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PRELIMINARY EVALUATION OF PINK (*Oncorhynchus gorbuscha*) AND SOCKEYE (*O. nerka*) SALMON INCUBATION AND REARING IN GRAVEL INCUBATORS AND TROUGHS

By:
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Commissioner

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Data presented in these reports is intended to be final, however, some revisions may occasionally be necessary. Minor revision will be made via errata sheets. Major revisions will be made in the form of revised reports.

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PRELIMINARY EVALUATION OF PINK (Oncorhynchus gorbuscha) AND SOCKEYE (O. nerka) SALMON INCUBATION AND REARING IN GRAVEL INCUBATORS AND TROUGHS

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INTRODUCTION

A pilot project was begun in 1972 at the Kitoi Bay Hatchery on Afognak Island to evaluate a gravel (crushed-rock) incubation system for production of salmon fry. This report presents the results of the first year's operation and a preliminary evaluation of incubator fry survival and quality compared to traditional trough incubation of eggs and rearing of fry.

History

The concept of simulating a natural streambed environment in artificial propagation was considered by fishery workers in the early 1900's (Babcock, 1911; Robertson, 1919). In Alaska, one of the first experimental prototype gravel incubation systems with upwelling flow was constructed in the outlet compound of Little Kitoi Lake and in the Kitoi Hatchery in 1959 (Sheridan, 1960). These early experiments met varying degrees of success and not all the requirements for incubation and survival of eggs and fry were known.

Salmonid studies of the behavioral and physiological aspects of the early development of alevins (Marr, 1963, 1965; Bams, 1969) led to the development of a more refined gravel incubator (commonly referred to as the "Bams Box"). Pilot studies of this system were conducted by R.A. Bams of the Fisheries Research Board of Canada at Hooknose Creek, King Island, B.C. (1967-1968) and later at Headquarters Creek, Vancouver Island, B.C. Research by Bams (1970, 1972) indicated that pink salmon fry incubated in a gravel and rock environment were superior to fry hatched in a conventional tray incubator and were equivalent in size and quality to wild fry. Egg to fry survival in the gravel incubator was routinely four to ten times greater than natural production and marine survival of these fry was not less than 90% of wild creek fry survival to adults.

On the basis of these promising results, the Division of Fisheries Rehabilitation, Enhancement and Development of the Alaska Department of Fish and Game initiated in 1971, two pilot projects to evaluate the feasibility of gravel incubation systems for salmon enhancement in Alaska. The Kitoi project, funded by the State, was operational in 1972, while a cooperative project with the National Marine Fisheries Service at Auke Creek in Southeastern Alaska began in 1971 (Bailey 1972, 1973). In effect, the three pilot systems (Headquarters Creek, Vancouver Island; Auke Creek, Southeastern Alaska; and Big Kitoi Creek, Westward Alaska) provided a test of gravel incubator technology for nearly the full range of natural pink salmon production along the Pacific Northwest coast.

Research at Auke Creek and Headquarters Creek compared vertical tray incubators to gravel incubation of pink salmon while the Kitoi study compared trough culture and rearing of pink and sockeye salmon fry prior to release with gravel incubation methods. Wild creek fry provided a control check on survival and quality at all three sites. The Kitoi study, therefore, contributed additional knowledge on the feasibility of gravel incubation systems for salmon enhancement.

STUDY SITE

Big Kitoi Creek, adjacent to the Kitoi Hatchery, at Kitoi Bay on Afognak Island (Figure 1) has a native stock of pink salmon that spawn in the intertidal area and 120 m upstream. A falls prevents fish passage further upstream. A spawning area of approximately 2,500 m^2 has produced adult returns estimated at 35,000 fish, however, annual returns usually range from 4,000 to 8,000 pink salmon.

Big Kitoi Lake, at an elevation of 30.5 m above sea level, is the source of water for both the hatchery and the creek. A steel pipe 35.6 cm in diameter and approximately 0.5 km in length transports water by gravity flow from a dam at the lake outlet to the hatchery.

Kitoi Bay is closed to commercial salmon fishing and minor fishing effort for salmon in outer Izhut Bay is not considered to significantly affect the Big Kitoi Creek pink salmon run. Kitoi Bay has at times been opened for closely restricted fishing to harvest salmon surplus to escapement requirements.

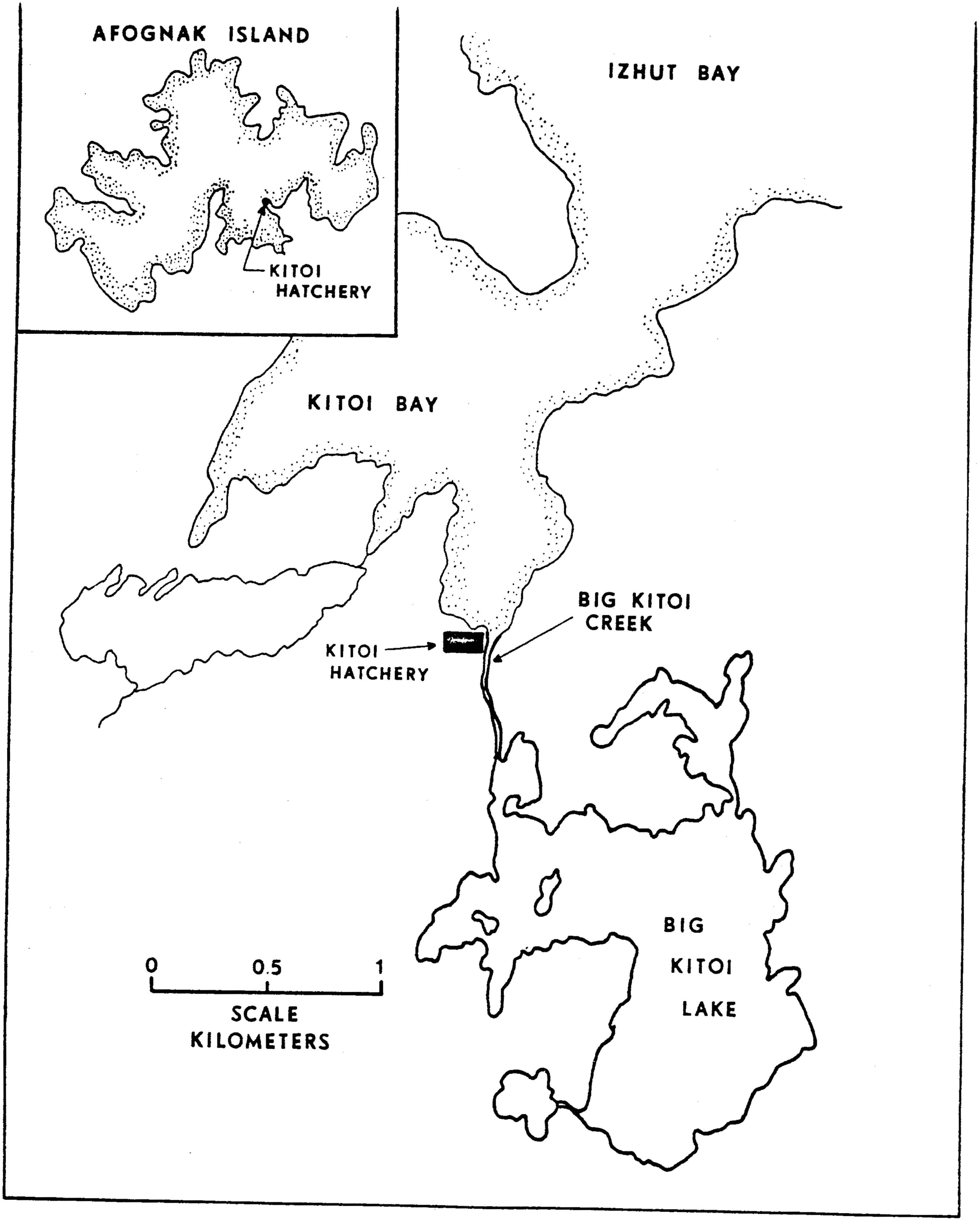

Figure 1. Location of Big Kitoi Creek and the Kitoi Hatchery on Afognak Island.

METHODS

Egg Sources and Treatment

Four lots of pink salmon eggs were fertilized from the Big Kitoi Creek brood stock between August 29 and September 10; the peak period of natural spawning. Care was taken to be non-selective of fish size and to sacrifice less than half of the creek escapement for spawn. Eggs of each female were taken by incision and fertilized in a spawning bucket with the sperm of two to three males. After every fifth female, the eggs were washed and water hardened. Fertilized eggs were then incubated to the eyed stage in wire mesh egg baskets suspended within a trough.

A single lot of sockeye eggs was taken September 9 at Red Lake on Kodiak Island about 100 miles southwest of Kitoi. Spawning technique was the same as for the pink salmon except that eggs were flown to the hatchery within a few hours after fertilization.

Routine procedures of malachite green treatments, shocking, and picking dead eggs were followed in the hatchery before planting of eggs in the incubators or traying them in the troughs.

Egg Incubation

Eyed pink and sockeye eggs were either planted in gravel incubators or trayed in the troughs between October 27 and 31 as shown schematically in Figures 2 and 3. Eggs were mixed to assure a random distribution of each lot in either the incubators or corresponding troughs.

The number of eggs to be planted into each incubator was determined from the average of ten individual counts of eggs of each species required to displace 200 ml of water. This average egg count was then projected to number of eggs per liter to obtain the total eggs required. Eggs were evenly divided in eight vertical layers of crushed rock during incubator loading.

Each of the four incubator units were 1.2 x 1.2 x 1.2 m deep fiberglass boxes with a system of perforated polyvinyl chloride (PVC) piping that provided an upwelling flow of water through eight 7.7 cm layers of 1.9 to 3.2 cm diameter crushed rock and eggs. The bottom and distribution piping of each box was covered with crushed rock followed by 2.6 cm of pea gravel and 5.1 cm of birdseye gravel to act as a pressure layer and fish barrier. Water and emergent fry passed out of the top of the box through a 5.1 cm diameter outlet drain into fiberglass troughs (Figure 4).

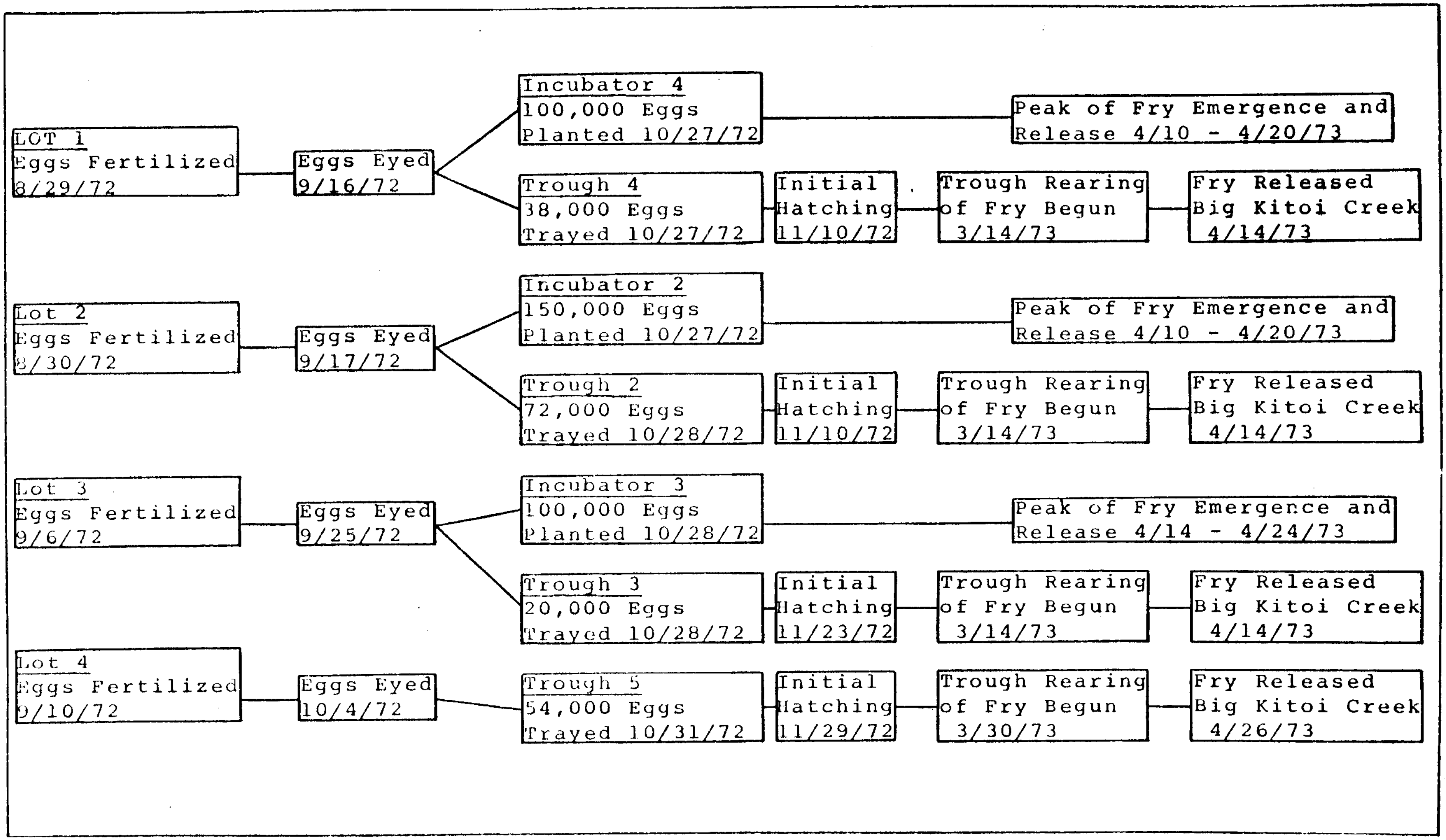

Figure 2. Schematic of pink salmon incubation and rearing chronology using gravel incubators and traditional trough culture at the Kitoi Hatchery, 1972-1973.

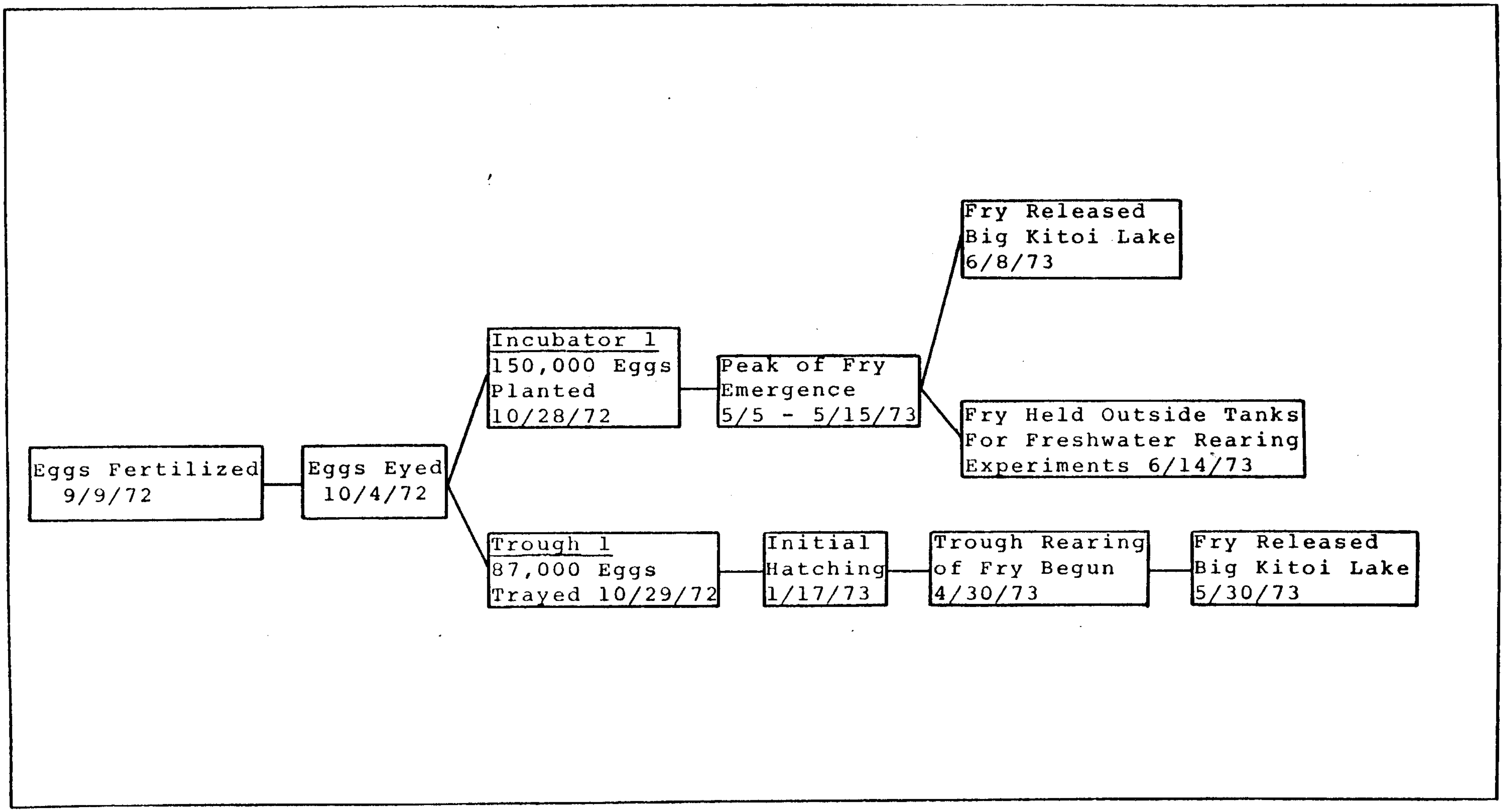

Figure 3. Schematic of sockeye salmon incubation and rearing chronology using gravel incubators and traditional trough culture at the Kitoi Hatchery, 1972-1973.

Figure 4. Kitoi Hatchery gravel incubation system after expansion to eight units in 1973. Emergent fry are counted in fiberglass troughs. Incubators 1 and 2 are ready for loading with eggs and crushed rock (foreground).

Eggs incubated in wooden hatchery troughs were distributed on fine wire mesh trays stacked vertically. Metal divider plates were placed in the troughs to create an upwelling water flow through the egg stacks. After hatching, the fry were held in the trays until the yolk sac was absorbed before release into the troughs for rearing.

Water for the incubators first entered a headbox where it was filtered by two fine mesh screens that were cleaned daily. A single incubator with distribution piping installed, but no gravel or rock, was connected directly to the main hatchery pipe without water filtration as a check on the need and efficiency of the filtration system. Unfiltered water for the troughs came directly from the main pipe.

A water flow of 53 to 68 liters per minute was maintained for the incubators throughout the period of operation. Sixty-eight liters per minute was the maximum that could be obtained for the incubators with the headbox-filter arrangement. The single incubator connected directly to the hatchery header pipe was adjusted to 64 liters per minute and readjusted periodically thereafter when flows became minimal. Trough flows were approximately 38-53 liters per minute during incubation and 19-30 liters per minute during rearing.

Water temperature of troughs, incubators and Big Kitoi Creek were recorded daily while water flows in incubators and troughs were checked twice a week and water chemistry once a week as routine hatchery procedures.

Fry Counting and Indexing

All fry emerging from the incubators were collected in troughs and hand counted daily before release. Premature fry emergents (yolk sac fry that prematurely emerged throughout the winter) were counted separately and placed in floating trays within the troughs to continue development. Pink fry from Big Kitoi Creek were collected in two index nets attached to collecting boxes with baffle plates to prevent fry mortality due to water velocity. Fry were counted daily and either released back into the creek or sampled for quality analysis.

Fry Quality Samples

Samples of 50 fry were taken from the troughs, incubators, and Big Kitoi Creek index nets every 3.5 days and preserved in 5% formalin in "whirl-pack" plastic bags. After 6 weeks all the samples taken on a single day were examined. Fork lengths (0.1 mm accuracy) and wet weights (0.1 mg accuracy) were recorded for individual fry. A development index:

$$K_D = 10^3 \sqrt{\frac{\text{weight (mg)}}{\text{length (mm)}}}$$ as used by Bams (1970, 1972)

was computed for individual fry as part of a computer program that also provided mean length and weight, development index, variance, standard deviation and error, and 95% confidence intervals for each sample. Development stage (based upon degree of yolk sac absorption and ventral slit closure) or period of rearing for the trough fry was recorded for each sample of fry.

Fry Releases

Pink fry were released into Big Kitoi Creek at night and at low tide above the intertidal area, but downstream from the index nets, on the same day that they emerged from the incubators. Trough reared pink fry were released April 14 and 26 in the same location as the incubator fry. Sockeye fry were either released into Big Kitoi Lake or held for freshwater rearing (Figure 3).

RESULTS

Hatchery Operation

The four gravel incubators containing eggs functioned throughout the winter without mechanical problems. Regulation of water flow and cleaning of the headbox filter and effluent troughs was the only essential maintenance. The headbox filter often needed cleaning several times a day due to considerable debris in the water supply.

The empty incubator connected directly to the hatchery water supply pipe without filter had a gradual reduction in flow from 64 liters on December 1 to 34 liters by January 30. The flow could readily be increased to a desirable rate by valve adjustment. The amount of sedimentation observed in the incubator, however, could have been deleterious to egg and fry survival. Filtration is, therefore, necessary for the Kitoi incubators.

Trough incubation and rearing required more handling of eggs and fry and more maintenance than the gravel incubation system. Eyed eggs were placed in vertical stacks of trays from the head of the trough to the outlet. Any accumulation of debris that impeded flow at the head stack had a resultant effect on water circulation and oxygen availability of the remaining stacks in the trough. At Kitoi there has been a problem in recent years with accumulated rust from the header pipe and debris in the water system plugging the fine mesh wire screening of the egg stacks. Additionally, iron eating bacteria in the water accelerates rusting and formation of rust globules on the trays.

In January of 1973 a substantial loss of fry occurred in the troughs due to the trays plugging and insufficient water circulation. The trays, containing yolk sac alevins, had to be separated from the stacks, cleaned and replaced in the troughs.

Fry incubated in the trough trays absorbed their yolk supply more rapidly than the incubator and creek fry and completed closure of the ventral slit approximately a month in advance of the normal period of emergence. Rearing of pink fry in the troughs began in March and rearing of sockeye fry began the end of April. The fry were fed Oregon starter mash daily and both species accepted food readily from the water surface.

Water Quality

Water chemistry samples taken during the incubation and rearing period indicated acceptable ranges of dissolved oxygen, free carbon dioxide, ammonia, and pH (Table 1). The minimum dissolved oxygen level recorded at Kitoi was 10.0 ppm in April. Availability of oxygen in relation to oxygen demand of the larvae is critical for successful incubation, hatching, and emergence. The potential number of eggs per liter per minute of flow that can be supported by the Kitoi incubation system will exceed that of many other sites with lower oxygen availability unless additional aeration is provided.

The Kitoi Hatchery lacks facilities for controlling water temperature. Hatchery water temperatures closely coincided with temperature of Big Kitoi Creek (Figure 5). The steel pipeline from Big Kitoi Lake to the hatchery may have a cooling effect on the water in the fall before snow cover and a warming effect in the spring, accounting for minor differences shown in Figure 5. Winter water temperatures are normally less than 3.0° C and reached a low of 1.2° C in January. Emergence of fry in April coincided with increasing water temperatures.

The Kitoi water supply, drawn from the lake outlet, collects debris ranging from spruce needles and moss to snails, freshwater shrimp, and occasional fish and mammal remains. Constant filtration and daily cleaning of filters are necessary.

Fry Emergence

Premature emergence of yolk sac fry from the incubators occurred sporadically during the winter (Table 2). The reason for premature emergence at

Table 1. Range of water chemistry at the Kitoi Hatchery during incubation studies, 1972-1973.

	Water Chemistry			
Source	Dissolved O_2	Free CO_2	Ammonia	pH
		November 1972		
Incubators	13.0 - 15.0 ppm	3.0 - 4.0 ppm	-----	7.5 - 8.0
Troughs	14.0 - 15.0	4.0	-----	7.5 - 8.0
Head Box	14.0 - 15.0	3.0 - 4.0	-----	7.0 - 7.5
Big Kitoi Cr.	15.0 - 16.0	3.0 - 4.0	-----	8.0 - 8.5
		December 1972		
Incubators	11.0 - 13.0	3.0 - 4.0	-----	7.0 - 8.0
Troughs	11.0 - 13.0	3.0 - 4.0	-----	7.0 - 8.0
Head Box	12.0 - 13.0	3.0 - 5.0	-----	7.5 - 8.0
Big Kitoi Cr.	12.0 - 14.0	3.0 - 3.5	-----	7.5 - 8.0
		January 1973		
Incubators	12.0	2.5 - 3.0	trace	7.0 - 8.0
Troughs	11.0 - 13.0	2.5 - 3.0	trace	7.5 - 8.0
Head Box	12.0	2.5 - 3.0	trace	7.5
Big Kitoi Cr.	13.0	2.5 - 4.0	trace	7.5 - 8.5
		February 1973		
Incubators	11.0 - 12.0	2.0 - 3.0	trace	7.5 - 8.0
Troughs	11.0 - 12.0	2.0 - 3.0	trace	7.5 - 8.0
Head Box	11.0 - 12.0	2.0 - 3.0	trace	7.5 - 8.0
Big Kitoi Cr.	12.0	2.0 - 3.0	trace	8.0 - 8.5

Table 1. Range of water chemistry at the Kitoi Hatchery during incubation studies, 1972-1973 (continued).

Source	Water Chemistry: Dissolved O_2	Free CO_2	Ammonia	pH
	March 1973			
Incubators	12.0 - 13.0 ppm	2.0 - 3.0 ppm	trace	7.0 - 7.5
Troughs	11.0 - 13.0	2.0 - 2.5	trace	7.5
Head Box	12.0 - 13.0	2.0 - 3.0	trace	7.0 - 7.5
Big Kitoi Cr.	12.0 - 13.0	2.0 - 3.0	trace	8.0 - 8.5
	April 1973			
Incubators	11.0 - 12.0	2.0 - 3.0	trace	7.0 - 7.5
Troughs	10.0 - 12.0	2.0 - 2.5	trace	7.0 - 7.5
Head Box	12.0 - 13.0	2.0 - 2.5	trace	7.0 - 7.5
Big Kitoi Cr.	13.0	2.0 - 3.0	trace	7.5 - 8.5

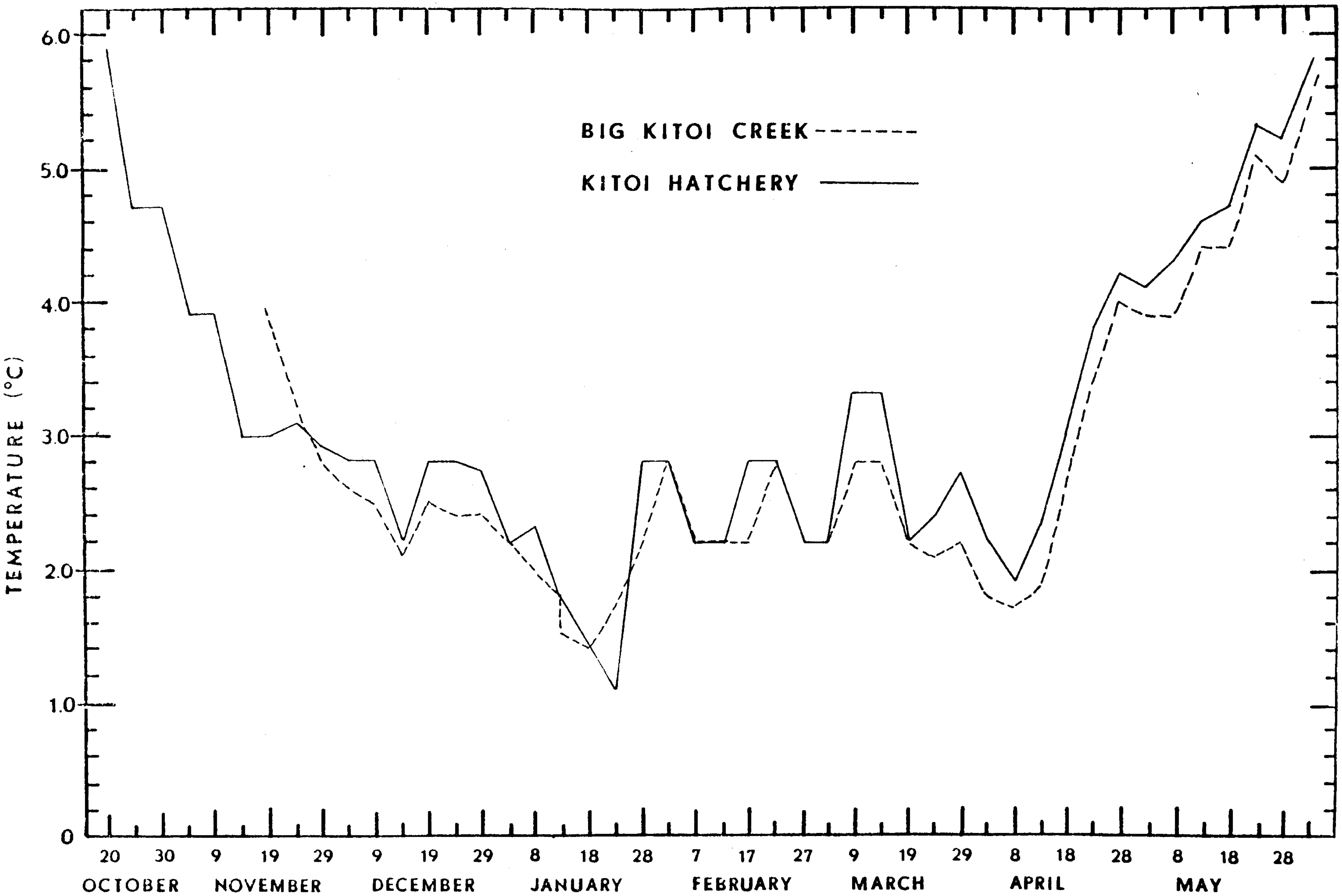

Figure 5. Water temperature in Kitoi Hatchery incubators and troughs and Big Kitoi Creek during the period of incubation and emergence, 1972-1973.

Table 2. Number of premature yolk sac fry emergents from the Kitoi incubators, 1972-1973.

	Sockeye	Pink		
Month	Incubator 1	Incubator 2	Incubator 3	Incubator 4
November	0	2	0	0
December	0	144	3	1
January	6	440	6,174	16
February	42	1,513	151	6,387
March[1/]	3	163	74	35
April[1/]	4	---	---	---
Total	55	2,262	6,402	6,439

1/ As of March 25 for the pink salmon and April 15 for the sockeye.

Kitoi is not clear. It has been demonstrated that premature hatching occurs when dissolved oxygen attains a critical level, i.e., availability approaches demand (Bams, 1969). However, oxygen levels were not critical at Kitoi and the incubators with the highest egg densities had fewer premature emergents, at equivalent flows, than the low density incubators. Each of the three incubators of pink salmon had several distinct periods of premature emigration without apparent relationship to development or physical factors within the incubator environment. The number of premature sockeye yolk sac fry emergents was far less than for the pink fry. Premature emergence of yolk sac fry has also been observed at the Auke Creek Hatchery (Bailey, 1972, 1973), but to a lesser extent.

Emergence of developed (ventral slit fully closed) pink fry began the end of March, rapidly increased in April, peaked in mid-April, and declined in late April. The timing of emergence from the incubators coincided closely to emergence of wild fry in Big Kitoi Creek (Figures 6 and 7). Index net catches of creek fry indicated a more prolonged and almost bimodal period of emigration.

Emergence of sockeye fry from the single incubator began the end of April, peaked on May 9 and 10, and was completed by early June (Figure 8). The timing of emergence of natural Kitoi Lake sockeye was unknown.

Total fry emergence from the incubators containing pink salmon exceeded the calculated egg loading densities by 2.8 to 11.0 (Table 3). Sockeye fry emergence was 97.5% of the calculated egg density. The water displacement method of determining number of eggs is considered accurate within ±5% at the 99% level of confidence (Burrows, 1951). Accuracy of the Kitoi egg counts (based upon standard error of the mean) was calculated to be ±1.18% for the pink salmon eggs and ±0.73% for the sockeye eggs. An error in determining egg loading density was therefore most likely in either measuring water displacement samples of eggs during incubator loading or unknowingly selecting eggs of a slightly different size than the random egg size in the preliminary samples that were counted. Apparent error in calculating number of eggs loaded precludes the determinations of accurate egg to fry survival rates for the incubators other than stating that survival appeared highly favorable. The 97.5% fry survival calculated for the sockeye may be accurate since only one lot of eggs was involved in incubator loading.

A pre-emergent pink fry density of 11.4 per 0.1 m^2 was inferred for Big Kitoi Creek from fifteen samples taken April 10, 1973. Projecting this density to the available creek spawning area provides a point estimate of 285,000 (±57,000) fry that emigrated from the creek. The total index net catch of 9,559 wild pink fry from Big Kitoi Creek is 3.35% of the point estimate for total fry emigration.

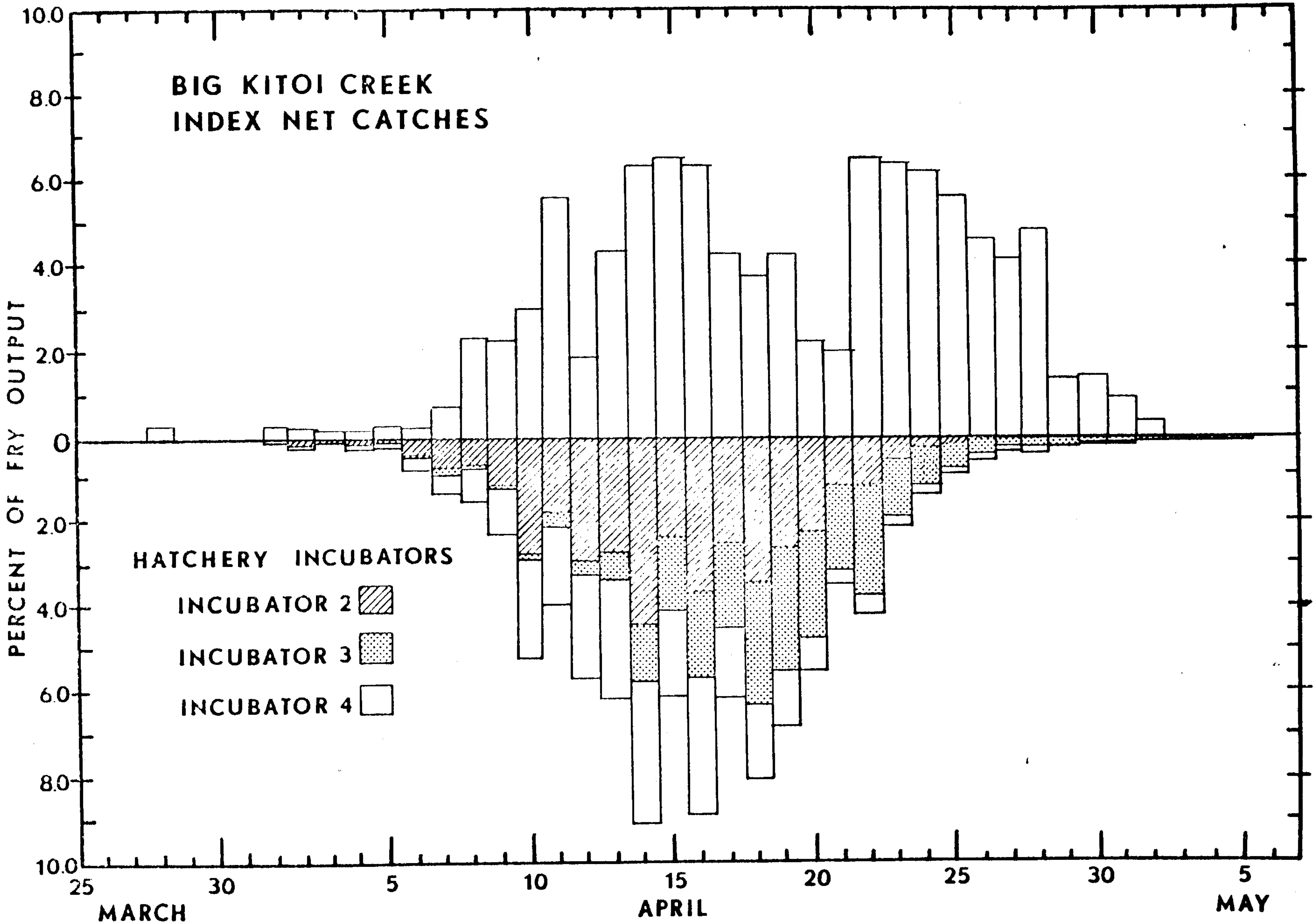

Figure 6. Daily pink fry catch from creek index nets and emergence from hatchery incubators in percent of total fry, 1973.

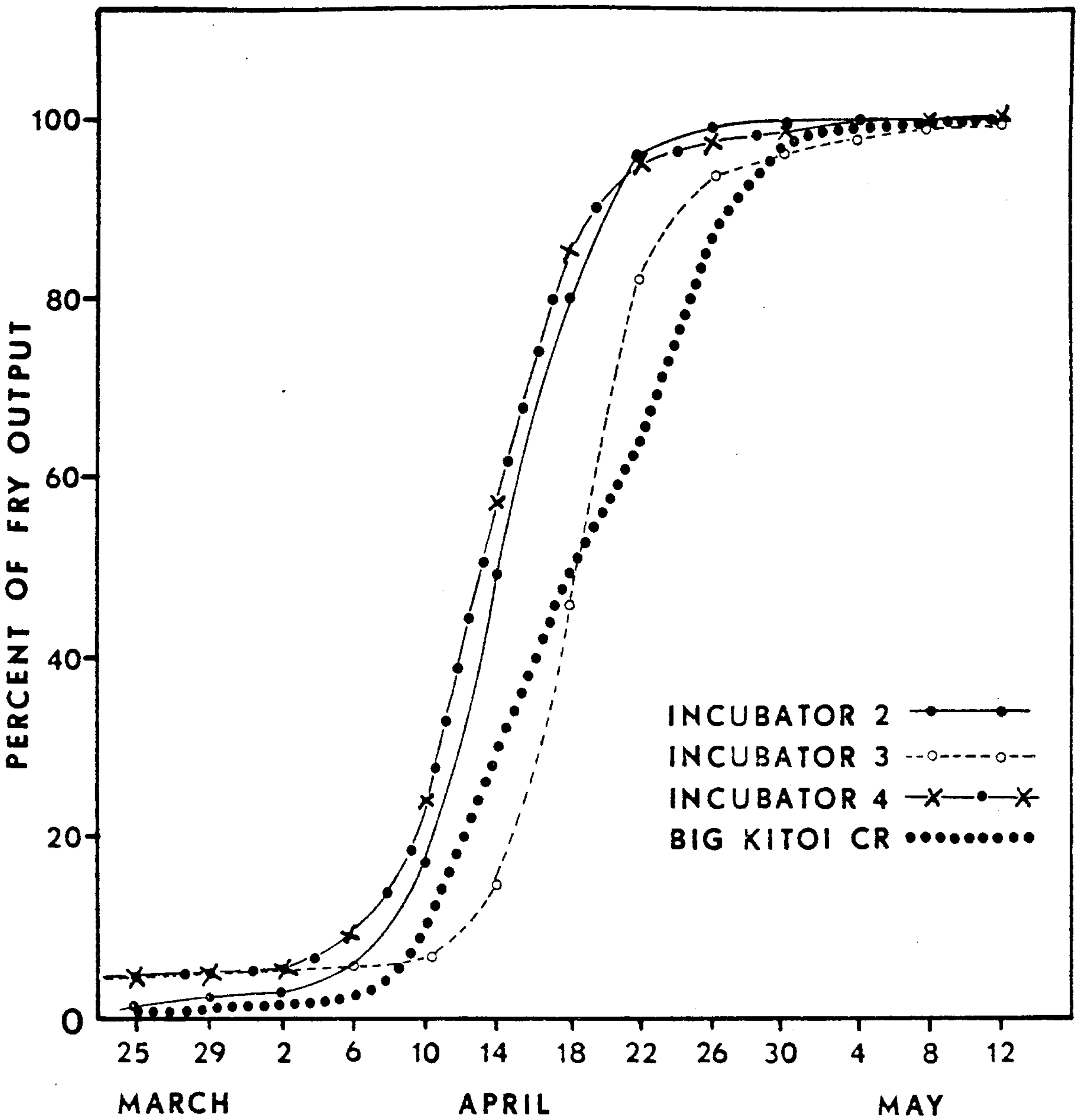

Figure 7. Cumulative percent of pink fry emergence in Big Kitoi Creek and the hatchery incubators. The origin of trend lines indicates the small percentage of yolk sac fry that emerged prematurely from the incubators prior to March 25.

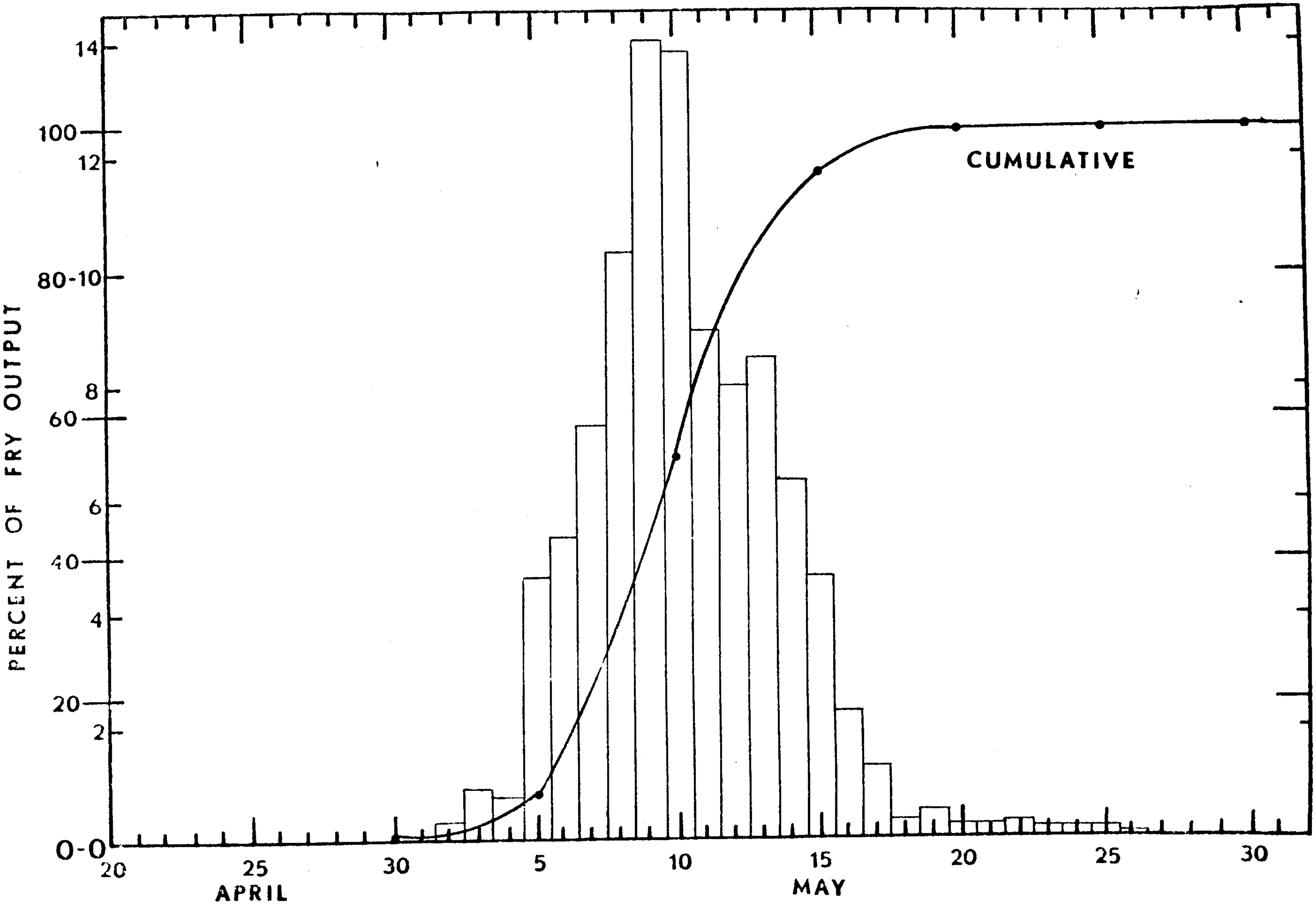

Figure 8. Daily sockeye fry emergence (bars) from incubator 1 in percent of total fry. The cumulative percent of fry emergence is shown by the trend line.

Table 3. Egg loading densities and total fry emergence from Kitoi Hatchery incubators, 1972-1973.

	Sockeye	Pinks		
Incubator No.	1	2	3	4
Calculated loading density	150,000	150,000	100,000	100,000
No. of fry emergents	146,286	154,222	107,148	110,151
Emergence to loading density ratio (%)	97.52	102.81	107.15	111.01

Fry Quality and Development

A total of 3,493 pink and sockeye salmon fry was sampled from Big Kitoi Creek (373 pink only), the four incubators (1,881) and the troughs (1,239) during the period of emergence and rearing to evaluate fry quality and development (Appendix Table 1, Table 4, and Table 5). Fry quality is based upon the premise that fry of a larger size are stronger and more vigorous than smaller fry and ultimately have a greater likelihood of survival to mature fish. A comparison of fry size and quality between hatchery and creek is restricted to the same parent stock, since fry size at emergence is, in part, controlled genetically as well as physiologically and environmentally.

The stage of fry development is expressed as an index (K_D) of the ratio of weight to length. During early fry development and yolk sac absorption, a continuous decline in the ratio of weight to length occurs. Therefore, a fry with a K_D value of 2.000 is less developed than one with a value of 1.900. Once the fry begin feeding, the weight-length ratio becomes an index of condition that increases as the fish become more robust. It is important to clarify application of the K_D index since in this study it expresses both development stage of fry emergents and condition of trough reared fry.

Wild pink salmon fry from Big Kitoi Creek averaged 33.29 mm and 251.6 mg (Table 4) and were larger than either incubator or trough reared fry. Development of the wild fry ranged from an index value of 1.380 to 1.909 ($\bar{x}$ of 1.893). Pink salmon fry from the three incubators were nearly equivalent in size to the wild fry. Fry incubated and reared in the troughs were considerably smaller than either incubator or wild fry (Appendix Table 1, Table 4, and Figure 9) and showed greater variation in size and quality between lots and troughs.

Rearing of pink salmon fry in the troughs for approximately one month before natural emergence was not beneficial in increasing fry size; and quality was inferior to incubator and wild fry. Even though trough fry readily accepted food, the conversion of food into flesh was poor at the cold March and April water temperatures. Energy expenditure for swimming activity in the troughs apparently nullified any benefit gained by feeding and rearing.

Extensive sampling throughout the period of pink fry emergence also indicated (Appendix Table 1) a tendency for incubator and wild creek fry to be of a smaller size (lower quality) at the beginning and end of the emergent period. The highest quality fry emerged at the peak of emergence. Smaller less vigorous fry possibly took longer to complete emergence than the larger more active fry.

Fry quality in the high density incubator (150,000 eggs) was equivalent to quality of fry in the lower density incubators (Table 4). It is assumed that

Table 4. Grand mean lengths, weights, and developmental indices (K_D) of creek, incubator and trough reared sockeye and pink fry, Kitoi Hatchery, 1973.

Source and date	Sample size	Length (mm) Mean	Length (mm) Standard deviation	Weight (mg) Mean	Weight (mg) Standard deviation	K_D Index Mean	K_D Index Standard deviation	Development stage
SOCKEYE FRY								
Incubator 1								
May 1-29	393	29.33	0.939	194.7	21.95	1.973	0.0372	ventral slit closed
Trough 1								
April 11-May 29	395	29.87	1.071	215.9	31.09	1.998	0.0535	ventral slit closed on feed 30 days
PINK FRY								
Big Kitoi Cr.								
April 5-30	373	33.29	1.119	251.6	28.55	1.893	0.0415	ventral slit closed
Incubator 2								
April 4-29	399	33.12	0.980	258.5	27.62	1.921	0.0429	ventral slit closed
Trough 2								
April 4-14	199	31.08	1.454	204.2	39.11	1.887	0.0540	ventral slit closed on feed 32 days
Incubator 3								
April 9-30	300	33.04	0.961	258.6	23.64	1.926	0.0352	ventral slit closed
May 7-14	99	32.50	0.901	219.6	21.20	1.854	0.0387	ventral slit closed
Trough 3								
April 9-13	100	31.63	1.515	230.3	45.90	1.928	0.0515	ventral slit closed on feed 31 days
Incubator 4								
April 3-28	347	33.02	1.094	252.9	27.40	1.912	0.0366	ventral slit closed
May 7-20	149	32.73	0.945	223.8	21.80	1.852	0.0453	ventral slit closed
Trough 4								
April 3-13	199	31.87	1.179	225.3	33.49	1.904	0.0505	ventral slit closed on feed 31 days
Trough 5								
April 10-26	149	32.32	1.289	250.7	35.52	1.946	0.0474	ventral slit closed on feed 29 days

Table 5. Mean lengths, weights, and developmental indices (K_D) of incubator and trough reared sockeye fry, Kitoi Hatchery, 1973.

Source & date	Sample size	Length (mm) Mean	Length (mm) Standard deviation	Weight (mg) Mean	Weight (mg) Standard deviation	K_D Index Mean	K_D Index Standard deviation	Development and rearing stage
Incubator 1								
5/1	50	29.36	0.778	200.6	18.78	1.992	0.0314	ventral slit closed
5/7	50	29.34	0.853	196.3	22.98	1.978	0.0402	ventral slit closed
5/10	50	29.23	0.826	197.0	18.40	1.989	0.0281	ventral slit closed
5/13	49	29.34	0.860	194.1	18.30	1.972	0.0311	ventral slit closed
5/16	50	29.33	1.055	193.0	26.10	1.966	0.0334	ventral slit closed
5/19	47	29.58	0.903	200.3	21.33	1.976	0.0402	ventral slit closed
5/22	48	29.13	1.082	186.2	24.69	1.956	0.0430	ventral slit closed
5/29	49	29.37	1.152	189.8	25.03	1.953	0.0501	ventral slit closed
Trough 1								
4/11	49	29.55	0.744	202.6	19.94	1.985	0.0385	ventral slit closed
5/1	50	28.53	0.738	172.6	15.84	1.950	0.0358	on feed 2 days
5/8	50	28.99	0.966	189.8	20.47	1.980	0.0496	on feed 9 days
5/14	49	29.58	1.059	202.6	22.35	1.983	0.0399	on feed 15 days
5/16	50	29.76	1.052	217.2	32.02	2.014	0.0578	on feed 17 days
5/19	49	30.34	1.052	229.3	35.88	2.010	0.0505	on feed 20 days
5/22	49	30.64	1.317	248.2	37.69	2.046	0.0603	on feed 23 days
5/29	49	31.58	1.639	264.9	64.51	2.015	0.0954	on feed 30 days

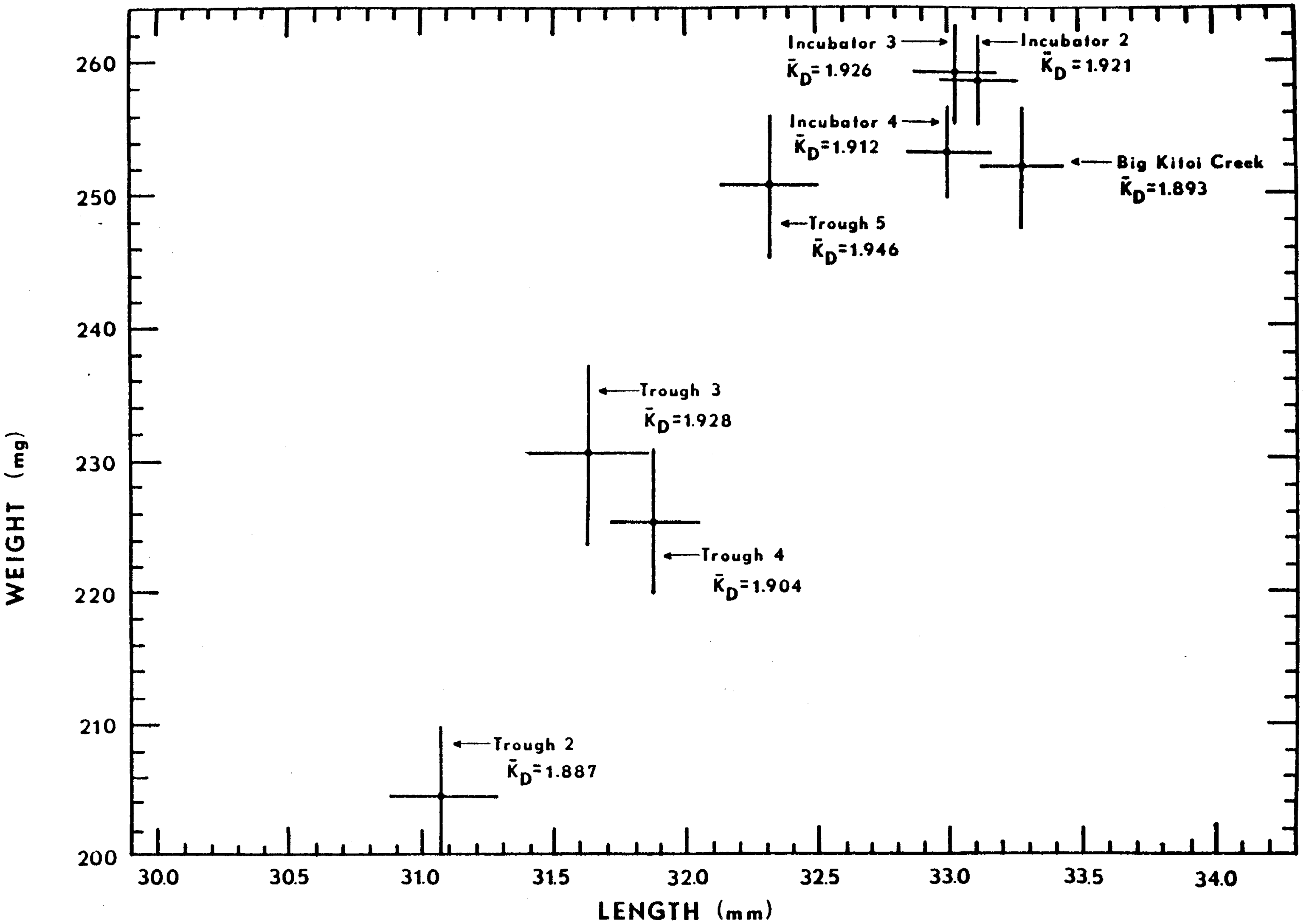

Figure 9. Comparison of mean size and development (K_D) of pink fry from incubators, troughs, and Big Kitoi Creek in April. Mean size is shown by the center dot; horizontal and vertical lines on either side of the dot indicates two standard errors (±) on either side of the mean for length and weight respectively. Refer to Table 4 and Appendix Table 1 for sample data summary.

when optimum egg loading density is exceeded both survival and quality of fry will be decreased. Since this was not apparent, it is concluded that the optimum density is greater than 150,000 pink salmon eggs per gravel incubator at Kitoi.

Trough incubation and rearing of sockeye fry produced larger fry of higher quality than sockeye fry from the gravel incubator. Trough fry during the first nine days of rearing were smaller (0.57 mm and 13.5 mg difference) than fry emerging from the incubator, however, after approximately 15 to 20 days of feeding the trough fry exceeded the average size of incubator fry (Table 5 and Figure 10). A trend line (Figure 10) approximating growth rate of sockeye during May indicates a relatively rapid increase in size of fry reared compared to fry size at emergence from the incubator. The warmer May water temperature in the hatchery resulted in a higher and more favorable food conversion for the sockeye than for the pink salmon.

Development of sockeye fry incubated in the troughs just prior to feeding was nearly equivalent to the mean index for sockeye fry from the incubator. Shortly after feeding the index generally increased as the fry grew during rearing (Figure 10).

Fry Release

A total of 369,219 pink salmon fry from the incubators and 123,911 pink fry incubated in the troughs were released in Big Kitoi Creek between April 14 and May 31. Adult returns from the estimated 285,000 wild fry and the hatchery fry are anticipated in 1974. Hopefully, this return will produce sufficient spawning stock for a mark and recovery evaluation to assess marine survival of incubator, trough, and wild fry.

Sockeye fry were held at Kitoi for continuation of freshwater rearing studies and also liberated (112,705 fry) into Big Kitoi Lake.

DISCUSSION

The first year's operation of a pilot gravel incubation project at the Kitoi Hatchery successfully demonstrated the potential of this concept for mass production of pink and sockeye salmon fry nearly equivalent in size and quality to wild fry. Major advantages of incubating salmon eggs and fry in a gravel-crushed-rock system compared to conventional hatchery methods are: (1) increased fry size and quality, (2) high egg to fry survival, (3) development

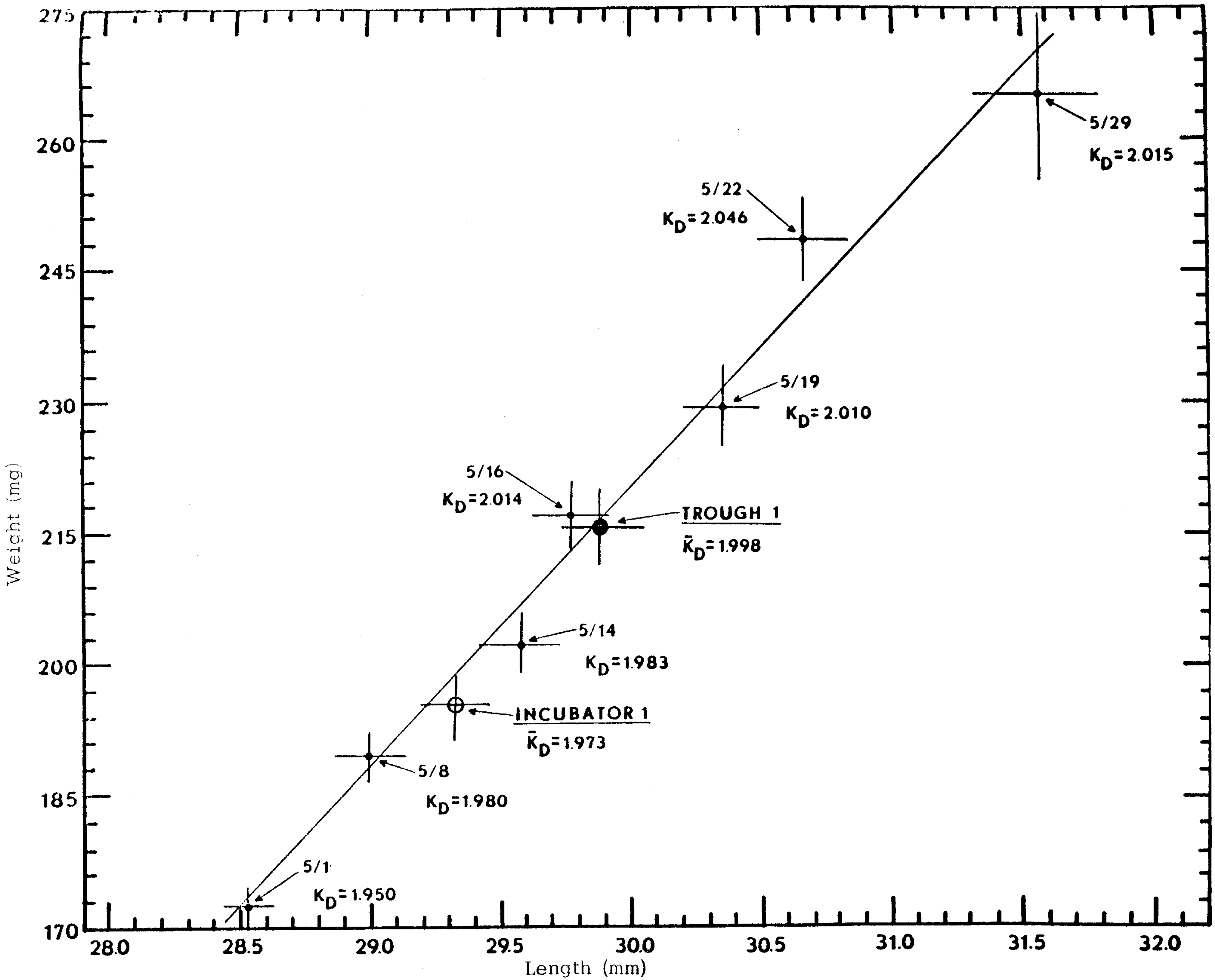

Figure 10. Comparison of mean size and development (K_D) of sockeye fry from incubator and trough. A center dot indicates mean size; horizontal (length) and vertical (weight) lines on either side of the dot indicates two standard errors (±) on either side of the mean. The trend line approximates growth rate of trough reared fry from sample

and emergence timing similar to wild stocks, and (4) relatively little maintenance between egg loading and fry emergence. High fry survival and quality, and emergence timing equivalent to wild fry has resulted in every test of the basic gravel incubator system (Bams 1970, 1972; Bailey 1972, 1973) and was also confirmed by the Kitoi project in 1972-73.

Pink salmon incubated in the troughs at the Kitoi Hatchery absorbed their yolk sacs more rapidly than gravel incubator fry and were sufficiently developed to begin rearing and feeding by mid-March. Even after a month of rearing in the troughs, however, these fry were of a smaller size than pink fry emerging from the incubators in April. The lack of growth is attributed to a poor food to flesh conversion due to cold water temperatures in March and April and to expenditure of excessive energy in swimming to maintain position within the troughs. The gravel environment within the incubators, and under natural conditions, appears to provide an essential support mechanism required during early development to produce fry of high quality.

Rearing of pink salmon fry at Kitoi may possibly have been successful in increasing fry size if the hatchery water could have been heated. Pink salmon fry, reared throughout the summer at the hatchery incidental to freshwater rearing of sockeye, attained a length of 41 mm and 383 mg by the end of June. In July when water temperatures reached 10.0° C and higher, growth was accelerated to the extent that the pink salmon became larger than the sockeye in the same pen and preyed upon them.

If pink fry could be reared at a warmer water temperature and fry size could be significantly increased by the time of natural emergence, then, theoretically, marine survival could be increased. However, other physiological factors combined with alteration of the normal pattern of emergence and rearing could offset any benefit gained and eventually be detrimental genetically to the native stock in the fry release area. Therefore, the gravel incubation system that is capable of producing pink salmon fry equivalent in quality and emergence timing to native wild stocks is considered to be a more practical method at present for pink salmon enhancement.

Development of pink salmon fry and timing of emergence is related to time of spawning of the parent stock and water temperature regime during egg and fry incubation. Pink fry emergence at Kitoi extended throughout the month of April in 1973. The quality of both wild and gravel incubation fry, however, was highest during the peak of the emergent period. Theoretically, the likelihood of these fry surviving to mature fish would be greater than the smaller early and late fry emergents. This type of natural selection would tend to maintain quality of the native stock in future cycles and possibly also influence time of return as mature fish.

Incubation and rearing of sockeye fry in the troughs during May resulted in relatively rapid growth of fry. Initially the trough fry were smaller at the time of ventral slit closure than fry emergents from the incubator. After two weeks of feeding and rearing the trough fry grew larger than incubator fry. A maximum sockeye fry size could be attained by use of a gravel incubation system followed by a period of freshwater rearing and feeding prior to release. Sockeye rearing experiments at Kitoi demonstrate this to be a practical and valid concept for sockeye rehabilitation and enhancement.

Sockeye fry may be better suited than pink fry for early spring rearing in freshwater. A species, such as sockeye, which normally spends its early pre-smolt life in freshwater would quite likely have evolved physiological and genetic mechanisms that would enhance fry survival under cold freshwater conditions in the early spring. In contrast, pink fry would possibly adjust better to a short period of estuarine rearing to increase size and quality before seaward migration.

Salmon incubation and rearing studies are being continued at Kitoi to evaluate and assess the potential of these concepts for rehabilitation and enhancement of salmon stocks. In 1973, the pilot gravel incubation system was expanded from four to eight units, the headbox filter was replaced by a simpler dual line strainer, incubator plumbing was modified, and fry marking facilities were installed in the hatchery.

The 1973-1974 project is designed to determine optimum egg loading density of the incubators and to confirm density projections based upon dissolved oxygen and water flow requirements. Pink salmon fry from the gravel incubators, troughs, and wild fry from Big Kitoi Creek will be fin-clipped in the spring of 1974 to begin an evaluation of marine survival of fry to adult return. We hope to assess more concisely the relationship between fry size and quality to marine survival. The final phase of this project will be the development of practical field incubation and rearing systems on remote lakes and streams for salmon rehabilitation and enhancement in Alaska.

ACKNOWLEDGMENTS

Mr. Brad Sele, Fish and Game Technician, supervised data collection and field operations for this project. The successful operation of the incubator system and evaluation results are credited to the dedicated efforts of Department technicians and fish culturists at the Kitoi Hatchery. Mr. Jack Bailey of the Auke Bay Biological Laboratory, NMFS, is thanked for my use of laboratory computer facilities in fry quality analysis.

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APPENDIX

Appendix Table 1. Mean lengths, weights, and developmental indices (K_D) of creek, incubator and trough reared pink salmon fry, Kitoi Hatchery, 1973.

Source & date	Sample size	Length (mm) Mean	Length (mm) Standard deviation	Weight (mg) Mean	Weight (mg) Standard deviation	K_D Index Mean	K_D Index Standard deviation	Development and rearing stage
Big Kitoi Creek								
4/5	29	32.58	1.497	241.6	37.47	1.907	0.0446	ventral slit closed
4/8	50	33.24	0.975	256.4	27.59	1.909	0.0340	ventral slit closed
4/11	50	33.13	1.419	248.6	36.83	1.892	0.0411	ventral slit closed
4/14	49	33.60	1.172	258.1	28.93	1.892	0.0390	ventral slit closed
4/17	50	33.32	0.974	246.6	21.29	1.880	0.0312	ventral slit closed
4/22	49	33.48	1.049	253.5	24.40	1.889	0.0431	ventral slit closed
4/26	50	33.69	0.800	254.5	19.24	1.880	0.0400	ventral slit closed
4/30	46	33.29	1.063	253.2	32.65	1.896	0.0591	ventral slit closed
Incubator 2								
3/28	50	32.90	1.049	272.2	22.35	1.969	0.0444	yolk sac 90% absorbed
4/4	50	33.26	0.844	253.9	21.14	1.902	0.0388	ventral slit closed
4/7	50	33.34	1.033	261.5	24.88	1.917	0.0393	ventral slit closed
4/11	50	33.24	0.830	267.8	47.36	1.933	0.0773	ventral slit closed
4/14	49	33.32	1.022	264.4	25.90	1.924	0.0335	ventral slit closed
4/17	50	32.99	1.000	261.6	25.00	1.937	0.0334	ventral slit closed
4/21	50	32.80	0.940	258.6	24.45	1.940	0.0303	ventral slit closed
4/25	50	33.06	1.146	257.3	27.58	1.922	0.0434	ventral slit closed
4/29	50	32.94	1.024	243.0	24.68	1.893	0.0474	ventral slit closed
Trough 2								
3/8	48	31.36	0.868	222.7	28.74	1.929	0.0573	yolk sac 85-95% absorbed
3/27	49	30.92	1.242	210.9	32.88	1.920	0.0632	yolk sac 90-95% absorbed
4/4	50	30.74	1.413	197.0	35.47	1.886	0.0467	ventral slit closed-on feed 22 days
4/7	50	31.01	1.371	205.6	36.00	1.897	0.0494	on feed 25 days
4/11	49	31.19	1.411	207.9	38.62	1.891	0.0541	on feed 29 days
4/14	50	31.37	1.620	206.3	46.36	1.873	0.0658	on feed 32 days

Appendix Table 1. Mean lengths, weights, and developmental indices (K_D) of creek, incubator and trough reared pink salmon fry, Kitoi Hatchery, 1973 (continued).

		Length (mm)		Weight (mg)		K_D Index		
Source & date	Sample size	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Development and rearing stage
Incubator 3								
2/3	50	28.24	0.863	175.2	18.67	1.979	0.0615	yolk sac 85% absorbed
4/9	50	33.30	0.800	266.6	21.51	1.931	0.0304	ventral slit closed
4/13	50	33.09	0.784	265.0	18.55	1.940	0.0339	ventral slit closed
4/18	50	33.14	0.984	264.2	22.13	1.935	0.0324	ventral slit closed
4/22	50	33.03	1.155	256.3	29.55	1.920	0.0331	ventral slit closed
4/26	50	32.93	0.860	251.4	21.03	1.915	0.0322	ventral slit closed
4/30	50	32.74	1.183	248.0	29.08	1.916	0.0494	ventral slit closed
5/7	49	32.42	0.857	231.0	20.52	1.891	0.0323	ventral slit closed
5/14	50	32.58	0.945	208.2	21.88	1.817	0.0451	ventral slit closed
Trough 3								
3/9	50	30.81	1.304	224.6	29.96	1.969	0.0491	yolk sac 85-95% absorbed
4/9	50	31.49	1.299	228.8	41.57	1.934	0.0550	ventral slit closed- on feed 27 days
4/13	50	31.77	1.731	231.9	50.24	1.922	0.0481	on feed 31 days

Appendix Table 1. Mean lengths, weights, and developmental indices (K_D) of creek, incubator and trough reared pink salmon fry, Kitoi Hatchery, 1973 (continued).

		Length (mm)		Weight (mg)		K_D Index		
Source & date	Sample size	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Development and rearing stage
Incubator 4								
2/3	46	29.52	1.351	191.2	28.10	1.947	0.0702	15-25% of yolk sac remaining
2/19	48	30.70	0.857	233.7	22.07	2.004	0.0481	" "
4/3	50	33.56	1.274	265.5	29.10	1.913	0.0300	ventral slit closed
4/6	48	33.38	0.983	270.1	26.52	1.935	0.0275	ventral slit closed
4/10	49	32.61	1.242	249.2	29.88	1.926	0.0333	ventral slit closed
4/13	50	32.77	1.130	250.8	33.08	1.919	0.0434	ventral slit closed
4/16	50	32.82	0.930	252.2	23.42	1.923	0.0370	ventral slit closed
4/24	50	33.02	1.136	248.3	26.56	1.901	0.0465	ventral slit closed
4/28	50	32.96	0.961	233.9	23.21	1.867	0.0385	ventral slit closed
5/7	49	32.56	0.883	221.7	20.03	1.857	0.0352	ventral slit closed
5/15	50	32.99	0.816	199.4	19.28	1.769	0.0372	ventral slit closed
5/20	50	32.65	1.136	250.3	26.10	1.929	0.0492	ventral slit closed
Trough 4								
4/3	49	31.76	1.079	218.5	29.10	1.893	0.0472	ventral slit closed on feed 21 days
4/6	50	32.10	1.185	229.7	30.72	1.904	0.0496	on feed 24 days
4/10	50	31.65	1.190	225.5	35.68	1.917	0.0538	on feed 28 days
4/13	50	31.97	1.262	227.6	38.47	1.903	0.0514	on feed 31 days
Trough 5								
3/28	50	31.27	1.179	239.2	34.77	1.980	0.0509	yolk sac 80-85% absorbed
4/10	50	31.97	1.324	250.0	33.07	1.966	0.0497	ventral slit closed on 90% of fry-yolk sac 85-90% absorbed on remaining 10%
4/14	49	31.97	1.133	246.3	30.94	1.957	0.0443	ventral slit closed on feed 17 days
4/26	50	33.02	1.411	256.0	42.54	1.916	0.0481	on feed 29 days