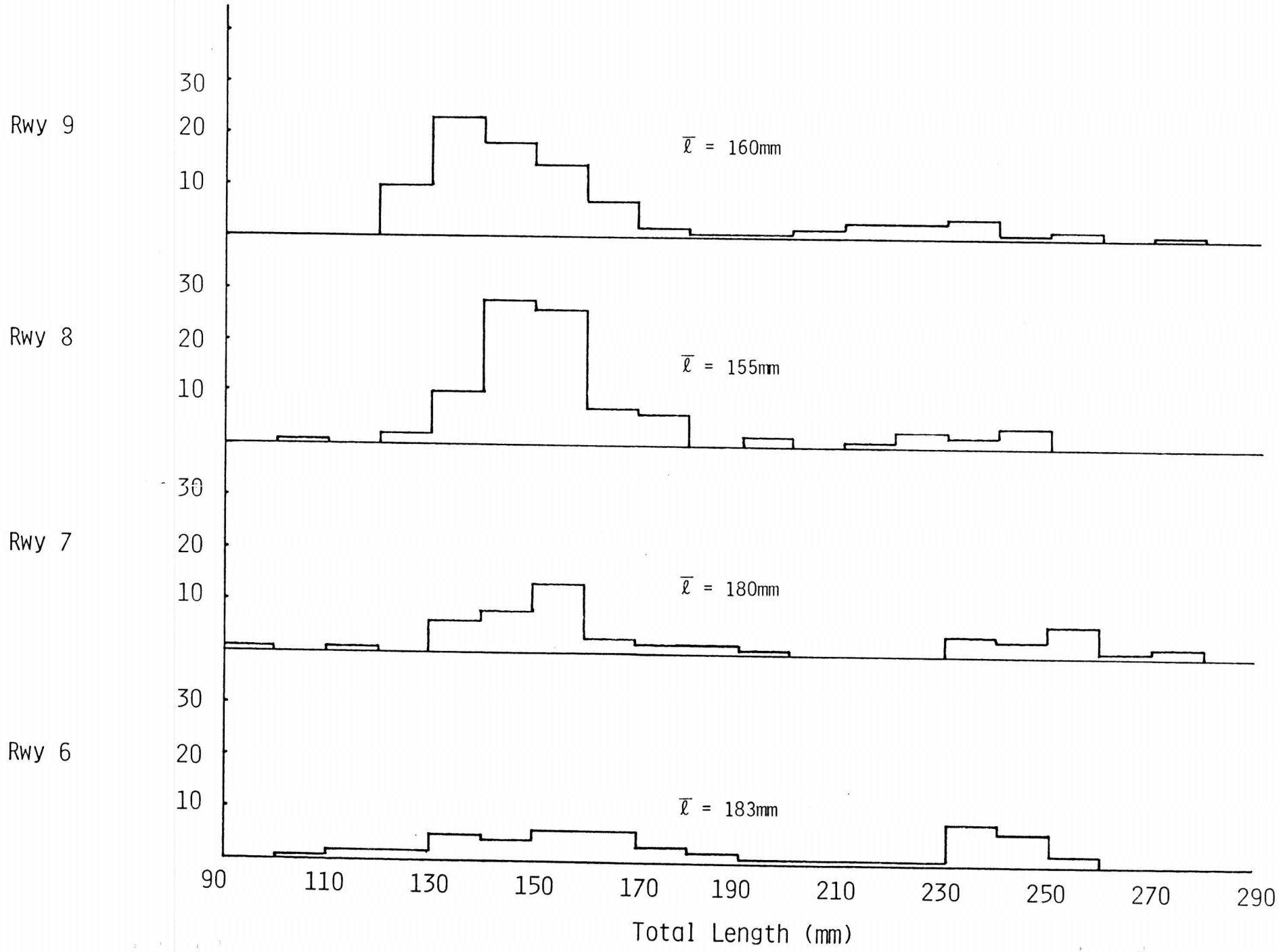
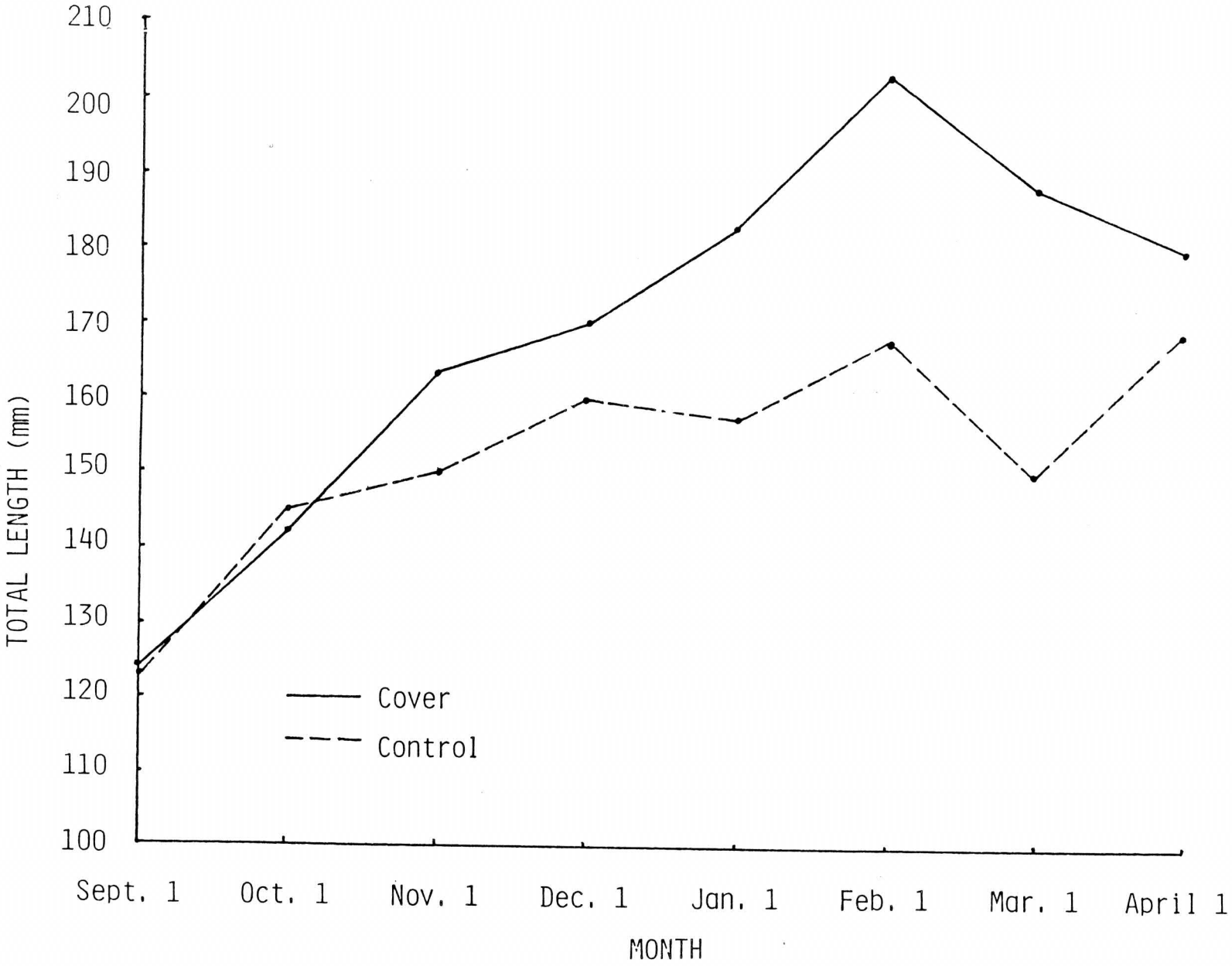


Figure 5. Growth of spring chinook salmon as expressed by total length at beginning of each month throughout trial.



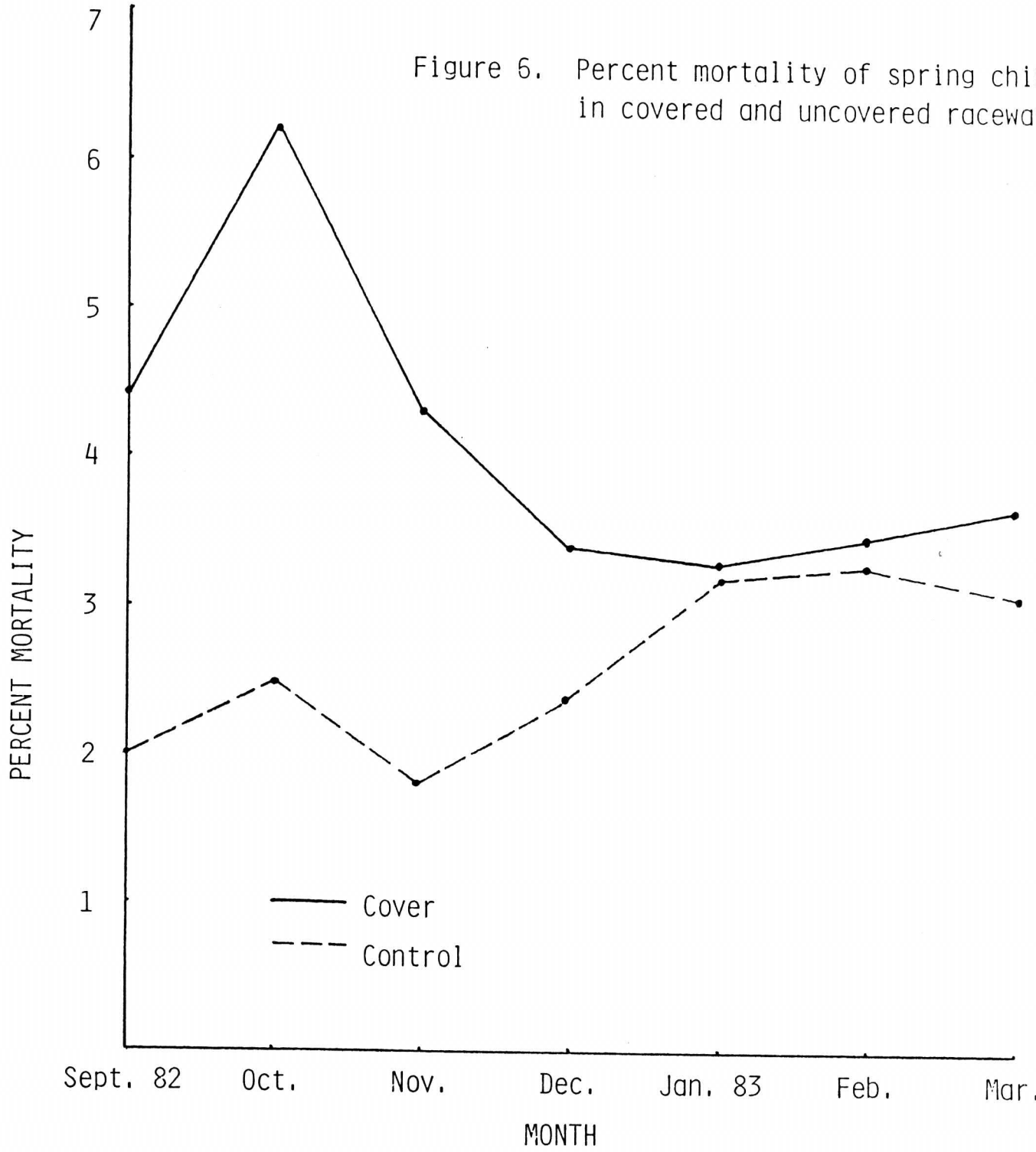


Figure 6. Percent mortality of spring chinook salmon in covered and uncovered raceways.

Table 1. Data summary of spring chinook salmon performance in covered and uncovered raceways.

	Covered Raceways					Control Raceways				
Parameters	Rwy 2*	Rwy 3**	Rwy 4	Rwy 5*	Total/Mean	Rwy 6	Rwy 7*	Rwy 8*	Rwy 9**	Total/Mean
No. Fish										
initial	32039	31849	31568	31421	126877	31681	32070	32136	31789	127676
final	18852	23408	22971	17743	82974	26393	18603	22660	24537	92193
Size										
initial no/kg	50.1	50.1	50.1	50.1	50.1	53.3	53.3	53.3	53.3	53.3
(no/lb)	(22.7)	(22.7)	(22.7)	(22.7)	(22.7)	(24.1)	(24.1)	(24.1)	(24.1)	(24.1)
final no/kg	16.7	12.5	11.7	12.5	13.3	13.1	12.1	17.8	19.3	15.3
(no/lb)	(7.6)	(5.7)	(5.3)	(5.7)	(5.9)	(6.0)	(5.5)	(8.1)	(8.7)	(6.9)
Weight										
initial kg	641	638	632	629	2540	598	605	606	600	2409
(lb)	(1411)	(1403)	(1390)	(1384)	(5588)	(1315)	(1331)	(1333)	(1319)	(5298)
final kg	1127	1867	1970	1415	6379	1972	1537	1272	1282	6063
(lb)	(2480)	(4107)	(4334)	(3113)	(14034)	(4339)	(3382)	(2798)	(2820)	(13339)
Length										
initial mm	124	124	124	124	124	122	122	122	122	122
(in)	(4.9)	(4.9)	(4.9)	(4.9)	(4.9)	(4.8)	(4.8)	(4.8)	(4.8)	(4.8)
11-18-82 mm	170	170	170	170	170	157	157	157	157	157
(in)	(6.7)	(6.7)	(6.7)	(6.7)	(6.7)	(6.2)	(6.2)	(6.2)	(6.2)	(6.2)
final mm	175	183	183	183	180	183	180	155	160	170
(in)	(6.9)	(7.2)	(7.2)	(7.2)	(7.1)	(7.2)	(7.1)	(6.1)	(6.3)	(6.7)
Condition Factor										
initial	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
11-18-82	1.23	1.23	1.23	1.23	1.23	1.24	1.24	1.24	1.24	1.24
final	1.088	1.295	1.398	1.309	1.273	1.226	1.378	1.481	1.274	1.340
Density										
initial	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17
final	.26	.41	.44	.31	.36	.44	.35	.33	.32	.36
Total Mortality:	7157	8441	8597	7270	31465	5288	4300	3666	7252	20506
Food Fed										
kg	1433	1998	1779	2088	7298	1611	1451	1433	1407	5902
(lb)	(3152.5)	(4394.5)	(3914.5)	(4594.5)	(16056)	(3544.5)	(3192.5)	(3152.5)	(3094.5)	(12984)
Weight Gain										
kg	486	1229	1338	786	3839	1375	932	666	682	3655
(lb)	(1069)	(2704)	(2944)	(1729)	(8446)	(3024)	(2051)	(1465)	(1501)	(8041)
Conversion:	2.95	1.63	1.33	2.66	1.92	1.17	1.56	2.15	2.06	1.61

* Numbers of fish in these raceways were reduced January 1983 to alleviate overcrowding.

** Sample Raceways.

Table 2. Feed consumption of spring chinook salmon in covered and uncovered raceways as compared to monthly water temperatures.

Month	Cover kg feed	(lb)	Control kg feed	(lb)	Water Temperature °Celsius	(°Farenheit)
Sept. 1982	1607	(3536)	1497	(3294)	12.9	(55.3)
Oct.	1864	(4100)	1409	(3100)	12.6	(54.7)
Nov.	1227	(2700)	1091	(2400)	9.4	(48.8)
Dec.	727	(1600)	500	(1100)	6.3	(43.4)
Jan. 1983	750	(1650)	500	(1100)	4.9	(40.8)
Feb.	568	(1250)	455	(1000)	4.7	(40.5)
Mar.	555	(1220)	450	(990)	4.7	(40.5)
Total/Mean	7298	(16056)	5902	(12984)	7.9	(55.5)

Table 3. Percent of spring chinook salmon in covered and uncovered raceways testing positive for BKD by F.A.T. analysis.

DATE	COVER	CONTROL
11-82	28	28
1-6-83	40	35
2-17-83	60	60
3-25-83	58	50

PROFILES OF CERTAIN HEMATOLOGICAL AND PHYSIOLOGICAL PARAMETERS IN JUVENILE SPRING CHINOOK SALMON (Oncorhynchus Tschawytscha) FROM FOUR HATCHERIES AND THEIR RELATIONSHIPS TO HATCHERY WATER TEMPERATURES

by

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During the period 1978-1980, we assisted biologists in our division in studies of imprinting and homing behavior in hatchery bred salmon and steelhead on the Columbia River and on tributaries to the Sanke River. Our contribution was an assessment of the health status and smoltification indexes of the fish at (or near) the time of release in 1978 and 1979, and a profile of the stocks tested during the spring of 1980. Certain aspects of the 1980 studies are presented here for spring chinook salmon.

Random samples of 60 fish each were collected from 1978 brood yearling spring chinook salmon during the spring of 1980 at Carson, Leavenworth and Kooskia National Salmon Hatcheries, and at the Idaho Department of Fish and Game Hatchery at Rapid River. Samples were collected at two week intervals from early March until early June, 1980. We used a mobile laboratory for collecting and preparing blood and tissue samples, and conducted the analyses at our NMFS laboratories and with private contractors.

The Carson, Leavenworth and Kooskia fish are primarily Carson Hatchery stock. The Rapid River Hatchery fish are from stocks that are native to the area (figure 1). The influence of the Carson hatchery stocks is due to intermittant transplants of eggs grom the Carson spring chinook to Leavenworth and Kooskia hatcheries.

Probably the most notable difference between the four hatcheries is the water temperature. Carson hatchery is fed by a stable supply of constant temperature sub-surface water, while the main rearing ponds of the other three hatcheries are fed primarily by surface waters with typical seasonal water temperature profiles (figure 2).

In 1980, Rapid River Hatchery had the fastest rising profile, followed by Kooskia and then Leavenworth hatcheries. The influence of the constant low temperature (approximately 7°C.) at Carson National Hatchery is apparent when a comparison is made of the growth curves during the spring of 1980 (fisure 3).

Other factors such as pond size, loading density, water flow and quality also influence growth, but by and large, water temperature has the greatest influence. Thus, throughout the course of the spring, the Carson Hatchery fish were the smallest, and Rapid River Hatchery fish were the largest.

The gill $Na^{\pm}$ - K^{+} ATPase activity profiles shown in figure 4 reveal four immediately obvious facts:

1. The peak of activity of the Rapid River stock was approximately 35 days earlier than the other three stocks, and the peak Na^{+} - K^{+} ATPase activity was the lowest of the four stocks.

2. The peak Na^{+} - K^{+} ATPase activity of the Carson Hatchery fish was the highest of the four groups, and completely independant of water temperature (since the water temperature is constant).

3. Regardless of geographical location, water temperature profile, or rate of growth, the Carson, Leavenworth, and Kooskia Hatchery fish and almost identically shaped Na+ - K^{+} ATPase profiles. Since the Carson Hatchery stock dominates in all three of these hatcheries, there is a suggestion here that genetics may influence this enzyme activity more than many other basic factors.

4. The enzyme activity in the fish in these four hatcheries was the inverse of such growth. The enzyme activity profiles of the Carson Hatchery fish were virtually identical in the years 1978, 1979 and 1980. But, during the peak week of enzyme activity there was no correlationn between enzyme activity and size of fish. Conversely, at Leavenworth Hatchery there was a positive correlation between enzyme activity and size of fish ($r+0.689$; $p(0.05)$ throughout the season, and during peak activity periods (23 April 1-r=o.699; 0.05, 28 April-r=0.729:p(0.05).

Previous investigators (Banks, et al, 1971), found positive correlations between average hematocrits and hemoglobins in fall chinook salmon reared at different controlled temperatures, and the water temperatures. These positive correlations were also highly significant for the Rapid River Hatchery spring

chinook. However, there was a significant NEGATIVE correlation (r= -0.0720;p(0.002) between the average hematocrits of the Leavenworth Hatchery spring chinook and the hatchery water temperatures in 1980. Spring chinook at Kooskia and Carson Hatcheries had hematocrit profiles that were almost identical to the gill $Na^+ - K^+$ ATPase profiles. Average $Na^+ - K^+$ ATPase activity and average hemstocrit values were significantly correlated throughout the season at Carson Hatchery (r=0.976; p(0.005). A comparison of the profiles of the average hematocrits of the fish in all four hatcheries (figure 5) indicates that these values can be quite independant of water temperature (Carson), and that diverse factors may be involved (Leavenworth). The same is true for average hemoglobin values (figure 6). Although we might expect an increase in hematocrit and hemoglobin values with an increase in water temperature to compensate for reduced oxygen tension, we have no immediate explanation for the steady decline of average hemoglobin values at Leavenworth and Kooskia hatcheries. Profiles of the mean cell hemoglobin concentrations, or MCHC(figure 7), which are a direct relationship of the red blood cell concentrations and the hemoglobin content are amazingly similar for the fish in all four hatcheries, with major peaks and troughs occurring at almost the same times. This is even more remarkable when one considers that the water temperature at Carson Hatchery is constant.

Plasma K^+ levels are frequently considered to be indicators of stress, and are expected to fluctuate depending on the type and degree of stress. There are several remarkable aspects of the plasma K^+ profiles shown in figure 8:

1. The shape of the profiles of the carson, Leavenworth and Kooskia Hatchery fish is almost identical regardless of the fact that these hatcheries are separated environmentally and geographically.

2. The profile of plasma K^+ in the Carson Hatchery fish is completely independant of temperature (which is constant).

The plasma Na+ and Cl profiles indicated that these two plasma electrolytes

also were independent of temperature in the Carson Hatchery fish (figures 9 and 10). There was a general downward trend of plasma Na+ in all four hatcheries with the progression of spring, but there appeared to be a greater differentiation in the Rapid River fish (markedly greater rate of decline). This was also true to a lesser extent for the plasma Cl profiles.

We can give no valid explanations at this time for the relationships that have been presented here. However, on the basis of the comparisons that have been made, genetics appears to be an important factor.

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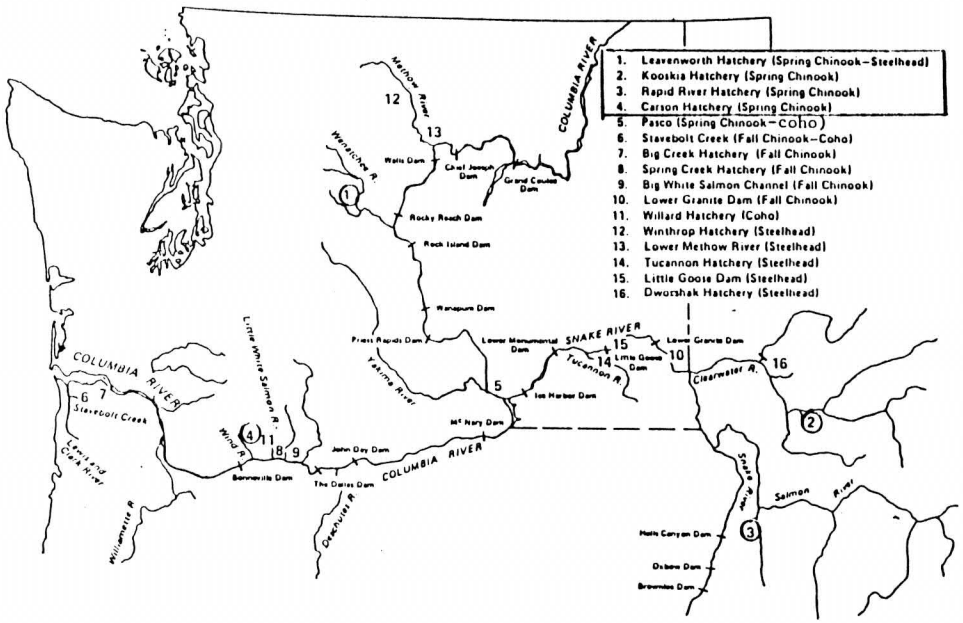

Figure 1. Area map indicating experimental homing sites and the four spring chinook hatcheries studied in 1980.

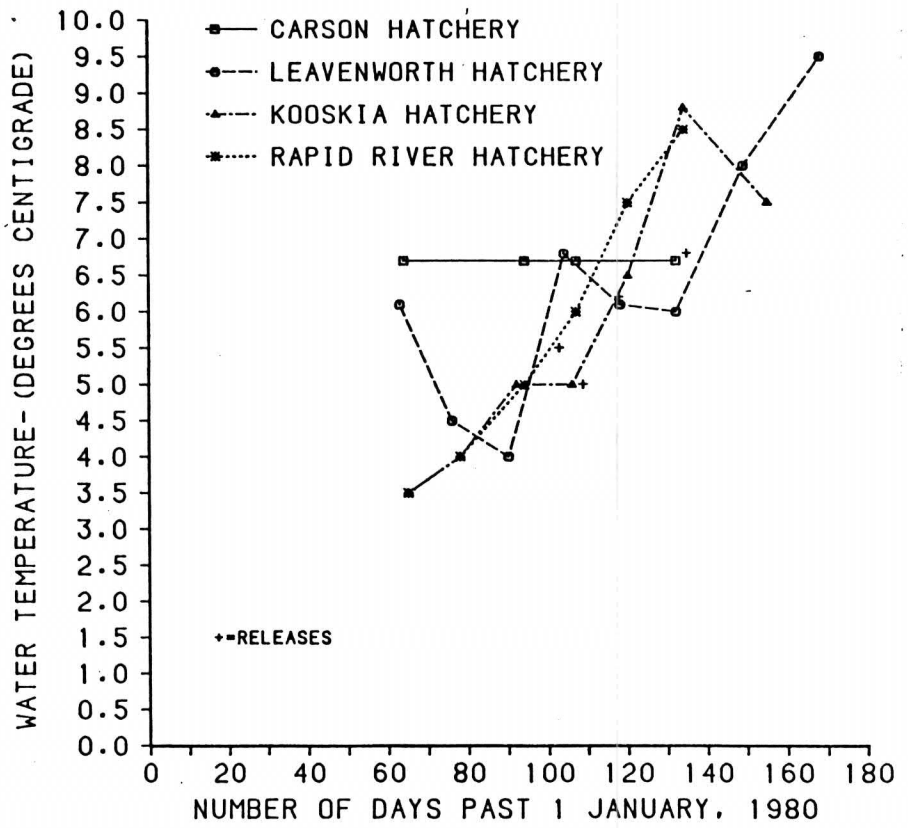

Figure 2. Average water temperatures (in °C.) at Carson, Kooskia, Leavenworth, and Rapid River Hatcheries in the spring of 1980.

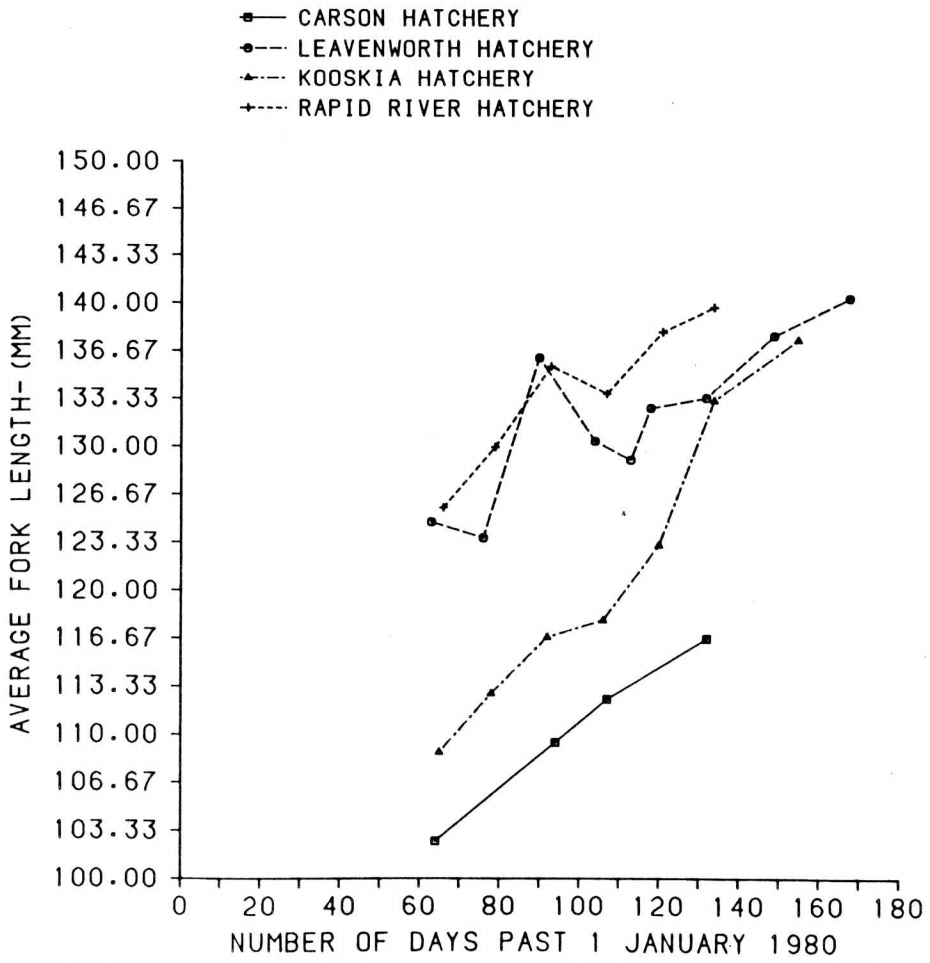

Figure 3. Average fork lengths of the Carson, Leavenworth, Kooskia, and Rapid River Hatchery spring chinook salmon studied in 1980.

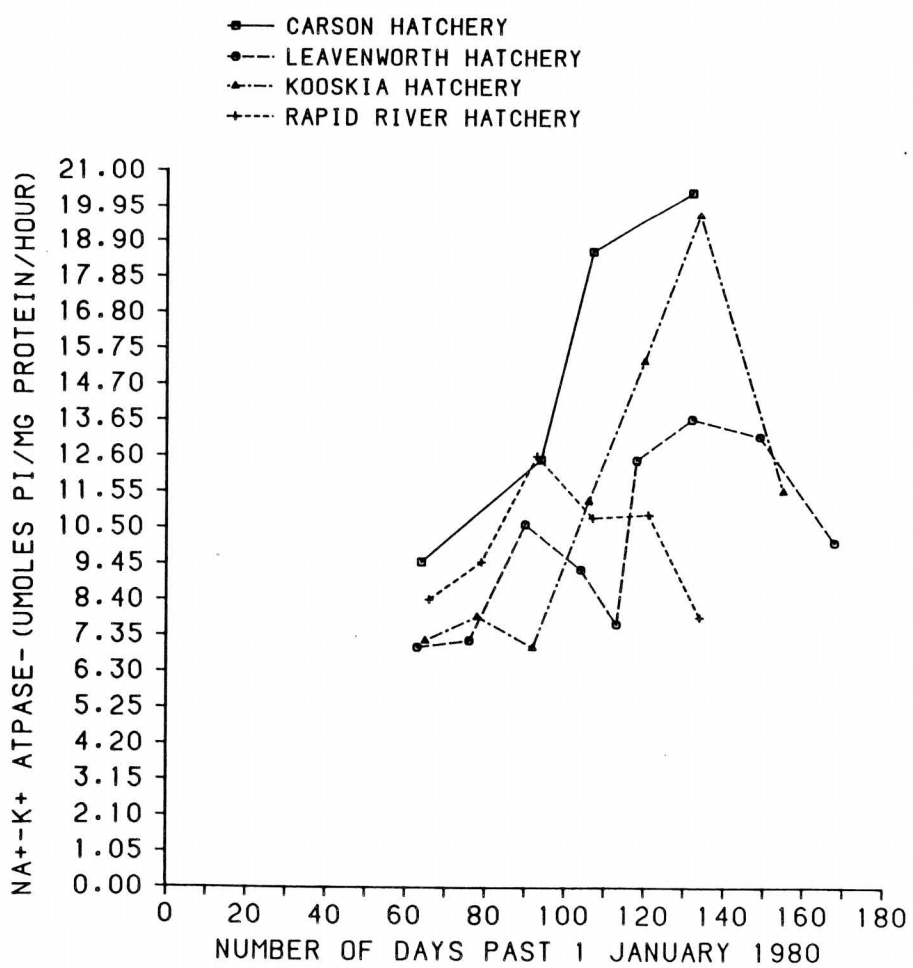

Figure 4. Average gill $Na^+ - K^+$ ATPase activities in the Carson, Leavenworth, Kooskia, and Rapid River Hatchery spring chinook salmon in the spring of 1980.

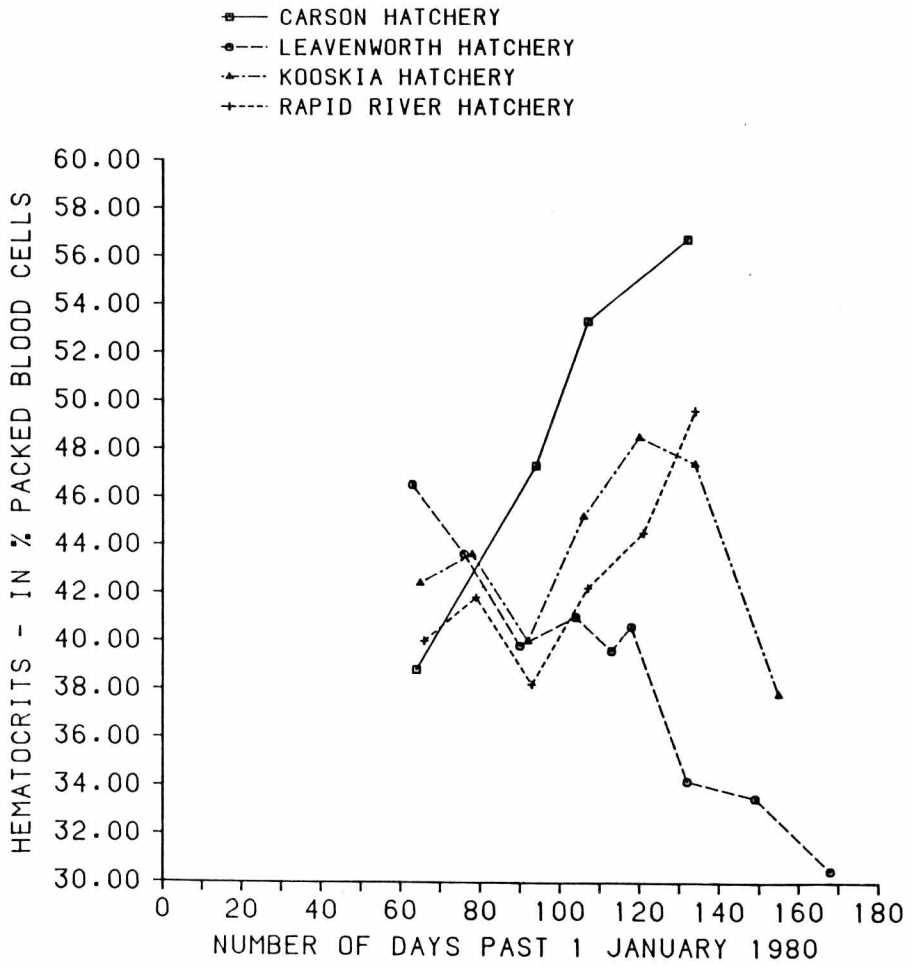

Figure 5. Average blood hematocrits values for the Carson, Kooskia, Leavenworth, and Rapid River Hatchery spring chinook salmon during the spring of 1980.

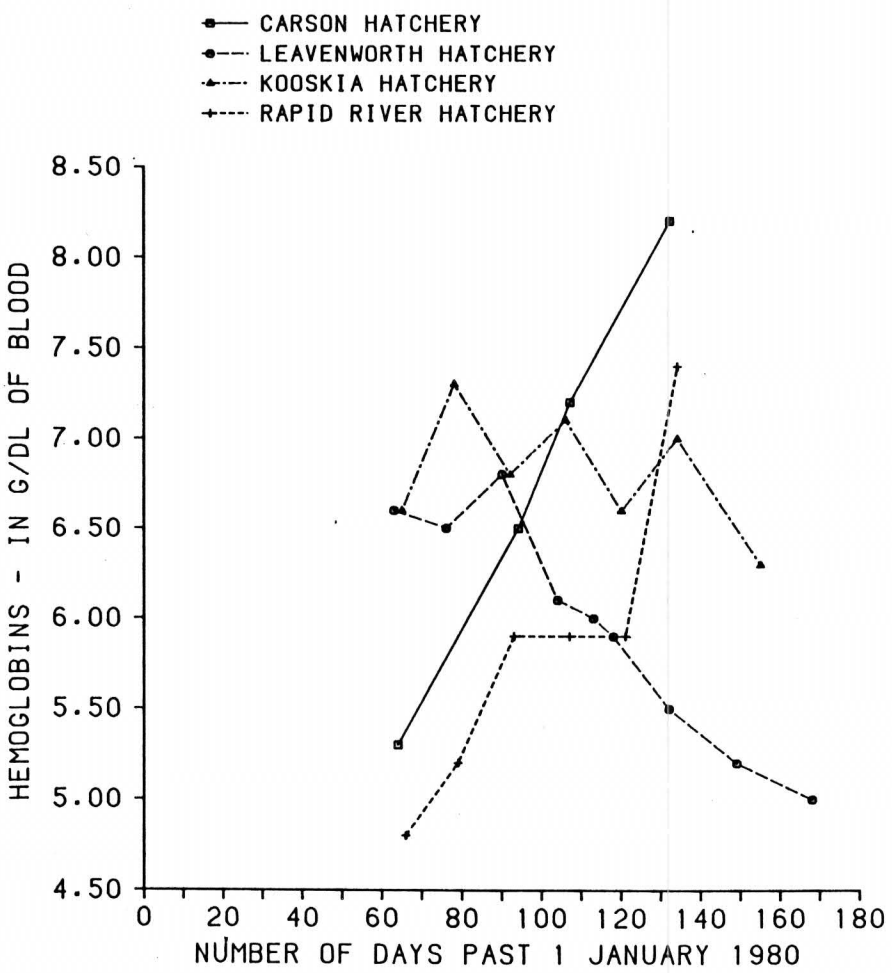

Figure 6. Average blood hemoglobin values for the Carson, Kooskia, Leavenworth, and Rapid River Hatchery spring chinook salmon during the spring of 1980.

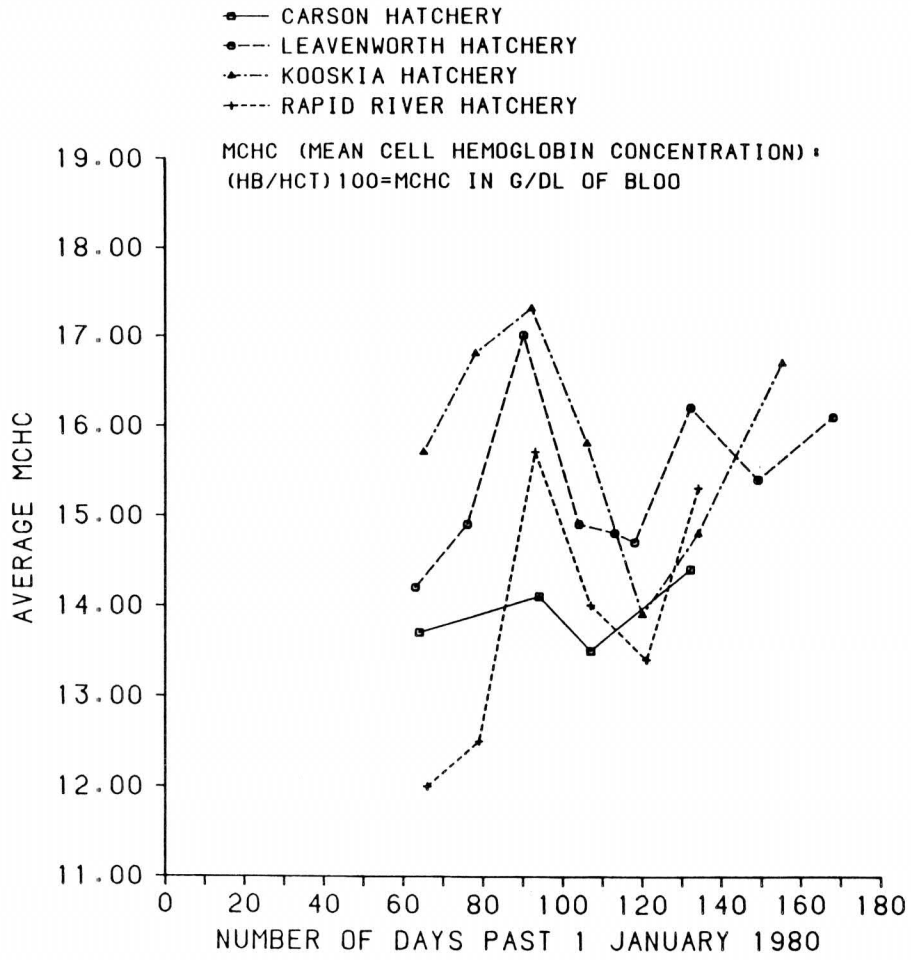

Figure 7. Average mean cell hemoglobin concentrations (MCHC) for the Carson, Leavenworth, Kooskia, and Rapid River Hatchery spring chinook salmon during the spring, 1980.

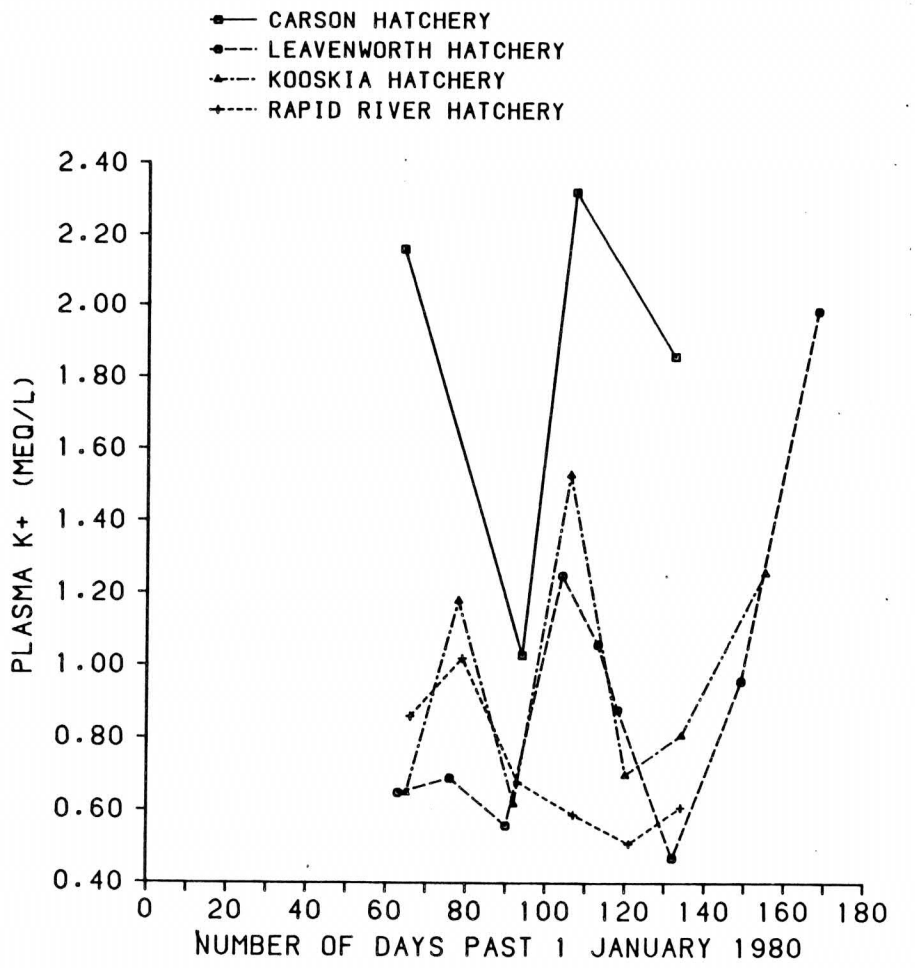

Figure 8. Average plasma K^+ levels in the Carson, Leavenworth, Kooskia, and Rapid River Hatchery spring chinook salmon during the spring, 1980.

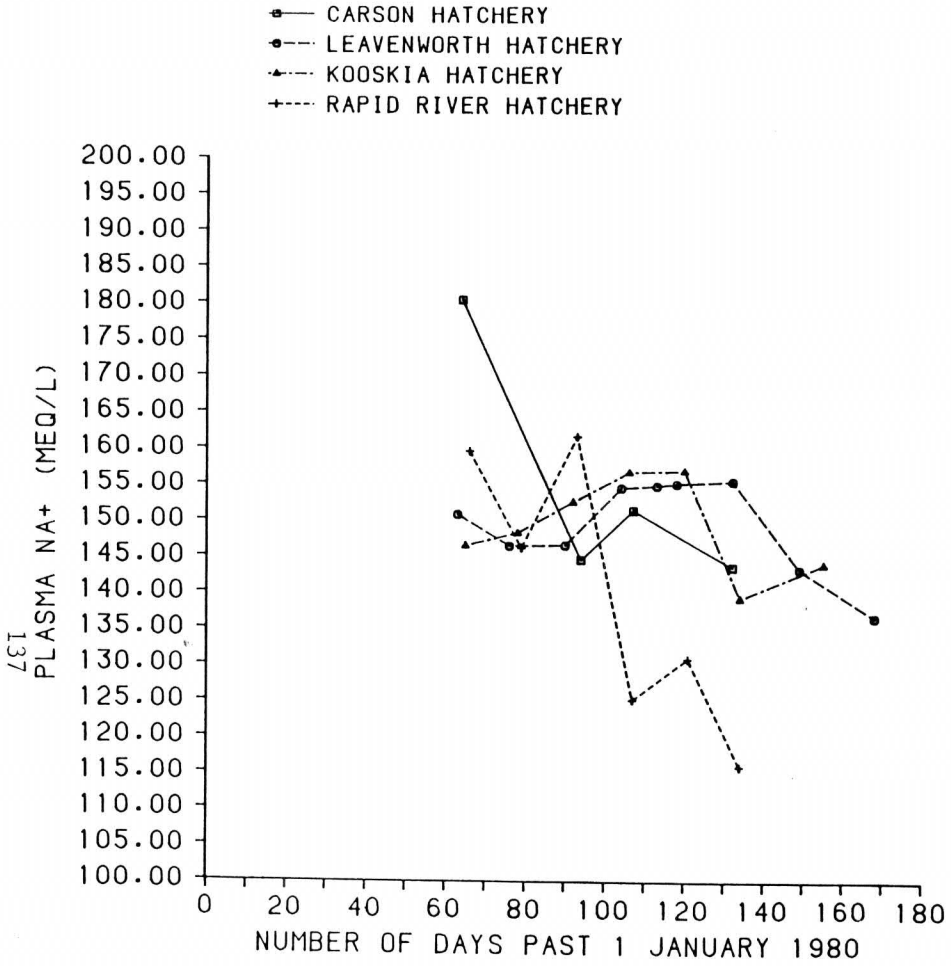

Figure 9. Average plasma Na^+ levels in the Carson, Leavenworth, Kooskia, and Rapid River Hatchery spring chinook salmon during the spring, 1980.

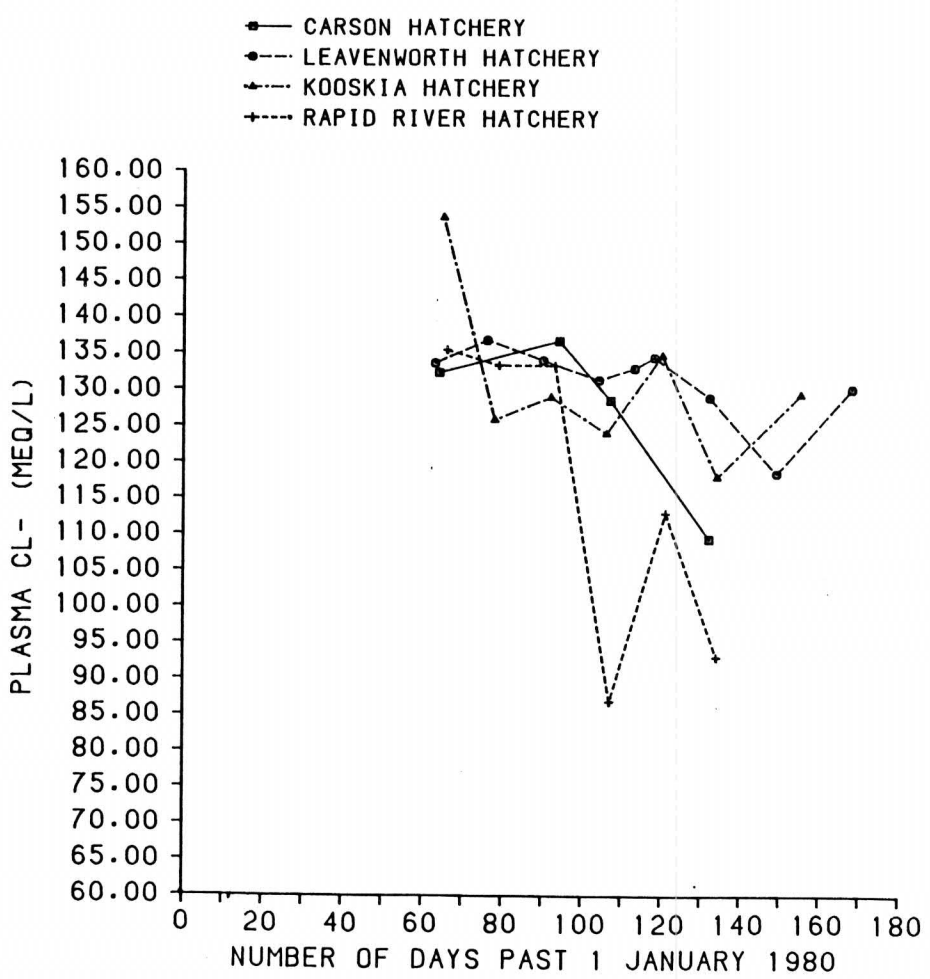

Figure 10. Average plasma Cl^- levels in the Carson, Leavenworth, Kooskia, and Rapid River Hatchery spring chinook salmon during the spring, 1980.

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IMPLICATIONS OF SHORT TERM WATER REARING OF SALMONS PRIOR TO RELEASE

Salmon enhancement has been an intergal part of the Lummi Tribal Fisheries Management Program since the early 1970's. Currently the Tribe operates two salmon hatchery facilities; Skookum Creek located on the south fork of the Nooksack River near Acme, Washington and the Sea Pond facility located along Lummi Bay near Bellingham, Washington. Currently four species of Pacific salmon, coho, fall chinook, spring chinook and chum, and steelhead trout are reared for release from both the fresh water and marine facilities. Annual smolt production averages 9 million fish weighing between 150,000 and 170,000 pounds.

All juvenile fish with the exception of chum salmon are initially reared at the Skookum Creek hatchery. During the spring approximately half the yearling coho production (1 to 1.5 million 30/LB Fish) and one quarter of the fall chinook (1 million 200-500/LB Fish) are transported to the salt water facility for one to two months additional rearing before being released in June. The integration of a salt water rearing program with a typical fresh water hatchery program has allowed the Tribe to make better utilization of rearing water and space and in some cases improve the adult fishery contribution of hatchery stocks.

Short-term salt water rearing of juvenile salmon requires some modifications to the typical hatchery program. Considerations must be given to the time and size of salt water introduction, preconditioning and salt water acclimation procedures of juvenile fish, disease vacination and release timing from the marine site. Accomodations must also be made for the eventual adult salmon return to the marine site. Consideration must be given to trapping methods, salinity of holding waters, and freeze protection since salaine water can reach subzero temperatures causing fish loss.

The procedures which are eventually adopted for any salt water rearing project may be quite site-specific depending upon the condition

of both the fresh water and marine operations as well as the objective of the particular program. The procedures currently used at the Lummi program reflects some 10 years of work evaluating various fresh and salt water rearing schemes in response to the extremes in rearing conditions at the Lummi facilities; an exceptionally cold fresh water hatchery which limits smolt size and sea water temperatures which may exceed 20°C as early as May.

COHO

During the past years, coho smolts have been transported to the marine pens in Lummi Bay as early as March and as late as July. Fish size at transfer ranged between 20-30 fish per pound. Salt water rearing extended from 2 weeks to 3 months with release sizes between 10-25 fish per pound. Among these various released groups, survival and fishery contribution has ranged from 1 to over 20 percent. With these results, the most successful patterns of transfer size and time, acclimation procedures and release timing have been identified and are now the most part standard operating procedures.

Vibrioses vacination and transfer: At Skookum Creek hatchery, the yearling coho are reared in 4, 1/3 acre earthen ponds. Hatchery water temperatures during April and May average 5-7°C, Smolts are transported in a 4,000 gallon tanker filled with warm well water (8-10°C) and approximately 500 gallons of sea water. A fish pump is used to load 3,000-4,000 pounds of juvenile coho into the tanker. Just before the fish enter the tank they pan across a dewatering grid, and are sprayed with a bivalent vibrio racine. The fish are in transit to the marine net pen site for 1½ hours. Upon reaching Lummi Bay, additional sea water is added to the tank and allowed to displace the freshwater for 30 minutes to an hour depending upon the temperature of the receiving water which during late April and May will range between 8-15°C. Salinity of the tank water at this time will run 10-20 ppt; the salinity of Lummi Bay will average 27-30 ppt. As a rule, we will transfer juvenile coho during late April to mid-May. Coho moved earlier from the cool water of Skookum Creek to marine net pens do not grow well, especially if the fish range between 28-30 per pound. Later salt water entries (late May and June) are possible, but one must contend with

warm sea water conditions (15-20°C) and allow for longer periods of acclimation.

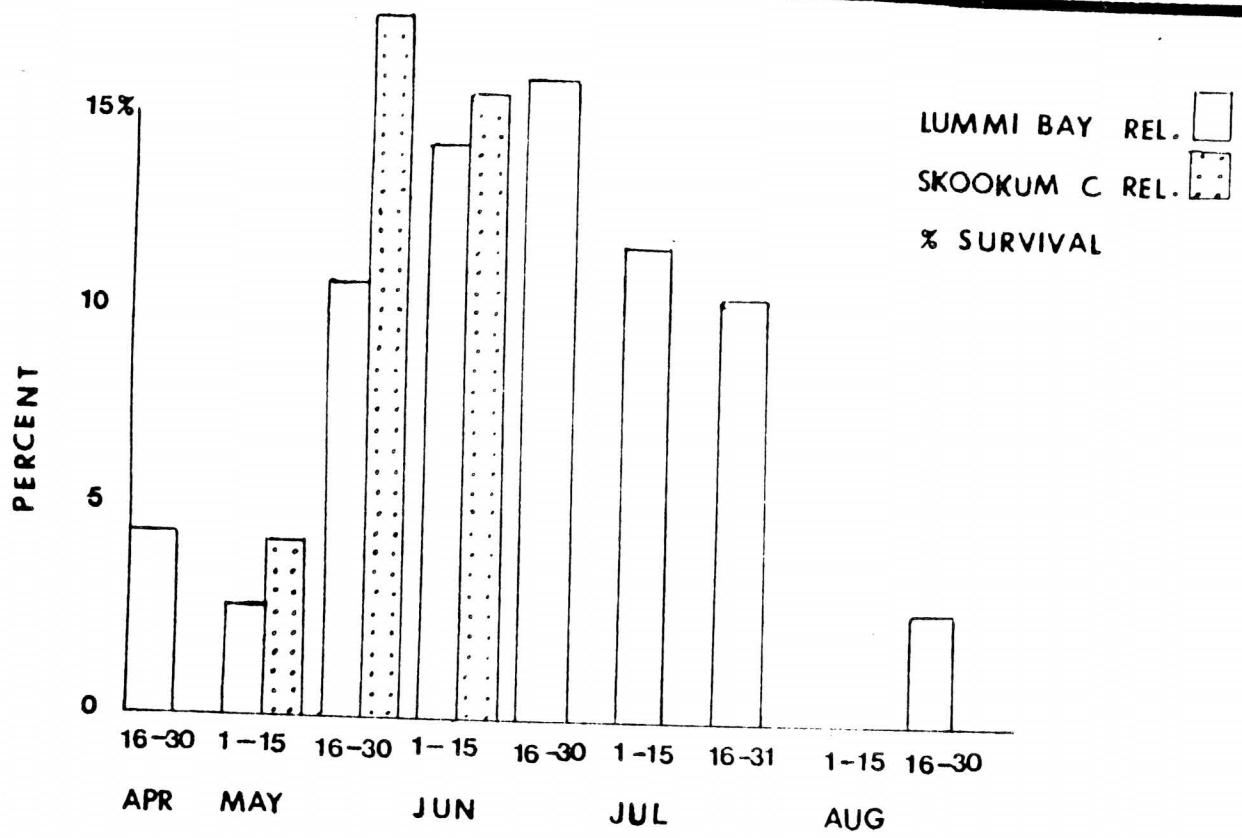
CONTRIBUTION: Tag recovery information indicates release timing affects the survival rates of coho hatchery releases, especially those reared in sea water prior to liberation. Tagged coho released during mid-May to early June had survival rates between 15-20 percent. Groups released during April and again in August had poorer rates of survival ranging between 0.5 - 5.0 percent. (Fig. 1) Initially, fresh water releases from Skookum Creek Hatchery have higher contribution rates then comparable groups released after salt water rearing. Beginning in 1978, the results of these earlier time-of-release studies were incorporated into the salt water program resulting in higher survival rates of the 1979, 1980, and 1981 adult Sea Pond coho returns.(Fig. 2)

FALL CHINOOK EVALUATION: Since 1975, fourteen groups of young fall chinook salmon have been coded wire tagged to evaluate their contribution and total survival following release from the Skookum Creek hatchery or the Lummi Bay facility. Juveniles released from the Skookum Creek hatchery are reared totally in fresh water and released from the hatchery outlet into the south fork of the Nooksack River. Lummi Bay chinook are typically incubated and reared at the hatchery until mid-May then transported to the ponds at Lummi Bay at a size of 150-250 fish per pound. At Lummi Bay, the chinook are reared in water ranging from 10 to 28 parts per thousand salinity until release during June. During the short rearing period in warmer saline water the juvenile chinook generally double in size and are larger at release than their fresh water reared counterparts at the Skookum Creek hatchery.

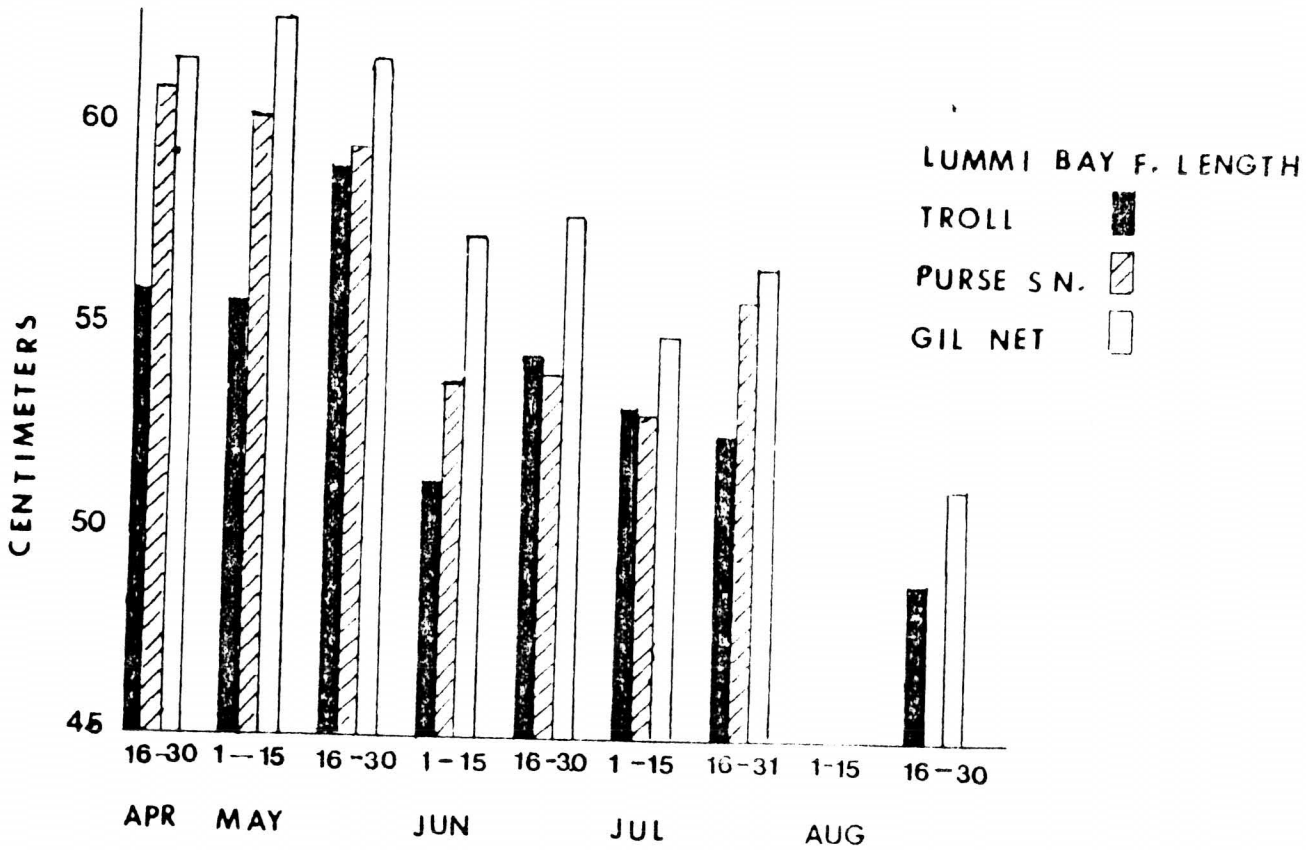
Disease problems prevalent in warm salt water rearing programs generally cause some losses of young chinook while at Lummi Bay, unlike coho, juvenile chinook are highly susceptable to vibriosis, a systemic bacterial infection. Although the chinook are vaccinated for vibrio before being introduced to sea water, they have yet to experience what we feel is consistent protection.

Observed tag recovery information is available from the 1974, 1975 and 1976 brood year releases. Initial data indicates the chinook released

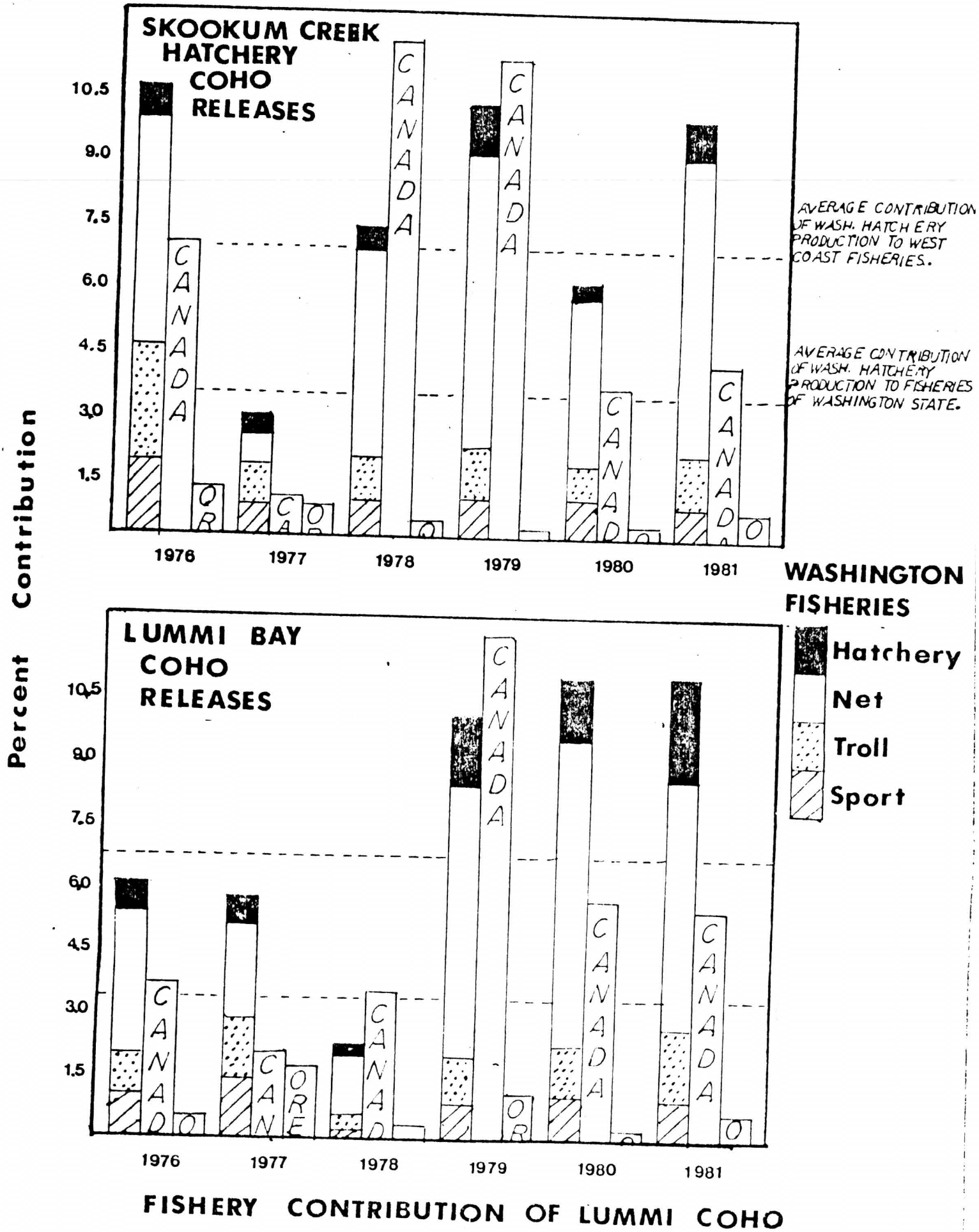
after a short period of rearing in sea water have a significantly higher rate of survival compared to those stocks released directly into the Nooksack River. (Fig. 3) Survival, of the 1975 and 1976 brood chinook released from Lummi Bay had six and ten times the rate of survival, respectively, over those groups released from Skookum Creek hatchery. A similar pattern seems to be developing for the 1977 brood. Estimated total survival is expected to range between 3-4 percent for the Lummi Bay 1975 brood and 0.5 - 1.0 percent for the Skookum Creek group. 1976 brood survival will range from 1.3 - 1.7 percent for Lummi Bay and 0.14 - 0.28 for the Skookum Creek releases.

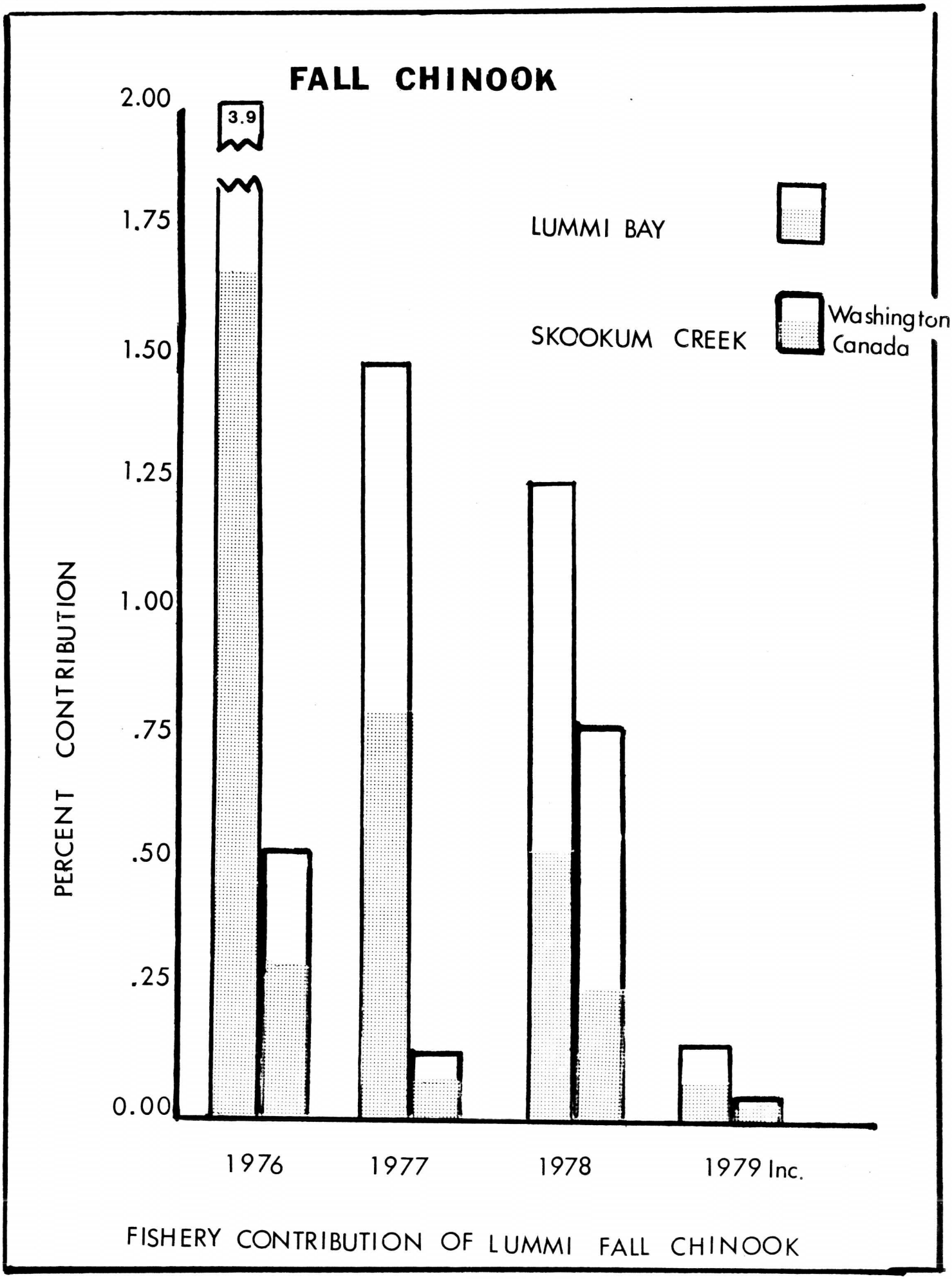


Comparison of time of release and fishery contribution for coho salmon.



Comparison of time of release and eventual size for coho salmon.


SKOOKUM CREEK HATCHERY COHO RELEASES
LUMMI BAY COHO RELEASES
Percent Contribution
10.5
9.0
7.5
6.0
4.5
3.0
1.5
7.6
CANADA
OR
1976
1977
1978
1979
1980
1981
AVERAGE CONTRIBUTION OF WASH. HATCHERY PRODUCTION TO WEST COAST FISHERIES.
AVERAGE CONTRIBUTION OF WASH. HATCHERY PRODUCTION TO FISHERIES OF WASHINGTON STATE.
WASHINGTON FISHERIES
Hatchery
Net
Troll
Sport
FISHERY CONTRIBUTION OF LUMMI COHO



FISHERY CONTRIBUTION OF LUMMI FALL CHINOOK

THE RELATIONSHIP OF TEMPERATURE AND EGG INCUBATION TIME OF ATLANTIC SALMON (Salmo salar)

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Past records of Atlantic salmon hatching dates were correlated with ambient incubation temperatures to provide the equation : log Y=9.42624-5.000361og(X+25.5) for predicting the number of days required for incubation. Through the use of a developmental index incubating lots of eggs can be monitored for time of "eye-up", shocking and hatching. The equation should prove to be more accurate than the current practice of maintaining thermal sums.

INTRODUCTION

Fish hatcheries in the Northeast currently use the sum of temperature units (TU) as an indicator of the hatching time of incubating Atlantic salmon (Salmo salar) eggs. While this practice yields an approximate hatching date its effectiveness is limited. Hatchery managers agree that the total TU to hatch is station specific and that varying TU are required at varying incubation temperatures. Without extensive station specific historical data concerning water temperatures and observed hatching dates, temperature unit based estimates of hatching dates are error prone. Even with extensive background data, as is found at Craig Brook National Fish Hatchery, total TU at hatch is inconsistent from year to year and has varied as much as 120 units at a given mean temperature (Fig.1). Such variations can lead to errors of as much as 18 days in predicting hatch dates. In order to plan for the hatching and initial feeding of fry it is important that the hatching date be more accurately projected.

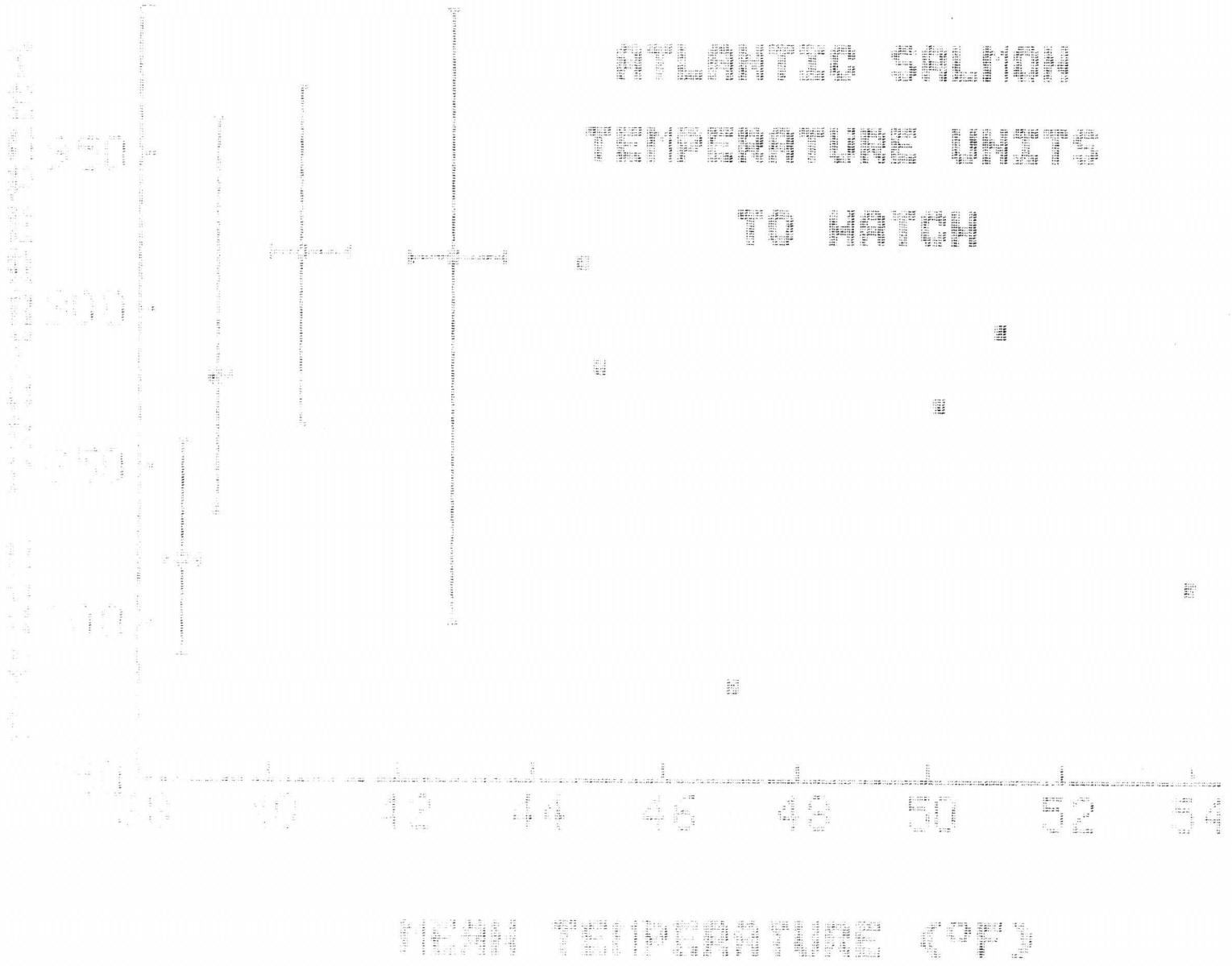

Figure 1. Temperature units ($\Sigma(^{o}F - 32)$) from fertilization to 90% hatch for Atlantic salmon Craig Brook National Fish Hatchery 1960-1963 , 1975-1983. Squares represent means, bars represent ranges.

Much of the published literature (Alderdice and Velsen 1978; Crisp 1981; Embody 1934; Gunnes 1979; Peterson, et al. 1977) on hatching time relationships for salmonid fish is from studies conducted on constant temperature regimes. Alderdice (1978) examined both constant and ambient temperature regimes and found that Chinook salmon (Oncorhynchus tschawytscha) development occurs more rapidly at ambient temperatures than at constant temperatures. Little published information is available concerning Atlantic salmon hatching time relationships under ambient temperature regimes. Alderdice and Velsen (1978) and Crisp (1981) concluded that the use of the TU relationship was less reliable than other formulae and agreed that the power law formula with temperature correction, α ; $D = a\ (T - \alpha)^b$ best fits the observed data for salmonid fish.

This paper presents a model for predicting Atlantic salmon egg hatch under ambient temperature conditions based on incubation data collected at Craig Brook National Fish Hatchery, East Orland, Maine.

METHODS

Atlantic salmon egg hatching dates and ambient incubation water temperature records at Craig Brook National Fish Hatchery were examined for the years 1960-1963 and 1975-1983. Eggs incubated during 1960-1963 were of Canadian origin, obtained from unspecified New Brunswick sources and incubated at Craig Brook. Eggs incubated during 1975-1983 were of Penobscot River (Maine) origin and may have been descendants of the New Brunswick eggs used in the resoration of the Penobscot River salmon runs. Mean water temperature during incubation was correlated with the mean number of days from fertilization to 90% hatch for 39 discrete groups of incubating Atlantic salmon eggs. Ninety percent hatch was used as it is more easily determined than the beginning of hatch or 50% hatch and it was the most consistently recorded reference point in the hatching records. The data were evaluated by geometric regression to provide an equation of the form: $Y = a\ (X - \alpha)^b$,

where Y = number of days from fertilization to 90% hatch

X = mean incubation temperature (^{o}C)

a & b = regression constants and

= a temperature correction constant.

Alpha (α) was determined by iterative means to provide a minimum sum of the squares of the difference between observed and predicted values of Y.

RESULTS

Mean temperatures for the observed data ranged from 3.57 to 12.18 ^{o}C (38.4-53.9^{o}F). The equation generated is

$$Y = 2{,}668{,}342{,}790\ (X + 25.5)^{-5.00036}$$

or in linear form,

$$\log Y = 9.42624 - 5.00036 \log (X + 25.5)$$

$$r^2 = .9659$$

$$N = 39$$

Figure 2 illustrates the relationship between temperature and incubation time as expressed by the above equation.

DISCUSSION

The ability to accurately predict hatching dates is important to the planning of a one- year smolt program or a fry stocking program. By manipulating incubation temperatures Atlantic salmon fry can be hatched at a time for optimum growth of for optimum stocking into streams. The above equation gives the fisheries manager the ability to plan for a program and make adjustments as temperature deviations occur. A modified form of the equation can also be used to predict "eye-up", safe shocking and shippment and hatching dates for incubating lots of eggs. If we consider the predicted value of Y to be the point of 100% development (i.e. 100% of the development to 90% hatch will occur after Y days) then it follows that in 1 day at $X^{o}C$, $\frac{100}{Y}\%$ of development will occur ; where Y is the predicted value for that day's temperature , X. Thus in the same manner that sums of TU are currently kept,

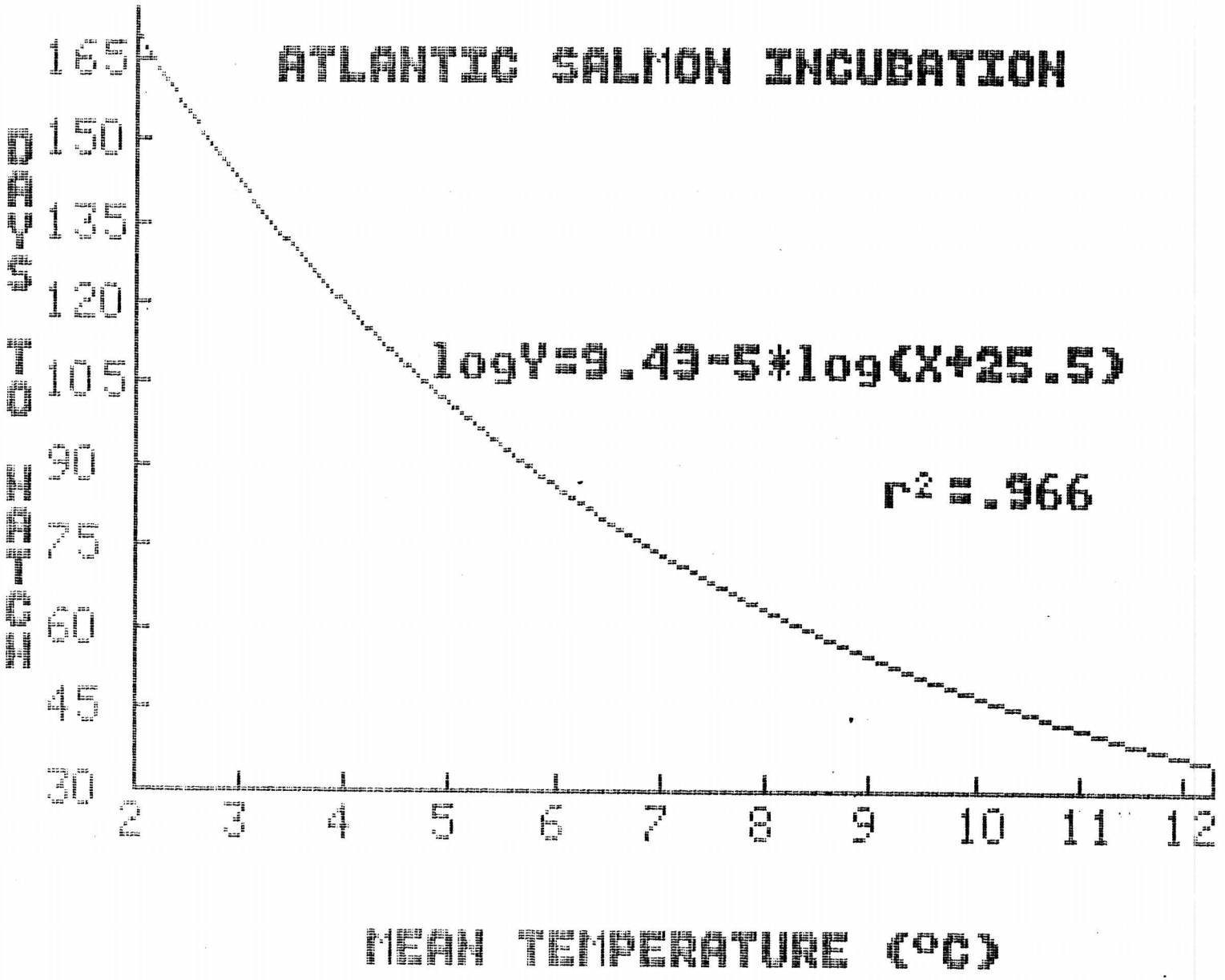

Figure 2. Days from fertilization to 90% hatch for Atlantic salmon, Craig Brook National Fish Hatchery, 1960 - 1963, 1975 - 1983.

we can accumulate sums of $\frac{100}{Y}$% which express the percent development to date as a percentage of the total time to 90% hatch. When the cumulative sum, or developmental index is 50, 50% of the development to 90% hatch has occurred. Likewise, when the development index is 100, the date of 90% hatch should be reached. To minimize tedious field calculations Table 1 is provided, which assigns a value of $\frac{100}{Y}$ to each daily temperature. To maintain a developmental index for an incubating lot of eggs add the value for each day's mean temperature to the current developmental index, beginning with zero on the date of fertilization. Table values beyond the range observed in this study (3.57-12.18°C) are extrapolated and provided for completeness. Based on the fit of the curve in Figure 2, any error experienced from extrapolating beyond our data (within lethal temperature limits) should prove negligible compared to current temperature measurement practices.

Examination of recent incubation records at Craig Brook National Fish Hatchery shows that faint eyes are observable at a mean development index of 49.3 (95% confidence interval = 46.7 - 51.9); safest shocking, shipping and disinfection has occurred at a mean index of 74.8 (70.9 - 78.5) ; and 90% hatch has occurred at a mean index of 101.5 (98.7 - 104.4).

The development index should prove useful to Atlantic salmon hatcheries planning or involved in one-year smolt programs and fry stocking programs as it is more reliable than the temperature unit method. It is species specific rather than station specific and it compensates for differences in incubation temperature.

ACKNOWLEDGMENTS

I thank the staff of Craig Brook National Fish Hatchery, past and present, for their extensive record keeping.

°C			°F		
	.0	.5		.0	.5
0	.404	.446	32	.404	.427
1	.490	.538	33	.450	.475
2	.590	.646	34	.510	.527
3	.705	.769	35	.555	.584
4	.838	.912	36	.614	.646
5	.990	1.074	37	.678	.712
6	1.163	1.259	38	.748	.784
7	1.360	1.468	39	.822	.862
8	1.583	1.704	40	.903	.946
9	1.833	1.970	41	.990	1.036
10	2.115	2.268	42	1.084	1.133
11	2.430	2.601	43	1.184	1.237
12	2.782	2.972	44	1.292	1.349
			45	1.407	1.468
			46	1.531	1.596
			47	1.663	1.732
			48	1.804	1.878
			49	1.955	2.034
			50	2.115	2.199
			51	2.286	2.375
			52	2.468	2.563
			53	2.661	2.761

Table 1

Development index values for Atlantic salmon incubated under ambient temperatures. Values outside the range of data examined (3.57 - 12.18°C) are extrapolated.

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mlh #4
11/28/83

34th ANNUAL FISH CULTURE CONFERENCE

Moscow, Idaho, December 7-8, 1983

TITLE: Growth and seawater tolerance of fall chinook smolts (*Oncorhynchus tshawytscha*) after prerelease treatment with formalin and potassium permanganate.

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Introduction

For many years Federal, State and private salmon and trout hatcheries have used various medications to treat the many maladies incurred by stocks of fish in crowded rearing systems. Among the more common drugs used for therapeutic and prophylactic treatments are formalin and potassium permanganate ($KMnO_4$)

Formalin (37% by weight formaldehyde) is used extensively for the control of ectoparasites. Although formalin toxicity is infrequent in young salmonids, treatment with a 1:4000 dilution in water warmer than 10°C can cause a loss if the fish have bacterial gill disease (Wood 1974). Piper and Smith (1973) found, after conducting an extensive survey of 74 United States hatcheries, that few problems developed from formalin toxicity if the chemical was properly used. Wedemeyer (1971) observed that the prescribed dosage of 1:6000 for ectoparasitic treatment caused a significant drop in blood Cl^-, Ca^{++}, total CO_2, and tissue vitamin C levels in rainbow trout (Salmo gairdneri). However, coho salmon smolts (Oncorhynchus kisutch) were less affected. Bouck and Johnson (1979) found that formalin treatments produced low level mortality in coho salmon smolts upon direct transfer to seawater and no mortality after four days delayed transfer to seawater.

$KMnO_4$ has been used quite regularly since 1904 for the treatment of numerous parasitic outbreaks. Use of the drug has also been effective against bacterial gill disease, providing certain precautions are taken; i.e., allowing for temperature variations and changing of rearing water (Wood 1974). Tucker and Boyd (1977) stated that varying organic load levels caused inconsistencies in effectiveness against bacterial gill disease, and that the value of the compound in the aquatic environment is inversely proportional to the load of the oxidizable organic matter in the water. Jee and Plumb (1981) observed that the effectiveness of $KMnO_4$ was much greater when treating fathead minnows (Pimephales promelas) infected with Flexibacter columnaris in organically depleted tap water vice organically enriched pond water. Bouck and Johnson (1979) indicated that presecribed treatments with $KMnO_4$ caused an 80% mortality in coho salmon smolts when the fish were transferred to 28 parts per thousand (ppt) seawater immediately after treatment. However, if the fish were held for four days post-treatment in freshwater, the mortality rate dropped to 12%.

At present, formalin is registered with the FDA as a parasiticide and $KMnO_4$ has been exempted from registration (Schnick and Meyer 1979).

Our objective in these studies was to determine if timing and medication treatment effects smoltification as measured by gill Na^+K^+ adenosine triphosphatase (ATPase) activity, seawater survival and growth.

Methods and Materials

Experimental Animals

In both the 1981 formalin study and the 1982 $KMnO_4$ study, eyed fall chinook eggs were transported to the USFWS, Seattle National Fishery Research Center's Marrowstone Field Station in October, disinfected in a 1:100 solution of Argentine[1/] (an iodine base disinfectant) and reared to swim-up in an eight tray Heath-Tecna incubator with a fresh water flow rate of approximately 3 gallons per minute (gpm).

In February, the fry (weighing approximately 450/lb) were placed in 68-liter rectangular glass aquaria in lots of 50 with each aquarium receiving about 1 liter per minute fresh water. The fry were allowed to acclimate to their new surroundings for about two weeks prior to commencing treatments.

Experimental Design

For the 1981 formalin study, the aquaria were randomly divided into two groups; 103 for formalin and "sham" treatment controls and ATPase analysis and 10 for unhandled, untreated controls. Of the 58 aquaria in the $KMnO_4$ study, 36 were randomly divided into two groups; 18 each for $KMnO_4$ treatments and "sham" treatment controls. Of the remaining 22 aquaria, four were used as untreated, unhandled controls and 18 were used to monitor ATPase activity. Bi-weekly treatments were begun in February and continued through May (Figs. 1 and 2). ATPase analysis was conducted according to Zaugg (1982).

Once smolting was determined by gil ATPase activity analysis, the fish were acclimated to 28 ppt seawater by exposure to 12-15 ppt seawater (isotonic) for 48 hrs for formalin treated fish and 24 hrs for $KMnO_4$ treated fish. Once the acclimation period was complete, the fresh water was turned off and the seawater flow rate increased to approximately 1 liter/minute. In both studies, smoltification occurred in May. Mean loading densities at the time of seawater entry in 1981 and 1982 were 4.1 gm fish and 4.6 gm fish per liter of water respectively. Lighting was simulated to approximate the natural photoperiod by weekly adjustments to overhead florescent lamps.

The 1981 formalin treatments were conducted according to Wood (1974) using a 1:6000 dilution in static fresh water for one hour. $KMnO_4$ treatments in 1982 were also according to Wood (1974) using 2 mg $KMnO_4$ per liter static fresh water for one hour each on three consecutive days. In both studies the aquaria were not drained at the end of the treatment, but thoroughly flushed with fresh water. In both studies, "sham" treatments were conducted in static situations and stirred as if the medications had been used.

[1/] Reference to trade names is for identification only and does not imply U.S. Government endorsement of commercial products.

All study fish were fed once daily to satiation with OMP II. However, feed was withheld for 24 hrs prior to $KMnO_4$ treatments to reduce the organic load.

Microbial Examination

In both studies, all post treatment mortalities, other than those which were lost to system failures, were examined microbiologically for pathogens using sterile brain heart infusion agar and asceptically removed kidney material.

Results

Na^+K^+-ATPase Activity Analysis

Some significant differences at the 95% confidence level did occur in formalin treated fish when compared to their "sham" treated controls using a "t" test for comparison. ATPase activity was analyzed for those fish treated 60 days or less prior to seawater entry (Figs. 3-7). However, the enzymes' activity was not consistent in those groups; i.e., when Group 2's activity was monitored on May 7, one day before seawater entry (Fig. 4), the treatment group was lower than the control but when Group 6 was monitored on May 7, the treatment group was higher than the control (Fig. 7). When Group 6 was again analyzed five days after seawater entry, the treatment group was lower than the control.

ATPase activity in $KMnO_4$ treated fish responded similarly to the formalin treated fish. Significant differences at the 95% confidence level occurred between "sham" treatments and unhandled, untreated controls (Fig. 8) and between treatments and unhandled, untreated controls (Fig. 9). However, the treatment and "sham" treatment groups were consistently lower than the untreated, unhandled controls.

Growth and Seawater Survival

No significant differences occurred in growth and seawater survival (20 day challenge) in the formalin and $KMnO_4$ treated fish when compared to their respective "sham" treated groups and unhandled, untreated controls.

Mortalities, post seawater exposure, were practically none in both studies for treatment and control groups. Formalin treated fish demonstrated $\geq$ 97% survival and $KMnO_4$ treated groups were $\geq$ 99% (Figs. 11 and 12).

Discussion

The inconsistencies observed in the ATPase activity of the formalin treated fish indicates that something may be occurring during the smoltification process with recently treated fish, but given the good growth and seawater performance, it may not be enough to cause alarm. We feel the important point to remember is that the ATPase levels, when compared between treatments, "sham" treatments and unhandled, untreated controls over time, did rise as expected, the fish did convert to 28-29 ppt seawater and did survive very well (97% overall) for at least 20 days (Fig. 11).

$KMnO_4$ treated fish were also determined to be unaffected by the treatments and demonstrated a 99% survival after 20+ days on seawater. Even when technical problems were included in the losses, the survival rate was 94% (Fig. 12). The 12 deaths in the $KMnO_4$ group that did occur post seawater acclimation were determined to be those fish not able to cross the fresh to seawater threshold. The mean fork length of the 12 was 20 mm less than that of the survivors. Again, the point to remember is that even though a few significant differences did occur in ATPase activity, the young smolts did very well when acclimated to seawater. However, a possible latent ATPase rise may be occurring if the fish are treated with $KMnO_4$ 20 days or less prior to seawater entry.

In conclusion we feel that when properly used, formalin and $KMnO_4$ will not affect the ability of smolts to enter seawater. However, care should be taken when using the chemicals because if improperly used, both chemicals could cause unnecessary damage to the health of the workers and the fish. Also of importance is the fact that this was a laboratory situation and the environmental factors at various rearing facilities may cause somewhat varied results when using the drugs.

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Figure 1. Experimental procedure to test the effect of formalin treatment on $Na^+ - K^+$ gill ATPase activity, growth, and freshwater-seawater transition of fall chinook salmon.

TREATMENT PHASE			DATE COLLECTION PHASE						
			Date and # Tanks Sampled for fish $Na^+ - K^+$ gill ATPase activity and Growth[d]						Date and # Tanks converted to seawater inflow
Date	Treatment	# Tanks Treated[a]	Feb 26	Mar 2	Mar 26	Apr 9	Apr 23	May 7	May 17 - May 19[e]
Feb 26	Formalin[b]	11	1	1	1	1	1	1	5
	Control[c]	11	1	1	1	1	1	1	5
Mar 2	Formalin	10		1	1	1	1	1	5
	Control	11		1	1	1	1	1	5
Mar 26	Formalin	9			1	1	1	1	5
	Control	9			1	1	1	1	5
Apr 9	Formalin	8				1	1	1	5
	Control	8				1	1	1	5
Apr 23	Formalin	7					1	1	5
	Control	7					1	1	5
May 7	Formalin	6						1	5
	Control	6						1	5
	Non-Treatment, Unhandled Control	10							10

[a] Each tank contained approximately 50 fish.

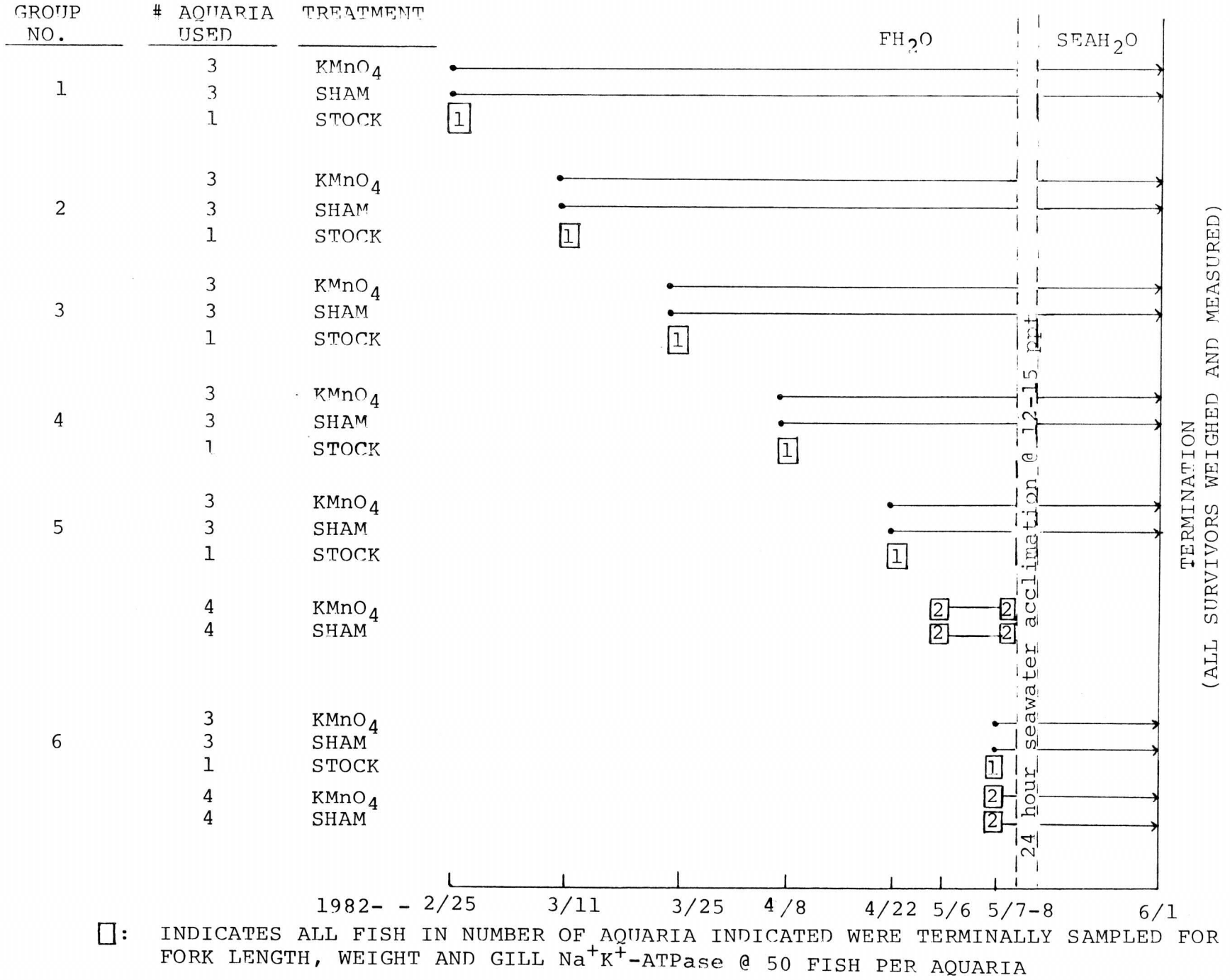
[b] Treatment procedures were according to Wood (1979).

[c] Control fish were handled exactly the same as fish exposed to formalin.

[d] Thirty fish, ten pools of three, were sampled for $Na^+ - K^+$ gill ATPase activity. Each fish was weighed to the nearest 0.1 gm and measured (fork length) to the nearest mm.

[e] Fish were exposed to 12-15 ppt salinity on May 17 and converted to 29 ppt salinity on May 19. Seawater survival was monitored for 20 days.

FIGURE 2.
EXPERIMENTAL DESIGN, AQUARIA ALLOCATION AND SAMPLING TIMES TO DETERMINE THE IMPACT OF $KMnO_4$ TREATMENTS ON FALL CHINOOK SALMON SMOLTIFICATION AND SEAWATER SURVIVAL



□: INDICATES ALL FISH IN NUMBER OF AQUARIA INDICATED WERE TERMINALLY SAMPLED FOR FORK LENGTH, WEIGHT AND GILL Na^+K^+-ATPase @ 50 FISH PER AQUARIA

FIGURE 3.
COMPARISON OF GILL Na^+K^+-ATPase ACTIVITY BETWEEN TREATMENT AND CONTROL GROUPS TREATED WITH FORMALIN. VALUES ARE MEANS $\pm$ STANDARD DEVIATION. 30 FISH WERE SAMPLED FOR EACH VALUE INDICATED.

■ : CONTROL
▭ : TREATED WITH FORMALIN

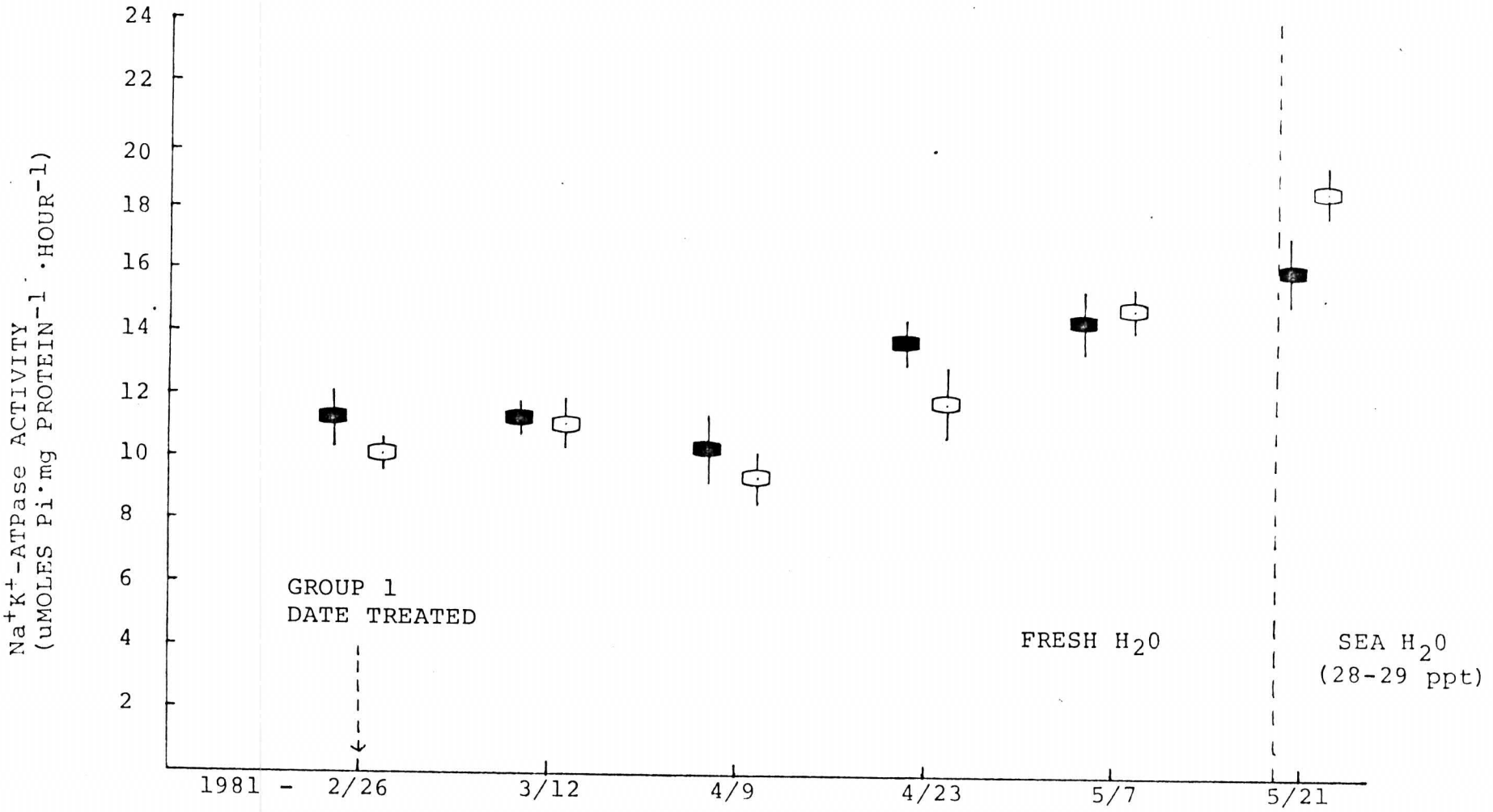


FIGURE 4
COMPARISON OF GILL Na^+K^+-ATPase ACTIVITY BETWEEN TREATMENT AND CONTROL GROUPS TREATED WITH FORMALIN. VALUES ARE MEANS $\pm$ STANDARD DEVIATION. 30 FISH WERE SAMPLED FOR EACH VALUE INDICATED.

■: CONTROL
□: TREATED WITH FORMALIN

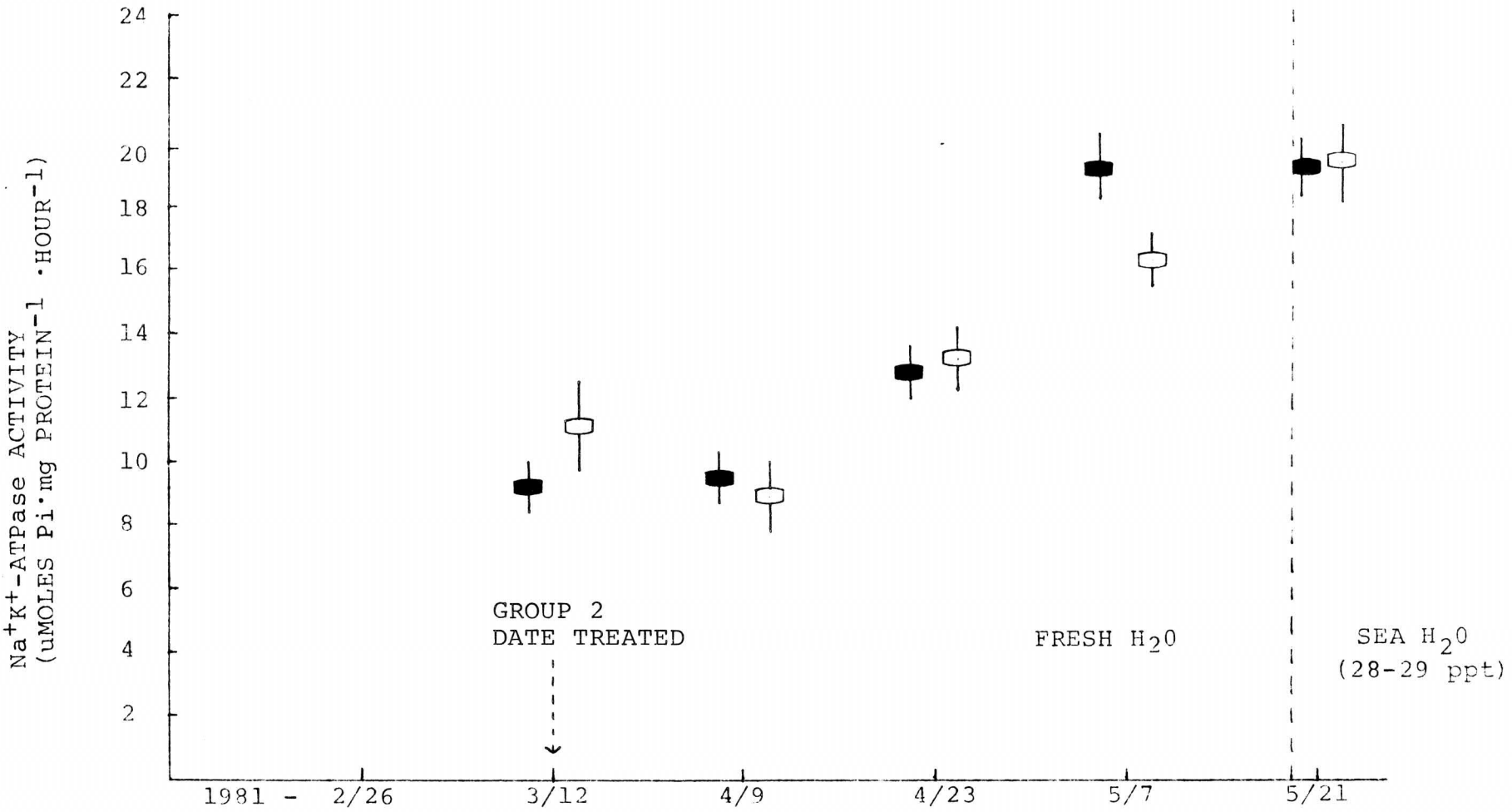


FIGURE 5.
COMPARISON OF GILL Na^+K^+-ATPase ACTIVITY BETWEEN TREATMENT AND CONTROL GROUPS TREATED WITH FORMALIN. VALUES ARE MEANS $\pm$ STANDARD DEVIATION. 30 FISH WERE SAMPLED FOR EACH VALUE INDICATED.

■: CONTROL
□: TREATED WITH FORMALIN

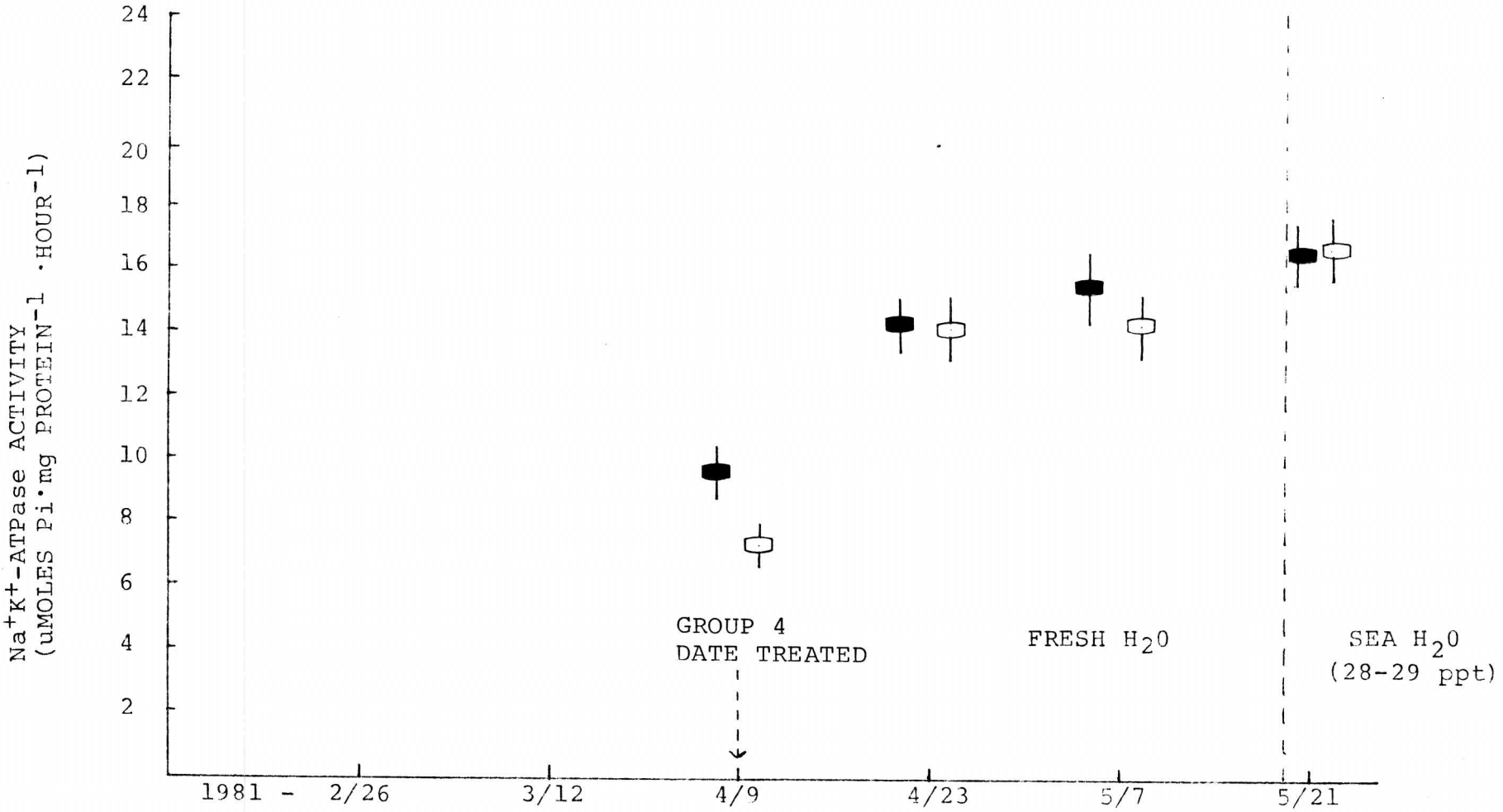


FIGURE 6.
COMPARISON OF GILL Na^+K^+-ATPase ACTIVITY BETWEEN TREATMENT AND CONTROL GROUPS TREATED WITH FORMALIN. VALUES ARE MEANS $\pm$ STANDARD DEVIATION. 30 FISH WERE SAMPLED FOR EACH VALUE INDICATED.

■: CONTROL
▭: TREATED WITH FORMALIN

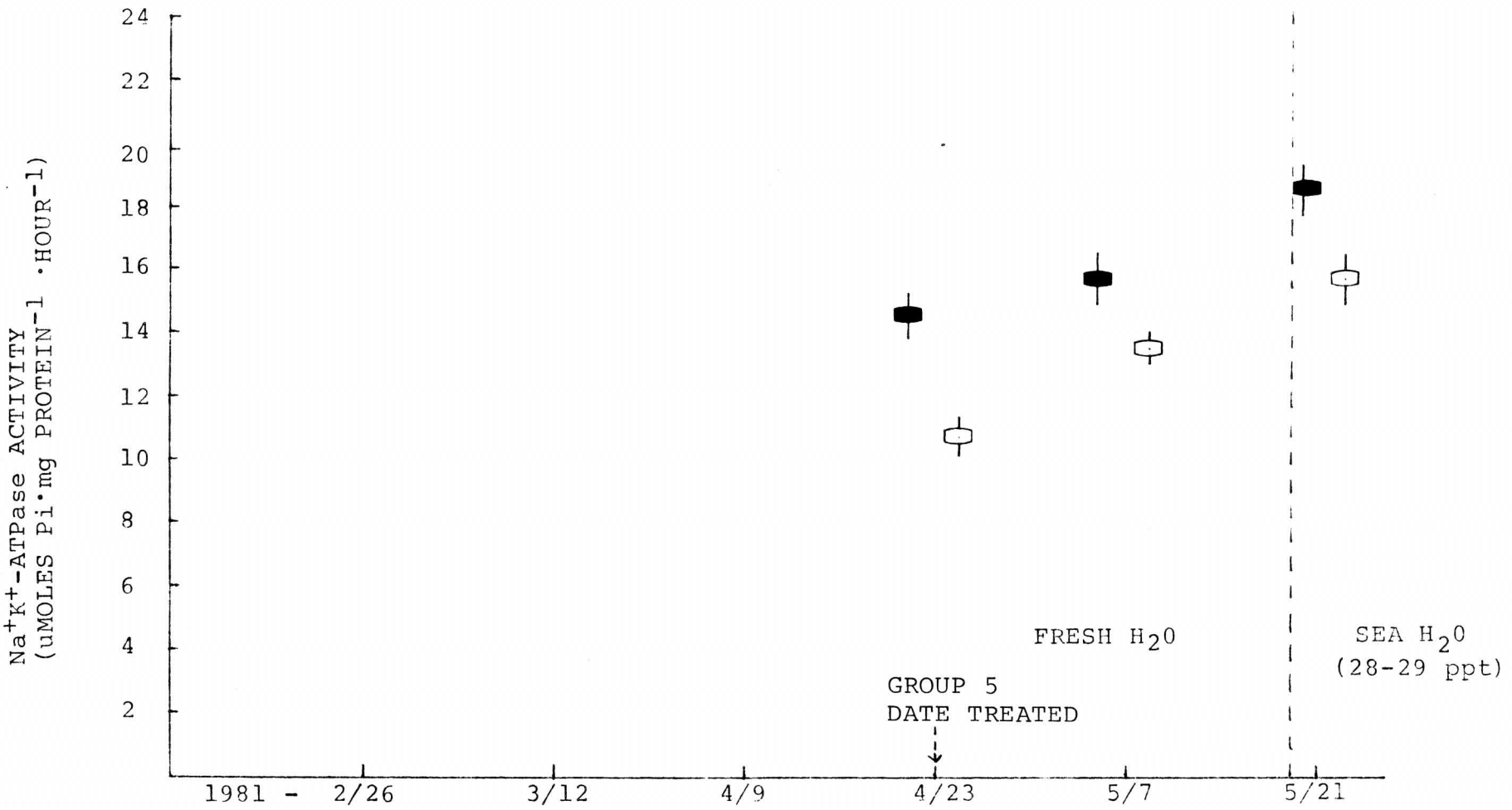


FIGURE 7.
COMPARISON OF GILL Na^+K^+-ATPase ACTIVITY BETWEEN TREATMENT AND CONTROL GROUPS TREATED WITH FORMALIN. VALUES ARE MEANS ± STANDARD DEVIATION. 30 FISH WERE SAMPLED FOR EACH VALUE INDICATED.

■: CONTROL
□: TREATED WITH FORMALIN

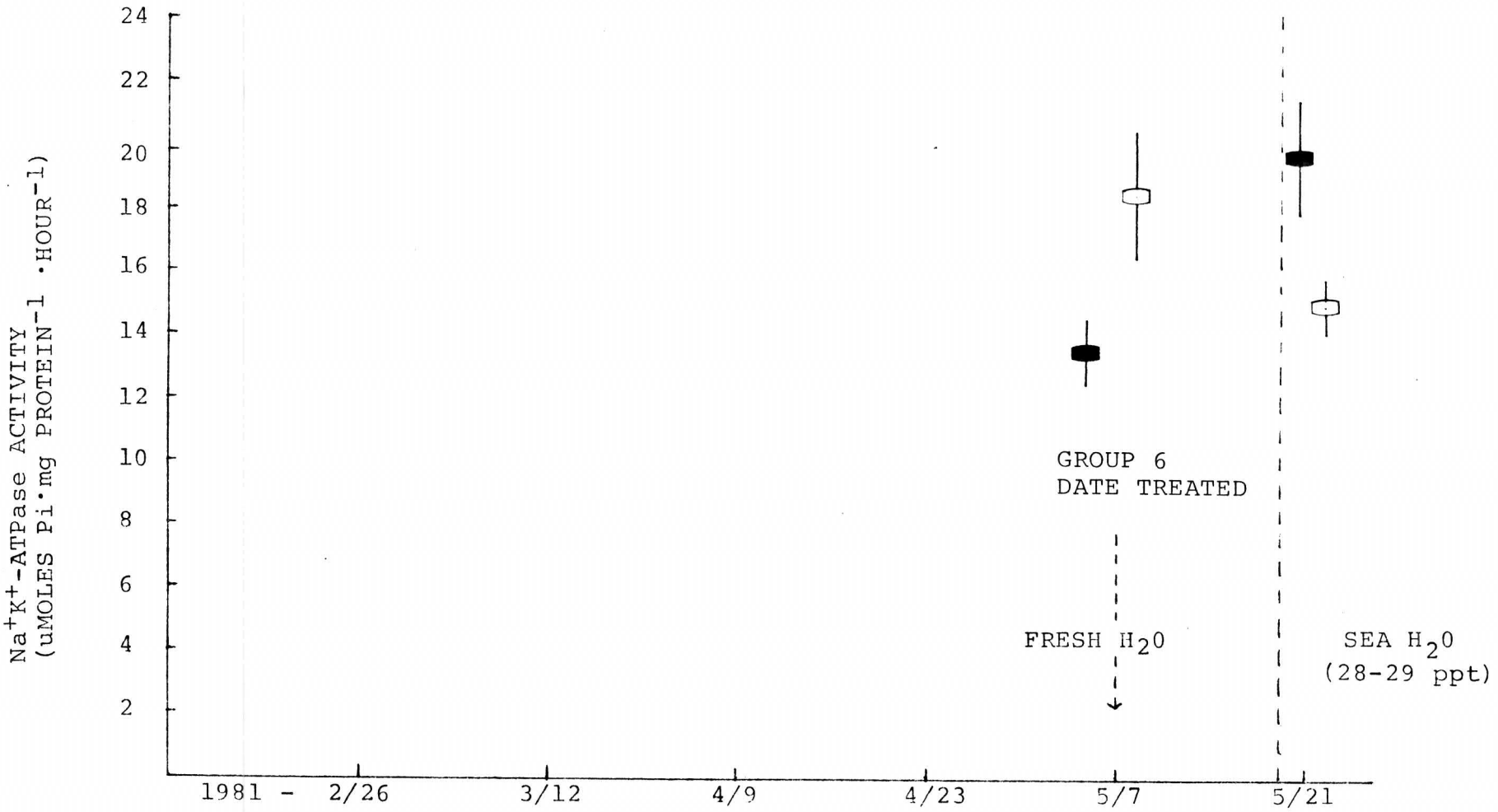


FIGURE 8.
COMPARISON OF GILL Na^+K^+-ATPase ACTIVITY BETWEEN TREATMENT AND CONTROL GROUPS TREATED WITH $KmNO_4$. VALUES ARE MEANS ± STANDARD DEVIATION. 10 SAMPLES WERE USED FOR EACH VALUE INDICATED.

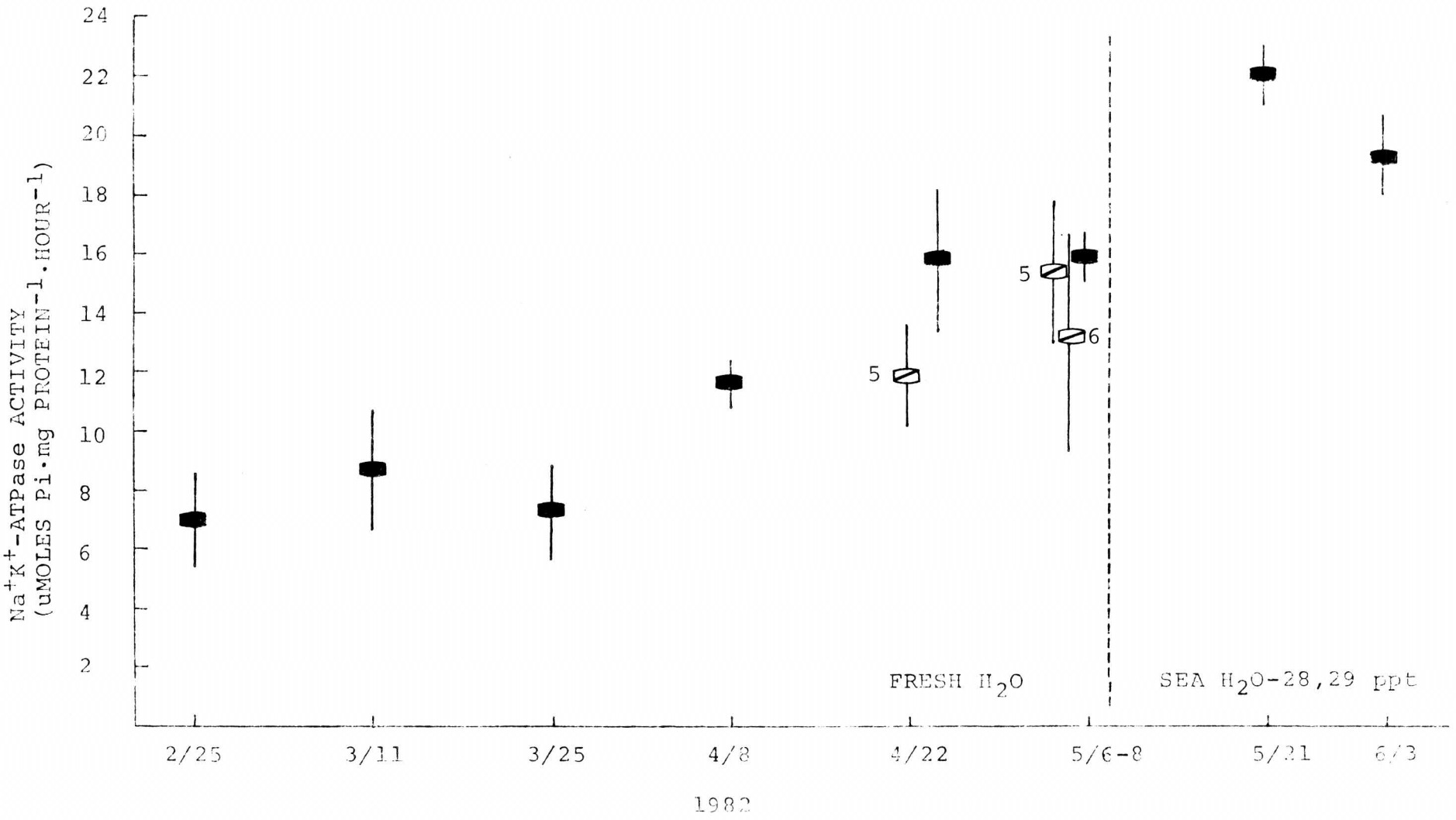


FIGURE 9.
COMPARISON OF GILL Na^+K^+-ATPase ACTIVITY BETWEEN TREATMENT AND CONTROL GROUPS TREATED WITH $KmNO_4$. VALUES ARE MEANS ± STANDARD DEVIATION. 10 SAMPLES WERE USED FOR EACH VALUE INDICATED.

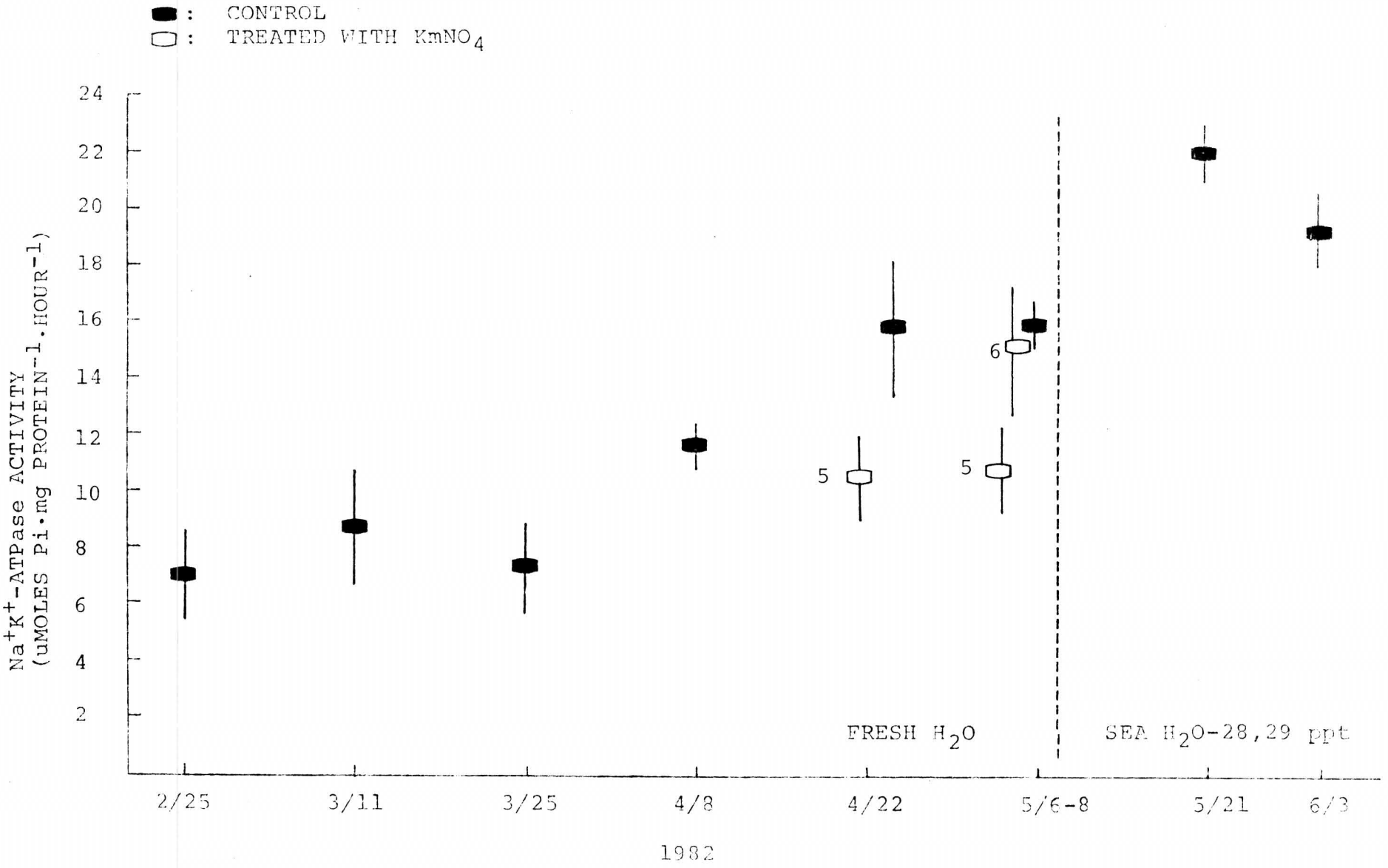


FIGURE 10.
COMPARISON OF GROWTH (FORK LENGTH) BETWEEN $KMnO_4$ TREATED, SHAM TREATED AND CONTROL FALL CHINOOK SMOLTS. SAMPLES SIZES ARE $\geq$20 WITH MOST $\geq$30.

GROUP NO. 6

[a] Indicates Significant Difference at the 0.95 Confidence Level

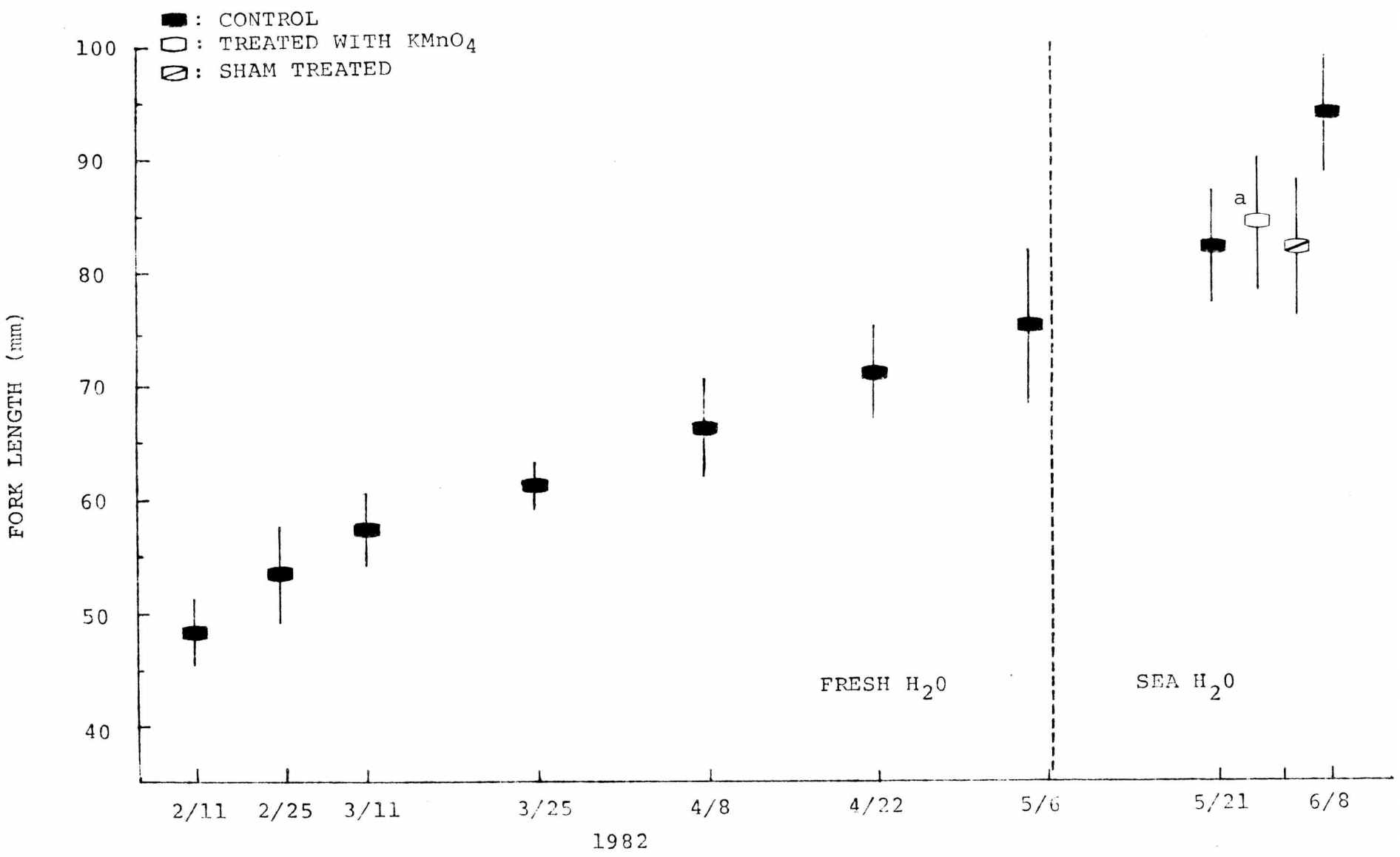


Figure 11. Seawater challenge survival (20d exposure) of fall chinook salmon treated or sham-treated (control) with formalin at different times prior to seawater entry.

Treatment Date (81)	Treatment	Number Tanks per Treatment	Total Number of Fish Challenged[b]	Total Number of Survivors	Range in Percent Survival Between Tanks	Total Percent Survival
Feb 26	Formalin	5	239	234	100%-96%	98%
	Control	5	239	234	100%-95%	98%
Mar 2	Formalin	5	239	233	100%-94%	97%
	Control	4[a]	181	174	98%-94%	96%
Mar 26	Formalin	5	245	234	98%-93%	96%
	Control	5	249	242	100%-90%	97%
Apr 9	Formalin	4[a]	204	195	100%-94%	96%
	Control	5	266	255	98%-92%	96%
Apr 23	Formalin	5	216	211	100%-94%	98%
	Control	4[a]	200	197	100%-96%	99%
May 7	Formalin	5	245	239	100%-94%	98%
	Control	5	244	240	100%-96%	98%
NO TREATMENT		10	481	465	100%-93%	97%

[a] Fish in tank were lost due to accidental water shut-off.

[b] Total numbers of fish in the tanks not equalling multipler of 50 are attributed to experimental (counting) error and "jump-outs."

FIGURE 12.
SEAWATER CHALLENGE SURVIVAL (20+d EXPOSURE) OF FALL CHINOOK SALMON TREATED OR "SHAM" TREATED (CONTROL) WITH $KMnO_4$ AT DIFFERENT TIMES PRIOR TO SEAWATER ENTRY.

TREATMENT DATE (82)	TREATMENT	NUMBER TANKS PER TREATMENT	TOTAL NUMBER OF FISH CHALLENGED[b]	TOTAL NUMBER OF SURVIVORS	RANGE IN PERCENT SURVIVAL BETWEEN TANKS	TOTAL PERCENT SURVIVAL
Feb 25	$KMnO_4$	3	149	149	-	100%
	Control	3	149	149	-	100%
Mar 11	$KMnO_4$	3	150	147	100%-98%	98%
	Control	3	150	150	-	100%
Mar 25	$KMnO_4$	3	149	148	100%-98%	99%
	Control	2[a]	128	124	100%-94%	97%
Apr 8	$KMnO_4$	2[a]	137	137	-	100%
	Control	3	149	141	98%-90%	95%
Apr 22	$KMnO_4$	3	150	147	100%-96%	98%
	Control	3	150	145	100%-90%	97%
May 6	$KMnO_4$	2[a]	133	133	-	100%
	Control	3	150	148	100%-96%	99%

[a] Fish in tank lost due to system failures post treatment date.

[b] Total number of fish in tanks not equalling multiplier of 50 are attributed to experimental (counting) error and "jump-outs".

RELATIONSHIP OF TIME OF RELEASE FOR HATCHERY REARED SPRING CHINOOK SALMON AND PRESPAWNING MORTALITY IN RETURNING ADULTS

by

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INTRODUCTION

Since 1973, the Oregon Department of Fish and Wildlife, through funding by the U.S. Army Corps of Engineers has conducted intensive studies to assess the effects of Lost Creek Dam on the fishery resources of the Rogue River. Prespawning carcass surveys conducted from 1977 through 1980 revealed that returning hatchery reared adult spring chinook were more susceptible to disease related prespawning mortality than wild fish. Percentages of hatchery fish (1977-80) were significantly higher ($P \leq 0.01$) for the Shady Cove to Tou Velle survey area (km 211-235, mi 131-146) as compared to proportions counted downstream at Gold Ray Dam (km 202, mi 125) (Table 1) (McPherson et al. 1982). The highest level of prespawning mortality occurred in 1977. Drought conditions aggravated by the initial filling of Lost Creek Reservoir resulted in low spring and summer flows, and high water temperatures contributing to favorable conditions for the production of disease organisms. Data collected in 1977 suggests that in excess of 90% of the returning hatchery reared adult spring chinook died prior to spawning. While mortality declined to lower levels in later years (1978-80), hatchery fish continued to be more susceptible than wild fish to prespawning mortality.

Spring chinook studies conducted since 1975 at Cole Rivers Hatchery (located below Lost Creek Dam) have focused on the evaluation of the effects of various hatchery practices on survival to adulthood. These studies, which were jointly

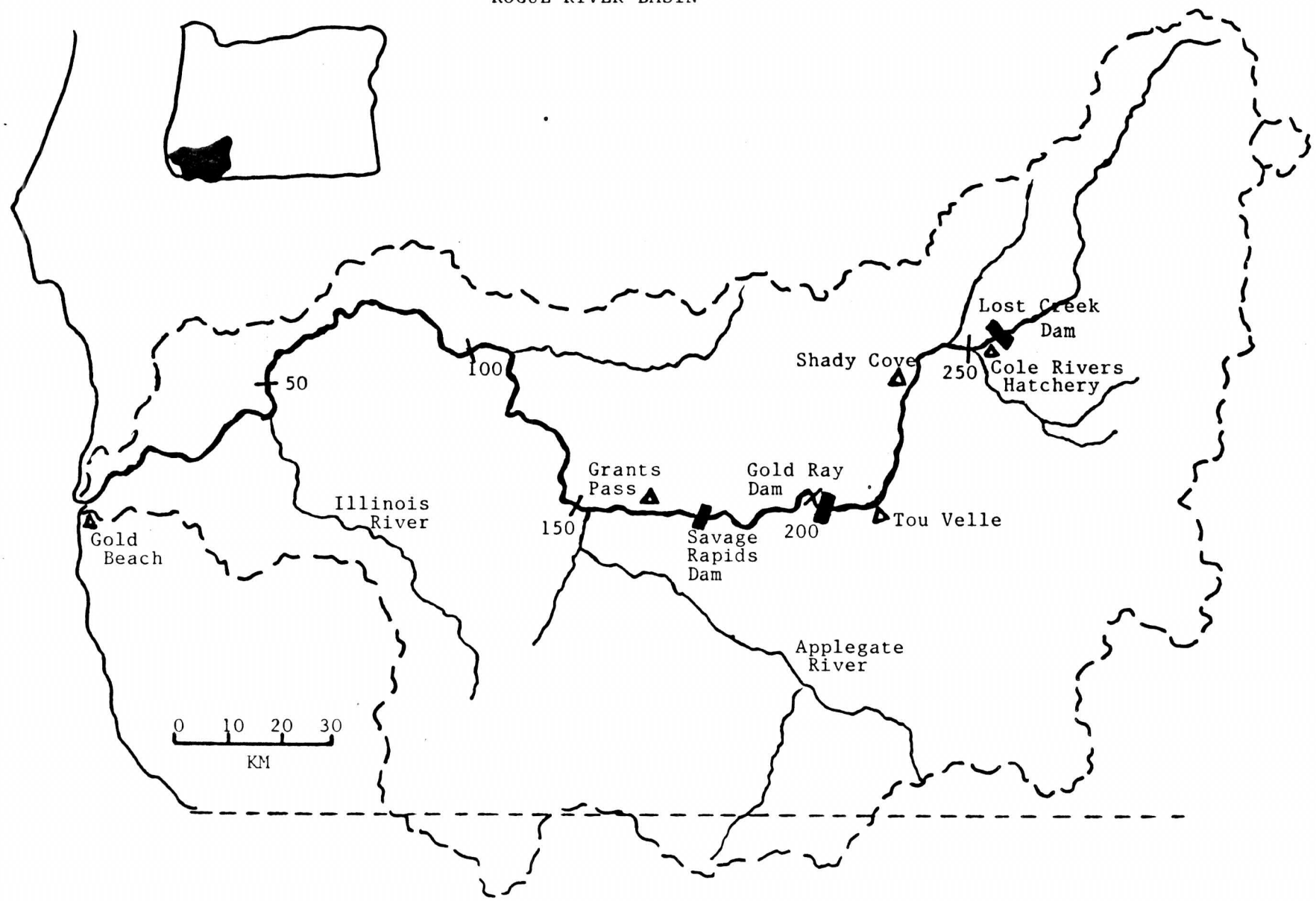

Fig. 1. Map showing locations in the Rogue River basin (numbers indicate kilometers from river mouth).

funded by the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers, provided data in 1981 and 1982 suitable for assessing the effects of time of release, size of release and vaccination against Vibrio anguillarum on prespawning mortality.

METHODS

Several experimental groups of spring chinook salmon were released from Cole Rivers Hatchery from 1977 through 1980 (1976 through 1980 broods) to test the effects of time and size at release and vaccination against Vibrio anguillarum on survival to adulthood (Evenson et al. 1982). Release sizes ranged from 12.3 to 26.9 fish/kg (5.6 to 12.2 fish/lb). With the exception of the 1976 brood, test groups were released as yearlings in October, December and March. All 1976 brood groups were released in October or December. Approximately 24,000 to 75,000 smolts from each release group were coded-wire tagged and marked by removal of the adipose fin to facilitate evaluation of adult survival.

Upon returning to Cole Rivers Hatchery in 1981 and 1982, adults from these experimental groups were placed in holding ponds and held for spawning. Fish retained for spawning that arrived at the hatchery prior to July 1, 1981 and June 19, 1982 were incorporated into an experiment testing the effects of erythromycin injections on bacterial kidney disease and survival to spawning (Evenson, 1982). These earlier arriving adults were randomly placed into erythromycin injected (treated) or non-injected (control) groups. Adults retained for broodstock that arrived after the above dates and before approximately August 20 were all injected with erythromycin. Adults arriving after August 20 were not included in the evaluation of prespawning mortality because of their brief holding period (one month or less) before the initiation of spawning.

Prespawning mortality was summarized by sex for non-injected adults (early arriving only), and combined erythromycin injected adults (early and late arriving)

for each coded-wire tag group. Adults that died prior to the initiation of spawning activities were considered prespawning mortalities, while those surviving after spawning began were catagorized as survivors whether they actually spawned or died (usually from handling) during the spawning period.

RESULTS AND DISCUSSION

Only age 4 and age 5 adults (1976 and 1977 broods) in 1981 and age 4 adults (1978 brood) in 1982 returned in sufficient numbers to facilitate meaningful analyses. Data from these groups provided no evidence that prespawning mortality was related to size at release or Vibrio vaccination; however, a relationship to time of release was suggested. Pooling of the data by release time revealed that adults from December release groups tended to show higher prespawning mortality rates than either October or March release groups (Table 2). For both injected and non-injected 1978 brood females returning in 1982, December release groups suffered significantly higher ($P \leq 0.05$) prespawning mortality than either October or March release groups. Three of these four differences were significant at the 99% level of significance. No other significant differences ($P > 0.05$) were found between groups.

These findings provide support for a hypothesis previously postulated to explain the disproportionately high percentages of hatchery spring chinook found in adult carcass surveys conducted in the upper Rogue from 1977 through 1980. In 1977, the year of highest prespawning mortality, furunculosis (Aeromonas salmonicida) and columnaris (Flexibacter columnaris) were the diseases identified as the most likely causes of this mortality. It was suggested that hatchery spring chinook released in the winter months (hatchery fish returning in 1977 were released between November and February) were less resistant than wild fish to furunculosis and columnaris because these diseases are repressed by cooler water temperatures (Holt, et al. 1975). Furunculosis and columnaris also do not generally affect juvenile salmonids at Cole Rivers Hatchery, because water temperatures are cool. In contrast, wild fish

Table 1. Percentage of marked hatchery fish counted at Gold Ray Dam by August 15 compared to that found among prespawning mortalities from Shady Cove to Tou Velle (km 211-235).

Area	1977	1978	1979	1980	Mean	F(d.f)
Gold Ray Dam	9.3	6.0	8.5	10.2	8.5	
Tou Velle to Shady Cove	24.7	26.8	13.0	15.3	20.0	12.38*(1.6)

*Significant at $P \leq 0.01$.

Table 2. Prespawning mortality by sex and release month for erythromycin injected and non-injected 1976, 1977 and 1978 brood spring chinook returning to Cole Rivers Hatchery in 1981 and 1982.

Release Month	% mortality (n) Injected Females	Injected Males	Non-injected Females	Non-injected Males
		1976 BROOD-1981 RETURNS		
October	35.5 (110)	32.6 (46)	46.4 (28)	21.4 (14)
December	57.1 (21)	33.3 (9)	50.0 (46)	50.0 (2)
		1977 BROOD-1981 RETURNS		
October	11.4 (35)	8.0 (25)	12.5 (8)	12.5 (8)
December	17.4 (23)	7.7 (13)	0.0 (1)	0.0 (2)
March	8.7 (23)	11.1 (18)	0.0 (1)	0.0 (3)
		1978 BROOD-1982 RETURNS		
October	5.2 (136)	10.3 (68)	5.3 (75)	7.1 (14)
December	18.5 (108)	16.4 (73)	54.3 (35)	0.0 (6)
March	2.9 (68)	6.1 (33)	11.1 (9)	0.0 (4)

which rear and migrate through the river in summer months, are undoubtedly exposed to these diseases. Similarly, hatchery fish released before or after the winter months may also receive exposures to these pathogens during seaward migration. This may build humoral immunity, resulting in greater resistance when they are again exposed to these diseases on their spawning migration. In contrast, hatchery fish released during periods when these pathogens are inactive would have no increased resistance. Data collected in 1981-82 from studies at Cole Rivers Hatchery are consistant with this hypothesis, however, the immune mechanisms involved are not well understood.

In conclusion, hatcheries that experience high prespawning mortality of adult anadromous salmonids should consider the possible implications of their hatchery practices, particularly time of release, upon the disease resistance of returning adults.

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CULTURE TECHNIQUES FOR SELECTED COLORADO RIVER IMPERILED FISHES

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INTRODUCTION

The aquatic resources of the desert west have been altered drastically during the past 100 years. The construction of large dams in deep canyons of southwestern rivers has had a major impact on many native fishes. The normal fluctuating flows have been blocked, creating large reservoirs and downstream sections dried up or altered by hypolimnetic releases of stored water. Many of our desert springs now have reduced flows or have dried completely as groundwater reservoirs have receded under the constant demand of the irrigation pump (Jensen, in press). These habitat alterations (lotic to lentic, different flow and temperature regimes and drying) have resulted in a steady decline in our native southwestern fish fauna.

The opportunity to focus attention on work with threatened fishery resources came with passage of the Endangered Species Act of 1973. In 1974 Dexter NFH began experimenting with holding native fishes to determine if captive populations could be reared in a hatchery environment. The initial efforts proved successful and by 1978 the Dexter facility was totally engaged in holding, spawning, rearing and distributing native desert fishes. We have held up to 20 species of imperiled fish and are presently holding 13 species (Table 1) with more introductions planned for the future.

Table 1. Fish species presently being held at Dexter NFH, New Mexico.[a]

		Federal status[b]
Family Cyprinidae		
Colorado squawfish	Ptychocheilus lucius	E
bonytail chub	Gila elegans	E
Chihuahua chub (2 populations)[c]	Gila nigrescens	E
Yaqui chub	Gila purpurea	P
woundfin	Plagopterus argentissimus	E
beautiful shiner	Notropis formosus	P
Family Cyprinodontidae		
Comanche Springs pupfish	Cyprinodon elegans	E
Leon Springs pupfish	Cyprinodon bovinus	E
desert pupfish	Cyprinodon macularius	C
Family Poeciliidae		
Gila topminnow	Poeciliopsis o. occidentalis	E
Big Bend gambusia	Gambusia gaigei	E
Family Catostomidae		
razorback sucker	Xyrauchen texanus	C
Yaqui sucker	Catostomus bernardini	

a) As of December 1, 1983.

b) E = Endangered.
P = Proposed for listing in Federal Register.
C = Candidate for future listing.

c) One from the Mimbres River, New Mexico and one from the Rio Piedras Verde, Chihuahua, Mexico.

The following station objectives were established to help plan and carry out the hatchery program: 1) maintain a viable protected gene pool of imperiled desert fishes, 2) develop techniques for culturing these native fishes, 3) study their biological requirements, 4) provide live and preserved fish to authorized agencies and institutions, 5) provide an exchange of expertise and data on culture and management, 6) publish findings, and 7) implement a public information program concerning the plight of, and recovery efforts for, rare fish species of the Southwest (Jensen, in press). This program was implemented to assist in the recovery of imperiled fish species as directed in recovery plans, cooperative agreements and intraagency directives. This paper discusses our culture efforts for some of the larger Colorado River fishes that are threatened with extinction.

FACILITY DESCRIPTION

Dexter NFH is located near the Pecos River in southeastern New Mexico, 200 miles southeast of Albuquerque. Situated in the Chihuahua Desert, the elevation is near 3,500 feet, average annual rainfall about 12 inches, and the growing season 180-200 days. Water is supplied by three shallow wells (45 to 150 feet in depth) capable of pumping 1750 gpm. Well water temperature is a constant 64^{o}F and is highly alkaline (pH 7.2 to 7.5). Total hardness averages 2,100 mg/l and total dissolved solids about 3,500 mg/l.

Fish culture facilities at Dexter consist of a holding house (with sixteen 360 gallon tanks, a hatching battery and laboratory), 35 earthen ponds and an artificial stream. Thirteen additional production ponds are presently under construction. All spawning activities that involve handstrippping of broodstock and egg incubation are carried out in the holding house. The production

ponds (including those under construction) vary from 0.1 to 1.8 surface acres and comprise a total of 17 acres. The stream is a 150 foot flow-through system constructed to provide a lotic habitat to experiment with stream-type fishes. Wastewater from all fish culture operations collects in sumps on the station that are isolated from all other surface waters in the area.

FISH CULTURE EFFORTS

Razorback Sucker

The razorback sucker (Xyrauchen texanus), one of the largest catostomids native to western waters, continues to decline in the Colorado River system. Adult razorbacks attain lengths up to three feet and weights up to 12 pounds (Minckley, 1973). Recent collections in both the upper and lower basins of the Colorado River have not produced any young fish. Documented reproductive activity occurs in Lake Mohave in the lower basin but there is no evidence of any recruitment to the aging population of adult fish. Utilizing otoliths, Bruce Taubert, Arizona Game and Fish Department (personal communication), recently showed razorback suckers from Lake Mohave to be between 30 and 35 years old. The precarious status of the razorback sucker prompted negotiation of a cooperative agreement between the State of Arizona and the U.S. Fish and Wildlife Service that called for the Service to stock 100,000 fingerling razorbacks annually into Arizona waters for ten years. Finalized in May 1981, this arrangement was pursued in lieu of listing the species (Johnson, in press). Development of cultural techniques for razorback suckers, initiated in 1981, was fairly well refined by 1983. A detailed account of the 1981 and 1982 spawning and hatching trials is reported by Inslee (in press). A brief summary of all three years work is presented here.

Until recently, sexual maturation of razorback suckers has

gone unreported in the literature. Minckley (1983) reported that razorbacks reared at Willow Beach NFH attained sexual maturity at six years when the fish were 14 to 16 inches in length. Fish less than 14 inches total length were not mature. Two-year-old male razorbacks reared at Dexter NFH were sexually mature and running milt in 1983. Microscopic examination of the milt showed it to contain viable spermatozoa. These fish averaged 15.6 inches and 1.6 pounds. Examination of female razorbacks (16.2 inches, 1.9 pounds) showed the ovaries to contain developing eggs; later in the summer a few of the females were releasing a few eggs. It appears that sexual maturation of razorback sucker is most closely related to size but males will mature in two years and females possibly in two years but at least in three years when the fish are well fed and grow rapidly.

Development of secondary sexual characteristics in female razorbacks is monitored periodically through January and frequently as spawning approaches in February. At Dexter females become gravid as the water temperature approaches $50^{o}F$ and are usually ready to spawn when the temperature reaches $55^{o}F$. As they ripen their abdomen and pregenital area softens and the genital papillae enlarges considerably. Ripe male razorbacks develop large tubercles on their anal and caudal fins while females occasional develop a few tubercles on the same fins. Females ripen at different times and the "best looking" fish are selected for each spawning period. It takes five or six weeks to complete spawning of all females.

Female razorbacks are injected with human chorionic gonadotropin (HCG) to finalize maturation and to stimulate ovulation of maturated eggs. Inslee (in press) determined that 100 International Units (IU) of HCG per pound of body weight injected intramuscularly to be the preferred hormone, dosage and site of

injection. Females receive HCG injections every 24 hours until all eggs have been ovulated. At the recommended dosage, they usually give a "show" of eggs at 36 hours and good spawns at 48, 60 and 72 hours; some females spawn out at 60 hours. Male razorbacks are injected with HCG at 300 IU per pound of body weight daily for two to three days. If milt production decreases, HCG injections are reinitiated to maintain production of male gametes.

Utilizing the wet method, eggs from ripe females are hand-stripped into pans, milt added from two or more males and the eggs stirred gently with a feather. Razorback sucker eggs are very adhesive so the eggs are "clayed" with slurried bentonite following fertilization. The clayed eggs are poured into floating egg baskets, gently washed to remove the bentonite and allowed to water harden for 30 minutes. Following water hardening, they are enumerated gravimetrically and placed in Heath incubator trays. Jar hatching experiments revealed that razorback sucker eggs are too fragile to withstand the rolling involved in this hatching technique (Inslee, in press). Marsh and Pisano (in press) conducted studies at Dexter to determine the influence of temperature on egg development and hatching success of native Colorado River fishes. They found that optimum incubation temperatures for eggs of the three species reported here was near 70^{o}F. Consequently, our well water is heated to 70^{o}F for egg incubation and fry development to swimup. Water flow through the Heaths is regulated at three gpm. At 70^{o}F razorback sucker eggs begin hatching at about 96 hours and continue through 144 hours; peak hatching occurs on the fifth day at about 120 hours. Fry are held in tanks until swimup, then stocked in rearing ponds. Stocking rates for razorback sucker fry have not been finalized; we have experimented with rates ranging from 80,000 to 200,000 per surface acre.

In 1983 we spawned a total of 55 wild razorback sucker females 46 of them (83.6%) successfully. The 46 fish produced 5,728,025 eggs for an average fecundity of 124,522. Egg viability at 72 hours

averaged 75.1%. This was a substantial improvement over 1982 when egg viability was 30.5%. This is attributed largely to improved condition of the broodstock resulting in better quality sexual products, handling of eggs prior to incubation, and incubation temperature. Of 281,658 fry stocked, 159,367 advanced fry were harvested for a 56.6% return. We restocked 158,367 advanced fry and returned 136,419 three-inch fingerlings (86.1%); 53,845 of these were restocked to produce five-inch fingerlings and we got a 91.8% return (49,433 fish). We feed regular Service diet trout feed; conversion was 2.03. This year we stocked 2,539,548 fry, 82,487 three-inch and 43,433 five-inch fingerling razorback suckers in Arizona waters. All fingerling fish were marked with coded wire tags.

Colorado Squawfish

Like the razorback sucker, numbers of Colorado squawfish (Ptychocheilus lucius) have been reduced drastically throughout their historic range in the Colorado River basin. They are extinct in the lower basin and only a remnant population survives in the upper basin. North America's largest cyprinid, Colorado squawfish historically attained lengths up to six feet and weights of nearly 100 pounds (Miller, 1961). Because of a lack of material, it is not known how long Colorado squawfish survived historically but all available data indicates that they are long lived. Nine-year-old squawfish reared in a hatchery environment average 20 inches in length and three pounds in weight. Knowing that razorback suckers live over 35 years it is not hard to speculate that a six-foot 100 pound Colorado squawfish would likely be at least 50 to 60 years old and probably older. Hatchery reared Colorado squawfish become sexually mature in their sixth year.

Development of secondary sexual characteristics in Colorado squawfish are monitored weekly as water temperatures approach $65^{o}F$ in early May. Colorado squawfish at Dexter normally spawn

in late May or early June as the water temperature approaches 70°F. Male squawfish develop heavy tuberculation over most of their body as they ripen and exhibit a golden green sheen compared to their normal olivacious green coloration. As the egg masses approach maturation in female Colorado squawfish, their abdomen softens and deepens and the genital papillae becomes reddened and flowery. Although some females ripen slightly ahead of others, we have found that all female squawfish must be spawned within a one to two week period once they have ripened or good eggs cannot be obtained. Eggs force-ovulated prior to this time or taken after the spawning peak have a very low viability if they are good at all. This requires close monitoring of the female brood fish to ensure procurement of viable sexual products.

Female Colorado squawfish are injected with carp pituitary (CP) to stimulate ovulation of maturated eggs. Hamman (1981) determined that two mg per pound of body weight injected intraperitoneally was the appropriate hormone, dosage and method of injection. Male Colorado squawfish normally stay ripe and fluid but receive injections of HCG at 150 IU per pound of body weight if fluidity decreases.

Colorado squawfish eggs are handstripped into pans utilizing the wet method as described for razorback suckers, milt from two or more males added and the eggs gently stirred with a feather to help ensure adequate mixing of the sexual products. Like razorback sucker eggs, Colorado squawfish eggs are extremely adhesive so the fertilized eggs are "clayed" to break down the adhesiveness and prevent clumping of the eggs. The eggs are then water hardened, enumerated and layed down for incubation as described for razorback suckers. Unlike razorback sucker eggs however, Colorado squawfish eggs can be hatched in Heath incubators or jars. In 1983 egg viability averaged 59% in Heaths and 66% in jars. However, viability percentages were more closely related to egg quality than to hatching

technique. Mean viability for the two hatching methods was 60.7%.

As with razorback suckers, Marsh and Pisano (in press) determined that the optimum hatching temperature for Colorado squawfish was near 70°F. Heated well water flows through the Heaths at three gpm and through the jars at one to two gpm, depending on the number of eggs in the jar. Colorado squawfish eggs also hatch between 96 and 144 hours with peak hatching at about 120 hours. Hatching success per viability expectations was excellent but we encountered severe fry loss due to "bunching" in the square corners of the holding tanks. Prior to swimup the fry would bunch together in piles up to two inches deep that extended outward five or six inches. If not dispersed the majority of the fry in these piles would suffocate; this occurred at night when the fry were unattended. Following swimup the fry are stocked in rearing ponds. We have stocked fry at rates varying from 25,000 to 80,000 per surface acre; as with razorback sucker fry, Colorado squawfish fry stocking rates have not been finalized.

In 1983 we spawned 26 Colorado squawfish females; 25 domestic brood (Toney, 1974) and one wild brood. Fecundity of the domestic brood fish (mean wt = 3.09 lbs) ranged from 57,766 to 113,341 with a mean of 77,436. The wild female (9.6 lbs) produced 242,981 eggs. The average number of eggs per pound of body weight was 25,241 for the domestic fish and 25,310 for the wild fish. A total of 2,178,883 eggs were taken from the 26 fish spawned. We stocked 234,000 fry in rearing ponds and returned 160,000 advanced fry (68%). We stocked 120,000 advanced fry and harvested 87,153 three-inch fingerlings for a 72% return. Feed conversion for Colorado squawfish was 3.90. The fingerlings were nosetagged with coded wire tags and stocked in selected ground-water ponds and backwaters of the Colorado River near Grand Junction, Colorado.

Bonytail Chub

Of the big, native Colorado River fishes, bonytail chub (Gila elegans) have come the closest to extinction. Apparently only a few old fish remain in two reservoirs in the lower basin (Minckley, 1973) and only an occasional collection has been made in the Gray Canyon area of the Green River in the upper basin (Tyus et.al., 1982). Extensive collecting efforts to obtain bonytail chub for culture purposes during the past five years has produced only 18 fish; five of these fish remain alive (two females and three males). Hamman (1982) successfully spawned bonytail chub at Willow Beach NFH in 1981. Fry obtained from this spawning were reared at Dexter NFH and now constitute a captive held broodstock. Spawning trials on a few of these two-year-old fish were initiated in 1983 and the results are summarized below. Like the razorback sucker and Colorado squawfish, bonytail chub are long-lived. Recent age determinations made by Bruce Taubert (personal communicaton) of two Lake Mohave specimens placed their age at 40 and 42 years.

Twenty-four female bonytail were spawned over a four week period during May utilizing CP to stimulate egg ovulation. Spawning and hatching techniques utilized were the same as those reported for Colorado squawfish except that jars were not tested. Good quality eggs were obtained throughout the spawning trial. The fish ranged from 0.1 to 0.5 pounds in weight with a mean weight of .28 pounds. Fecundity ranged from 1,015 to 10,384; mean fecundity was 4,677. Average number of eggs per pound of body weight varied from 5,075 to 29,930 with a mean of 17,280. A total of 119,764 eggs were taken with a mean viability of 67.5%. Eggs were hatched in Heath incubators at 70^{o}F. Fry were distributed to the Arizona Game and Fish Department and the California Department of Fish and Game; no fingerlings were reared at Dexter.

CONCLUSION

The current status of these Colorado River fishes can be attributed directly to man's activities, primarily alteration of their habitat. Recovery of these unique fishes now requires well planned and determined human action. Protection, habitat preservation and management, research, captive propagation, reintroduction and public education are all essential components of a successful recovery program (Jensen, in press). With no evident recruitment to declining razorback sucker and bonytail chub populations, the long life spans of these species are obviously all that have saved them from extinction at this date. Whether recovery efforts like those being carried out at Dexter will turn this precarious situation around remains to be seen. Meanwhile, we are obligated to devote our energies towards saving those species for which we have a moral and legal responsibility. If we can successfully accomplish even a portion of the objectives previously outlined, we may be able to preserve for future generations of Americans some of our most unique fishery resources.

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